BRANCH OF THE FEDERAL STATE
AUTONOMOUS EDUCATIONAL INSTITUTION OF HIGHER EDUCATION
Almalyk branch of NUST MISiS
DEPARTMENT "MINING BUSINESS"

TRAINING AND METODOLOGY COMPLEX
"RELIABILITY OF MINING MACHINES"

(for students of the following directions of education:
specialty 210504 -
"Mining", profile: Mining machinery and equipment)

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Compiled by:

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Reliability of mining machines

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BRANCH OF THE FEDERAL STATE
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Collection of lectures
on subject
"Reliability of mining machines"

INTRODUCTION AND BASIC CONCEPTS OF THE SUBJECT

The main task facing the mining industry is to ensure an increase in the extraction of minerals both by open and underground methods based on the widespread introduction of advanced technology and highly efficient reliable mining equipment.

Numerous accidents at mining enterprises caused by failures of various technical systems by one or another machine almost always entail not only downtime of expensive equipment, losses for the company, but also injuries and deaths of maintenance personnel.

Failures of mining equipment systems can lead not only to discomfort for workers, but also cause the sudden termination of complex technological processes at mining enterprises and, as a result, large material losses or catastrophic consequences.

In the last few decades, the situation has become more complicated due to the emergence of new and complex systems, and the consequences of their failures have become expensive from both social and economic points of view. For these reasons, it became necessary to create a theory capable of solving practical problems of increasing the reliability of various technical systems of mining machines.

The works of Yu. K. Belyaev, NP Buslenko, R.A. Gandzhumyan, B.V. Vasilieva, G.V.Druzhinina, I.N.Kovalenko, V.A.Kuznetsova, B.R. Levina, A.M. Polovko, A.D.Soloviev, A.L. dr.

The effective work of complex mining equipment largely depends on thefrom level theoretical and practical training of specialists. Master student in direction 5A310705 - Mining machinery and equipment should know:

arrangement of machines and equipment used for mining; the main trends in the development of mining machines in the world;

the principle of operation of various working bodies, transmissions and other elements of machines; fundamentals

of theory and calculation of working bodies of machines;
technical and economic performance indicators;
operating rules for the repair and maintenance of mining equipment;
issues of ensuring the safety of the service personnel. The specialist
must be able to:
calculate schedules for maintenance and repair of the main auxiliary mining and equipment;
to determine the parameters of the work of the working tool, working bodies, speed of movement, as well as the loads arising in the working bodies of machines;

perform enlarged calculations of resistance to movement of working bodies; determine the operational probabilistic reliability of machinery and equipment.

The purpose of studying the discipline "Reliability of mining machines" - the acquisition of knowledge and

skills in the application of applied methods of reliability theory to problems related to the calculation of reliability and durability of mining machines. These issues are still poorly covered in the educational literature.

The theoretical part of the course is reinforced by solving problems of practical importance.

The basis for studying the discipline is the courses "Mathematics", "Theoretical Foundations of Electrical Engineering", "Mining Machines", "Transport Machines", "Mining Mechanics".

Lecture number 1.

THE SCIENCE OF RELIABILITY

Lesson plan:

1. Introduction. About the science of reliability.
2. The theoretical basis of the science of reliability
3. Terms and definitions in the theory of reliability

One of the most important factors that must be taken into account when calculating, designing and operating electromechanical systems for various purposes, including machines of mining enterprises, is reliability.

This concept reflects the property of various products - electro-mechanical machines, equipment, etc. - to maintain the required quality indicators throughout the entire period of operation.

The science of reliability studies the patterns of changes in the quality indicators of technical systems and develops, on this basis, methods for ensuring the required or necessary duration and reliability of their work.

Proceeding from the unity of the approach to explaining the basic laws associated with solving the problem of reliability, in the further presentation we will use the terms "objects" and "products", meaning a certain set of components. An object (product) can be an electrical installation or a motor, an apparatus, as well as a set of products united by a common functioning process. In some cases, instead of the term "object", the more general term "system" is used, which is a collection of constituent parts or nodes - elements.

Reliability specific issues are:

terminology defined by the current regulatory and technical documentation; the time factor influencing the change in the initial parameters during the operation of

the systems;

predicting the behavior of system parameters during operation, maintenance, storage, etc.

The main difficulty in assessing the reliability of systems lies in the development of such calculation methods and sources of information about changes in their parameters, which would make it possible to predict their behavior under various operating conditions.

The theory of reliability of electromechanical equipment is one of the most important disciplines for mining electromechanics, laying the foundation for the correct operation of mining equipment and the design of new models. A low level of reliability affects the cost of production, time costs, and in certain cases threatens the safety of individuals and the ecology of the environment. The problem of reliability is at the center of modern technology, the study of the nature of reliability at different levels of its concretization makes it practically necessary and theoretically significant to develop the dialectics and methodology of modern technology. With the growth of the technical level of the means of complex mechanization, reliability becomes more and more important among the factors affecting the level of use of mining equipment. So, for example, downtime of production faces,

In technology, the solution to the problem of reliability is associated with the development of the theory of reliability, which is a scientific direction based on the methods of the theory of probability and mathematical statistics. The theory of reliability made it possible to develop real scientific criteria, its mathematical apparatus makes it possible to assess the quality of systems by their quantitative characteristics.

The development of the theory of reliability goes in three directions:

1. Study of the problem of the structure of reliability associated with the determination of the overall

reliability of complex devices with different connections of elements and with the development of a methodology for selecting elements and units of equipment and modes of their operation with a given degree of reliability.

2. Determination of the reliability of elements associated with the study of physical properties elements.

3. Investigation of the reliability of signal transmission in conditions of interference.

The most important technical qualities of a device depend on the reliability of the device as a whole and on the reliability of its elements.

Reliability is the quality of the system and at the same time its quantitative assessment. The probabilistic meaning of reliability is obvious. Reliability can be quantified. But the role of mathematics in the theory of reliability is not limited only to the role of some kind of "measuring instrument". It constitutes the most important analytical apparatus, which is used with great success for more efficient test planning both in the process of system design and in the organization of the operation process.

Reliability theory is based on the probabilistic nature of the very phenomenon of reliability. With this approach, from all the states in which this or that system can be, a set of such states is distinguished, which differ from each other in terms of reliability. This set is called the phase space of the system. Over time, various changes occur in the constituent parts of the system, for example, those associated with the "aging" of the elements. Therefore, if at the moment t1 the state of the system is described by the point x1, then at the moment t2> t1 the state of the system corresponds to the point x2. In this case, it may turn out that x2 ≠ x1

If we denote by x (t) G is the state of the system at time t, then the subsequent states x (t), depending on time, can be considered as a process proceeding in time. Since the change in states is random, the value x (t) can be considered as the trajectory of a random process occurring in the phase space of the state of the system G. When the phase space G = {x} is defined and a random process x (t) is specified in it, describing the evolution of the system over time, then the next step is the selection of various numerical characteristics of the system's reliability.

There are no elements that are absolutely reliable, i.e. such, the probability of failure-free operation of which is equal to one. Aging of elements takes place due to physical entropy, therefore, the reliability of this or that element is a decreasing function of time, and efforts aimed at increasing the reliability of an element only lead to a slowdown in the decrease in the probability of its failure-free operation.

Academician A.I. Berg defined the range of issues of the theory of reliability as follows: “The theory of reliability establishes the patterns of occurrence of failures and restoration of the operability of the system and its elements, considers the influence of external and internal influences on processes in systems, creates the basis for calculating reliability and predicting failures, seeks ways to increase reliability in design and manufacture systems and their elements, as well as ways to maintain reliability during operation ”(1963).

The main tasks of the theory of reliability are as follows:

the study of the patterns of occurrence of failures and recovery performance of products;

development of methods for quantitative determination and comparative assessment of reliability;

development of measures to improve reliability;

study of the relationship between external influences and processes occurring in the product.

Elimination of failures of various elements of mining machines is always associated with the need to carry out unscheduled repairs during work shifts and leads to a reduction in the time for a mining machine to perform its main functions. Sometimes elimination of equipment malfunctions can be combined with technological downtime. Therefore, reducing the time spent on eliminating the failures of mining machines is closely related to the ability to correctly assess the technical condition of the elements and units of the machine, as well as to establish the optimal frequency of equipment maintenance.

In solving all these problems, the methods and tools of the theory of reliability are used.

The theoretical basis of the science of reliability

The science of reliability is based on the results of fundamental research in the field of natural sciences, among which a special place is occupied by mathematics with all its main components: language, models and methods.

Language tools allow you to formalize the object and objectives of the study.

The model of the object under study, if it adequately reflects its properties, provides access to the research tools accumulated to date.

The generalized algorithm for solving the mathematical model (MM) is shown in Fig. 1. It can be seen that in addition to solving it with the help of mathematical methods, it is important to check the validity of the assumptions made. In other words, it is necessary to decide whether the neglect of some factors that were considered secondary or not worthy of attention in the development of MM is justified.

Mathematical methods provide researcher extensive kit analytical results, computational procedures and algorithms that speed up and facilitate the implementation of tasks.

The main mathematical apparatus in the theory of reliability are: probability theory and methods of mathematical statistics.

However, Acad. B.V. Gnedenko noted: “Mathematics is only a means of research and calculation. There should always be an engineering problem at the head, and for its solution the scientific apparatus that is closest to the nature of the phenomenon under study should be involved ”[1.1].

The main tasks of the theory of reliability: establishing the regularities of the occurrence of failures, studying the influence of external and internal factors on reliability, establishing numerical characteristics and methods for assessing and calculating reliability, developing methods for testing reliability, determining methods for ensuring reliability.

The first way is based on the study of the physical and chemical properties and parameters of the elements of technical devices, the physical and chemical processes occurring in them, the physical nature and the mechanism of failures. In this case, the current states of elements and systems are described by equations or mathematical models reflecting physical laws.

The second way is based on the study of statistical (probabilistic) regularities of the occurrence of failures of a large number of systems or products of the same type. In this case, failures are considered as some abstract random events, and the diverse physical states of elements and devices are reduced to two states - operable (serviceable) and inoperative (faulty), which are described by reliability functions.

Currently, the most developed statistical (probabilistic) theory of reliability. This is partly due to the high availability of research on the total influence of many different factors (structure and properties of materials, design of elements and devices, technological processes, external influences and operating modes) on the state of elements and devices.

The peculiarities of the developed probabilistic methods for assessing reliability are that the reliability indicators obtained in this case in most cases can not be associated with the physical characteristics of both individual elements and products as a whole, and with the factors affecting them. For this reason, these methods are of limited use in the design of various systems and products, especially when increasing reliability due to redundancy is impossible and the only way to ensure high efficiency of the system is the high reliability of its constituent components (elements).

It is obvious that the further direction of development of the theory and technology of reliability is a combination of statistical (probabilistic) methods with penetration into the physical (physicochemical) essence of the processes occurring in products. To do this, it is necessary to establish the dependencies of the main characteristics that determine the process

the functioning of a product or system, from the physical properties and parameters of materials, from the physicochemical processes of changing these properties and parameters and from the intensity of operational influences, taking into account the random nature of these processes.

Assessment of the reliability of products based on data on the physical properties of materials, on the characteristics of elements and influencing factors, presupposes the use of already known statistical (probabilistic) methods, since these characteristics are usually random functions of time or random variables.

It should be noted that that part of the theory of reliability, which is based on the physics of failures, does not yet have engineering methods of calculation for most cases, especially of mechanical engineering products. There is not even a general scheme for such a calculation, but there are only certain types of calculations that represent fragments of a complex solution. This situation is explained by the extreme complexity of the problem, since the engineering problem of determining the parameters of an object, taking into account wear, corrosion, fatigue, a decrease in mechanical and electrical strength, etc., is based on processes that are different in physical essence and characteristics. The complexity of the task is also aggravated by the fact that during operation, various factors of a probabilistic nature act on products, especially on electrical installations, as a result of which the processes of destruction of materials of products, leading to failures also become probabilistic.

For these reasons, not only predictive calculations of reliability are important, but also predicting the loss of performance and serviceability by the product.

It is generally agreed that research yields the best results.

Mathematical models that reflect the process of functioning of a product or system. However, the formalization of such models is not always possible. So, the main characteristics that determine the efficiency of the functioning process electromechanical systems, are insulation resistance, electrical and mechanical strength of electrical insulating materials, their moisture resistance,

environmental characteristics, the level of electrical loads, heating temperature, cooling conditions, etc., which are practically and theoretically difficult to take into account in a mathematical model, and sometimes impossible.

Terms and definitions in the theory of reliability

The unambiguous interpretation and understanding of various provisions in any theory is based on the use of generally accepted terms. For this, special standards are being developed, containing explanations of the most important terms. The main terms and definitions of the theory of reliability are set out in GOST 27.002-89.

General terms

Reliability - the property of an object to perform specified functions, keeping the values of established performance indicators within specified limits over time,

corresponding to the specified modes and conditions of use of the facility, repair, storage and transportation.

Reliability includes:

reliability;

durability;

maintainability;

persistence.

Reliability - the property of an object to continuously maintain performance for some time or some operating time.

Durability is the property of an object to remain operational until the onset of a limiting state with an installed system of maintenance (MOT) and repair.

Maintainability is a property of an object, which consists in its adaptability to the prevention and detection of the causes of its failures, damage and elimination of their consequences by carrying out repairs and maintenance.

Persistence is the property of an object to continuously maintain a good and efficient state during and after storage and (or) transportation.

To assess the reliability of an object, indicators are used.

The reliability indicator is a quantitative characteristic of one or more properties that make up the reliability of an object.

Object - an object of purpose and practical human activity. In the theory of reliability, the considered objects of a certain purpose are the result of human production activity: a product, a system, an element.

The product consumes its resource, the product is consumed by itself. The product is considered during the periods of design, manufacture, operation, research, reliability tests.

Technical system is an many elements, interconnected functionally and interacting with each other in the process of performing a certain range of tasks.

An element is the simplest component of the system within the framework of a specific consideration. The concept of a system and an element are relative and are transformed depending

on the task at hand.

Hours of work - the duration or amount of work of an object.

Serviceable condition (serviceability) - the condition of an object in which it meets all the requirements established by the normative and technical documentation (NTD).

Serviceable state (operability) - the state of an object in which it is able to perform the specified functions, while maintaining the value of the specified parameters within the limits established by the NTD.

Fault state (malfunction) - the state of an object in which it does not meet at least one of the requirements established by the NTD.

Inoperable state (inoperability) - the state of an object in which the value of at least one of the specified parameters characterizing the ability to perform the specified functions does not meet the requirements established by the NTD.

Damage - an event consisting in a violation of the serviceability of an object or its component parts due to the influence of external influences exceeding the level established in the NTD on the object.

Damage can be minor or major. The first means a violation of serviceability while maintaining serviceability, the second means a failure of the object.

Failure is an event that disrupts the performance of an object. The signs (criteria) of failures are established by the NTD for a given object.

Recoverable object - an object, the performance of which, in the event of a failure, is subject to recovery in the situation under consideration.

Unrecoverable object - an object, the performance of which, in the event of a failure, cannot be restored in the situation under consideration.

Recoverable and non-recoverable objects are considered depending on the stage of operation. For example, a weather satellite is recoverable during storage and non-recoverable during flight.

Lecture number 2.

INCREASING THE DURABILITY OF MINING MACHINES

Plan

1. Reliability of mining machines in design, manufacture and operation.

2. Increasing the durability of units and elements

A number of authors divide reliability into ideal, basic and operational.

1.Perfect reliability is the highest possible reliability achieved by

creation of a perfect design of an object with absolute consideration of all conditions of manufacture and operation.

2.Basic reliability - the reliability actually achieved by design,

manufacturing and installation of the object.

3. Operational reliability - the actual reliability of the object in the process of its operation, due to both the quality of design, construction,

manufacturing and installation of the object, and the conditions of its operation, maintenance and repair.

The most universal unit from the point of view of general methodology and theory of reliability is the unit of time. This is due to the following circumstances.

Firstly, the operating time of a technical object also includes breaks, during which the total operating time does not increase, and the properties of materials can change.

Secondly, the use of economic and mathematical models to justify the assigned resource is possible only using the assigned service life (service life is defined as the calendar duration from the start of operation of the facility or its renewal after a certain type of repair to the transition to the limit state and is measured in units of calendar time) ...

Thirdly, calculating the resource in units of time allows us to set forecasting tasks in the most general form.

The main purpose of analyzing the reliability and associated safety of production equipment and devices is to reduce failures (primarily traumatic) and related human casualties, economic losses and violations in the environment.

Currently, there are quite a few methods for analyzing reliability and safety. So the simplest and most traditional for reliability is the method of structural diagrams. In this case, the object is presented in the form of a system of separate elements, for which it is possible and expedient to determine the reliability indicators. Structural diagrams are used to calculate the probability of failures, provided that only one failure is possible in each element at a time. These limitations have given rise to other methods of analysis.

The preliminary hazard analysis method identifies hazards to the system and identifies elements for determining failure modes in consequences analysis, as well as for constructing a fault tree. It is the first and necessary step in any research.

Failure Mode Consequence Analysis is primarily hardware oriented and considers all failure modes for each element. Disadvantages are time-consuming and often overlooked combination of failures and human factors.

Criticality analysis identifies and classifies elements for improvement of systems, but often does not account for failures with a common cause of interaction between systems.

Event tree analysis is useful for identifying major sequences and alternative failure outcomes, but is not suitable for parallel sequence of events and for detailed study.

Hazard and health analysis is an advanced type of failure mode consequence analysis that includes the causes and consequences of changes in key production variables.

Cause-effect analysis demonstrates well sequential chains of events, is flexible and rich enough, but too cumbersome and time consuming.

Fault tree analysis is the most common technique that is widely used in various industries. This analysis is clearly focused on finding failures and at the same time identifies those aspects of the system that are important for the considered failures. At the same time, graphic, visual material is provided. Visibility gives the specialist the opportunity to deeply penetrate the process of the system's operation and at the same time allows him to focus on individual specific failures.

The main advantage of a fault tree over other methods is that the analysis is limited to identifying only those system elements and events that lead to a given system failure. At the same time, building a fault tree is a certain kind of art in science, since there are no analysts who would compose two identical fault trees.

To find and visualize the causal relationship using a fault tree, it is necessary to use elementary blocks that subdivide and connect a large number of events.

Thus, the currently used methods of analyzing the reliability and safety of equipment and devices, although they have certain drawbacks, still make it possible to quite effectively determine the causes of various kinds of failures, even in relatively complex systems. The latter is especially important in connection with the great importance of the problem of the occurrence of hazards caused by insufficient reliability of technical objects.

The durability of machines is laid down during their design and construction, is ensured during the production process and maintained during operation. Thus, the durability is influenced by structural, technological and operational factors, which, according to the degree of their influence, make it possible to classify durability into three types: required, achieved and actual.

The required durability is set by the design specification and is determined by the achieved level of technology development in this industry.

The achieved durability is conditioned by the perfection of design calculations and manufacturing processes.

Actual durability characterizes the actual use of the machine by the consumer.

In most cases, the required durability is greater than the achieved one, and the latter is greater than the actual one. At the same time, it is not uncommon for the actual durability of machines to exceed the achieved one. For example, with a mileage rate before overhaul (CR) equal to 120 thousand km, some drivers, with skillful operation of the car, reached a mileage without major repairs of 400 thousand km or more.

Actual longevity is subdivided into physical, moral, and technical and economic.

Physical durability is determined by the physical wear and tear of a part, assembly, machine to their ultimate state. For units, physical wear of the basic parts is decisive (for the engine - the cylinder block, for the gearbox - the crankcase, etc.).

Moral durability characterizes the service life beyond which the use of a given machine becomes economically impractical due to the emergence of more productive new machines.

Technical and economic durability determines the service life, beyond whom holding repairs given cars becomes economically impractical.

The main indicators of machine durability are technical resource and service life.

The technical resource is the operating time of the object before the start of operation or its resumption after medium or major repairs before the onset of the limiting state.

Service life - the calendar duration of the object's operation from its beginning or renewal after medium or major repairs to the onset of the limiting state.

These indicators for specific types of machines can be expressed as average values of resources and service life separately before overhaul, between overhauls and before decommissioning the machine.

In the presence of data on the resource (service life) of N objects, the statistical assessment of the average resource Tr (average service life) is determined by the formula

where tpi is the resource of the i-th object.

In addition to average resources and service lives, the gamma percentage resource Tpγ is often used to assess the durability, which is the operating time during which the object does not reach the limit state with a given probability of γ percent. The specified percentage of objects is the specified probability. If γ = 90%, then the corresponding resource should be called ninety percent.

The gamma percentage resource is determined from the equation:

where γ is a given percentage of objects;

Fp (t) - resource allocation function.

Poor equipment reliability typically results in increased operating costs and downtime. In addition, with insufficient reliability, sudden failures of parts and components due to violations of the established technology can lead to severe accidents, the elimination costs of which are very high. However, the increase in reliability is associated with the complexity of the equipment and the increase in its cost. Therefore, it is necessary to set some optimal reliability based on the criterion of the minimum value of the design, manufacture and operation of equipment. Replication and manufacture of highly reliable equipment requires additional funds. However, as reliability increases, the number of failures, downtime, and the number of spare parts required decreases, which can reduce operating costs. Thus, with an increase in the availability of equipment, the cost of design and manufacture increases, and the cost of operation decreases. At the same time, there is a certain (optical) reliability at which the total cost of design, manufacture and operation is minimal. This optimal level of reliability is called the reliability rate.

The requirements for increasing the equipment uptime associated with ensuring the specified optimal reliability are so high that it is often impossible to meet these requirements without resorting to special measures to improve its reliability.

Improving reliability can be accomplished in three stages - design, production and operation. The main methods for increasing the reliability of equipment are: redundancy, reducing the rate of equipment failures, reducing the uptime and reducing the average recovery time.

Redundancy, as a means of increasing reliability, is most expedient to use to improve the reliability of equipment designed for continuous operation for a short time. The use of redundancy to improve the reliability of equipment designed for long-term operation is often associated with high redundancy or with the use of special redundancy methods.

Increasing the reliability of the equipment by means of its redundancy leads to a deterioration in such characteristics as weight, dimensions, cost, service conditions (an increase in the frequency of checks, the number of spare parts and parts) and therefore limits the use of this method in the design of drilling and oil and gas field equipment.

The decrease in the failure rate is associated with the implementation of a set of measures to improve the quality and, first of all, the equipment durability.

The durability of drilling and oil and gas field equipment depends primarily on the durability of the most critical parts and parts. The problem of increasing the durability should be solved in three directions: 1) design - at the design stage, 2) technological - during manufacturing, 3) operational - during use, maintenance and repair.

When designing equipment, the main tasks of creating a rational machine design are solved - simplifying the kinematic diagram. The correct choice of materials, ensuring the uniform strength of the main parts in assembly units, ensuring the economy and efficiency of the machine as a whole. At the design stage, it is necessary to select such sizes of parts to ensure such conditions of their work, under which the intensity of wear will be minimal. In this case, it is necessary to take the most advantageous loads and speeds of relative movement of the rubbing surfaces, provide for the most advanced lubrication devices, choose the optimal fit in the mates, etc.

To increase the durability of the machine, the designer must provide for the high maintainability of its main parts, that is, ensure the ease of maintenance and repair of the machine.

One of the effective measures in this direction is the maximum unification of assembly units and parts, which makes it possible to manufacture machines from standard assembly units and assemblies, which makes it possible to quickly and easily replace worn-out parts in them in the field of operation and repair them in a centralized manner on well-equipped specialized enterprises. A promising direction in increasing the durability of machines is the creation of self-adjusting and self-healing assembly units and systems. The essence of such solutions is to ensure the constancy of the basic design parameters of the mates during operation by means of their automatic adjustment and adjustment.

In the manufacture of equipment, various technological factors have a great influence on the durability of parts and the machine as a whole. The choice of the workpiece, the method of processing and hardening of the working surfaces of the parts, as well as the quality of the assembly, largely determine the durability of the mates and the reliability of the machine parts.

Technological methods of increasing the durability make it possible to achieve a decrease in the intensity of wear of parts by appropriate processing of the working surfaces and their hardening.

The operational properties of products are largely determined by the quality of manufacturing of parts, characterized mainly by geometric parameters, physicomechanical and physicochemical properties of working surfaces.

Based on the operating conditions, various requirements are imposed on the quality of the working surfaces, the accuracy of the manufacture of parts and their physical and mechanical properties.

The listed properties of the working surfaces of the parts depend on the material used and are formed by means of certain technological methods.

The main task of mechanical engineering technology is the development of technological processes that ensure the manufacture of machine parts with the best operational properties.

Technological directions for increasing the durability of equipment include: selection of the optimal combinations of the chemical composition and structure of the material of the parts; the use of optimal methods for shaping workpieces of parts and heat treatment; selection of optimal conditions for machining; improvement of the geometric parameters of the working surfaces of parts; the use of strengthening methods for processing the working surfaces of parts.

One of the technological directions for increasing the durability of machines is measures to improve the physical and mechanical characteristics of materials used for the manufacture of machine parts. The main strength characteristics of future parts are formed already at the stage of manufacturing blanks for these parts, by means of casting, pressure treatment, etc.

The method of obtaining the workpiece has a great influence on the dynamic strength of the material. So, the limits of fluctuations in the impact toughness of workpieces made of steel St. 3, obtained by casting and forging, are in the range of 2.0 - 20 kgf m / cm2.

Subsequent heat treatment, for example, normalization, can significantly (by 50-100%) increase some of the mechanical characteristics of such workpieces. A significant increase in the mechanical properties of workpieces is ensured thermomechanical treatment.

During operation, parts of the equipment are subjected to static and dynamic loads, intense wear and corrosion. Parts operate in abrasive and corrosive environments at high temperatures (-50 ° ... + 50 ° C).

As the wells deepen, the bottomhole temperature rises and the main parts of the drilling tool operate at a temperature of 200-300 ° C.

The specified operating conditions lead to premature failure of the main parts of drilling and oil and gas field equipment and tools.

Observations of the wear and damage of machine parts in operation make it possible to distinguish five main types of parts destruction:

1) deformation and fractures (brittle fracture, ductile fracture, residual deformation, fatigue fracture, contact fatigue damage);

2) mechanical wear (abrasion of metal vapors, abrasive wear);

3) erosion-cavitation damage (liquid erosion, cavitation, gas

erosion);

4) corrosion damage (atmospheric corrosion, corrosion in electrolytes, gas corrosion);

5) corrosion and mechanical damage (corrosion fatigue, corrosion cracking, frictional corrosion).

Deformation and fractures occur when an excessive increase in stresses in the material of a part exceeds the yield strength or ultimate strength.

The deformation of the material is accompanied by a change in the shape and size of the part.

Mechanical wear is manifested as a result of the interaction of rubbing pairs. There are three main types of friction, depending on the nature of the lubricant:

1. Liquid friction - rubbing surfaces of bodies are completely separated from each other a layer of grease.

2. Friction with incomplete or imperfect lubrication - rubbing surfaces partially touch with their protrusions; this type of friction is divided into three subspecies;

a) semi-fluid friction, when the lubricant layer is not thick enough and partial dry (solid) friction occurs;
6) semi-dry friction, when there is friction of hard surfaces on which there is some lubricant;

c) boundary, or molecular, friction, when the geometric truss of rubbing bodies correct, and the surface treatment is very clean, as a result of which a molecular film of lubricant forms between the rubbing surfaces.

3. Dry friction - friction of metal surfaces without lubrication.

The least wear of rubbing pairs is evidently observed during liquid friction. Wear of mates operating under fluid friction conditions occurs when starting machines, overloading and using inappropriate lubricants.

According to the conditions of fluid friction, sleeve bearings of shafts with high rotational speeds are calculated. Abrasive wear is manifested in movable interfaces due to the scratching and cutting action of hard abrasive particles. As a result of abrasive wear, a very intensive destruction of machine parts occurs.

Erosion-cavitation damage to parts of machinery and equipment occurs when a metal is exposed to liquid or gas streams moving at high speed. With an increase in surface hardness, the intensity of destruction decreases sharply.

Corrosion of metals and alloys is a process of their destruction due to chemical and electrochemical effects of the external environment.

Corrosion damage has the following main features:
metal destruction always starts from the surface;

the appearance of the part, as a rule, changes;

as a result of corrosion, the metal usually turns into oxides or oxide hydrates.
By the nature of the external environment, corrosion is divided into three main types:

atmospheric, gas and corrosion in electrolytes.

Corrosion-mechanical damage is such damage that occurs under the influence of corrosion and mechanical factors (stress, deformation, friction, etc.). The most common are corrosion fatigue, stress corrosion cracking and friction corrosion.

Corrosion fatigue is the process of destruction of metals and alloys under the simultaneous action of a corrosive environment and cyclic stresses. As a result of corrosion, microscopic pitting can occur on the surface of the part, around which stresses are concentrated, which are the cause of the formation of a network of microcracks.

Corrosion fatigue cracks develop more intensively when exposed to a corrosive environment.

To increase the durability of parts and machines operating under conditions of corrosive fatigue, it is necessary to carefully isolate the working surface of the part from the corrosive environment as much as possible, to reduce the magnitude and cyclicity of stresses acting in the surface fibers of the metal

Mechanical wear is the most common. In the work of each rubbing pair, three periods are more or less clearly distinguished:

1) running-in, the period of natural wear and tear and emergency wear.

the amount of wear during the running-in period (section OA) is explained by smoothing the irregularities of the mating surfaces until a stable roughness and constant contact area is achieved. It is essential that normal running-in conditions are observed to prevent premature equipment failure.

2) natural wear and tear (AB area), which is characterized by approximately constant wear rate.

3) The third period (section after point B) is characterized by rapid wear,

an increase in the gap in the mating, which leads to shocks during the operation of parts and causes increased plastic deformation of the material. This wear zone is called emergency, and the wear corresponding to

point B on the graph is called the limit. If a part has reached the limit of wear, then it must be immediately replaced with a new one or rebuilt.

In contrast to the limiting wear in repair practice, there is a distinction between admissible wear, in which a part can be left in the machine if its limit wear does not occur before the next repair. There is also rejection wear, which determines the complete unsuitability of a part for work and restoration. This applies to parts that have worked in the emergency wear zone.

Do not bring equipment to emergency wear. It should be stopped before wear is at its limit. This can only be achieved through strict adherence to the schedules of preventive inspections and repairs, during which the most reliable data on the amount of wear is obtained.

Lecture number 3.

ELECTROMECHANICAL EQUIPMENT FAILURES

Lesson plan:

1.Types of failures

2. Classification of failures

3.Conditions of electromechanical equipment use

4. Causes of electrical equipment failures

Failures and their classification

Sudden failure is a failure characterized by an abrupt change in one or more specified parameters of an object.

Gradual failure is a failure characterized by a gradual change in one or more specified parameters of an object.

Independent element failure - failure of an element of an object, not caused by damage or failure of other elements.

Dependent element failure - element failure caused by damage or failure of another element of the object.

Failure is a self-correcting failure resulting in short-term operational disruptions.

An intermittent failure is a failure of the same nature that occurs repeatedly.

Structural failure is a failure resulting from violations of established rules and (or)

design standards and (or) imperfection of design methods.

Production failure is a failure resulting from a violation of the established manufacturing process or repair of an object.

Operational failure is a failure resulting from violation of established rules and (or) operating conditions or the influence of unforeseen external influences.

Complete failure is a failure, after the occurrence of which the use of an object for its intended purpose is impossible until its operability is restored.

Partial failure is a failure after which the product can be used for its intended purpose, but with less efficiency.

The reason for the failure is the phenomena, processes, events and conditions that led to the occurrence of the object's failure. The occurrence of a failure can be caused by errors or a low level of design of the facility, non-compliance with the technology during production, violations of operating rules, various types of damage, natural processes in the facility itself (material fatigue, wear, corrosion, etc.).

When designing, errors are associated with the incorrect establishment of the mining and technical conditions of the object, the choice of the magnitude and nature of the loads acting on the elements, the combination of materials of the interacting units, and the calculation error. In modern conditions, a significant reduction in design errors is facilitated by the use of computer-aided design systems.

The source of failures due to poor-quality workmanship are errors of mechanical and heat treatment, residual stresses and hidden defects in the material. The number of technological failures is from 15 to 25%, the duration of downtime due to these failures is from 19 to 25%, and the complexity of elimination is from 17 to 30%.

Operational failures have the greatest specific weight, both in terms of quantity, and in terms of the duration and complexity of elimination. Up to 50% of their total number are failures caused by mining and technical reasons. These are mainly unexpected overloads of machines. Erroneous refusals are associated with violation of technical instructions, rules and regulations of operation, low professional training operators, untimely maintenance and repair of equipment. The relationships between different types of failures are shown in Table 1.1.

Table 1.1

Refusal ratio,%

Cars	**Construction rejection**	**Production th refusal**	**Operation Rejection**
Complex KM-87D	**17**	**19**	**64**
Combine BK-52	**12**	**23**	**65**
Plow installation of USB-2M	**3**	**7**	**90**

The operating mode significantly affects the reliability of parts, units of machines and complexes. The operating mode is estimated by the load factor:

$$K_{н} - P_{р}/P_{д},$$

where Pp - workload; Рд - maximum permissible load.

Failure symptoms are indicated in the technical and regulatory documentation for each product. The main sign of failures and malfunctions is their impact on the implementation of technical and economic requirements for equipment.

Failure Consequences are phenomena, processes, events and states caused by the occurrence of an object's failure.
Least trouble-free systems: power supply (16-26% of failures); dust suppression (16-24% of failures);

communication system of the combine with the conveyor (13.5-20% of failures).

The cutting part, feed mechanism and electrical equipment of the combine account for 9 to 25% of all failures (Table 1.2).

Table 1.2

Failure rate (downtime as a percentage of shift duration)

A car	**Treatment complex**			
	Eyes stingy harvester	**Zabo ny conveyor**	**Mechanizirov this support**	**Lump plex v the whole**
KM 87E witharvester 2K52M	**4.3**	**4.0**	**1.6**	**9.9**
KM 87E witharvester 1GSh68	**4.2**	**4.3**	**2.0**	**10.5**
1 KMD7 witharvester 1K101	**5.1**	**4.2**	**1.8**	**11.1**
1 KM88 witharvester 1K101	**6.3**	**3.7**	**2.0**	**12.0**
Donbass withharvester MK 67	**4.1**	**3.8**	**2.4**	**10.3**
Donbass withharvester 1K101	**6.0**	**5.3**	**2.4**	**13.7**

There is no fundamental difference between sudden and gradual failures, since sudden failures in most cases are the result of a gradual, but hidden from observation, change in parameters, when the fact of breakage of parts is perceived as a sudden event.

The causes of sudden and gradual failures are: brittle fracture, plastic deformation, creep, material fatigue, wear, metal corrosion, material aging.

Failures of elements of mining machines and complexes can be classified according to a number of

signs (Table 1.3).

Failure classification

Table 1.3

Classification attribute	Refusal type	Examples of
The nature of the change the main parameters of the object until the moment of occurrence	Sudden failure	The gap chains scraper conveyor (all parameters changed) Failure of one of the scraper conveyor drive units
Character changes the main parameters of the object until the moment of occurrence	Gradual failure	Bluntness cutting harvester tool, wear of electric locomotive wheel rims
Possibility subsequent use of the object after the occurrence of its failure	Complete refusal Partial refusal	The gap traction organ conveyor, scraper installation, pusher trolleys, refusal pump motor Failure of one electric motor of a multi-drive conveyor
The relationship between failures	Independent refusal Dependent refusal	Chipping of cemented carbide in the drill bit The gap traction organ due to its jamming Burnout electric motor at failure of one of the contacts of the starting device
Sustainability inoperability	Persistent failure Self-removing glitch	Breakage or excessive wear of any parts Slip ribbons, V-belt transmission, computer failures
Availability external manifestations of refusal	Obvious (explicit) Hidden (implicit)	Twisting of the drive drum of the belt conveyor Breaking toothed wheels radiator
Cause of occurrence refusals	Structural failure Manufacturing failure Operational failure	Error constructor, imperfection methods adopted designing Error at manufacturing, violation technologies, imperfection of technology Violation of PE, external impacts unusual for the standard of operation
Time emergence refusals	Test failure Failure period extra earning Failure under normal exploitation Refusal v the end exploitation	Wear and breakdown of parts due to violation of the instructions for exploitation Failure due to overload

Analysis and accounting of factors affecting mining equipment during operation are the basis for maintaining the level of reliability laid down at designing.

Factors affecting the reliability of mine electrical equipment

GOST 18311-80 defines the operating conditions of electrical equipment as a set of values of physical quantities that are external factors and affect its operation.

The main influencing factors of operating conditions are: temperature; relative humidity and dustiness of the air; temperature changes; Atmosphere pressure; air speed; vibration and shock loads; displacement during operation.

The operating conditions of electrical equipment are determined by the category of use of electrical devices, voltage quality, number of starts, operating mode of electrical installations, etc.

Analysis of the causes of failure of electrical equipment operating in coal and ore mines showed that climatic and mechanical factors, as well as operating conditions, have a significant impact on its reliability.

In accordance with GOST and a number of industry regulatory documents, the operating conditions of electrical equipment are classified according to degrees of severity. 15 degrees of hardness have been established for positive temperature, 9 for negative temperature, 20 for vibration loads, 4 for shock loads, 8 for relative humidity, etc.

High reliability and efficiency of electrical equipment can be ensured when the technical solutions (technical parameters,

Design, manufacturing technology, types of tests) correspond to strictly specified conditions (degrees of severity) of operation.

In accordance with this, the development takes into account the operating and limiting temperature, air humidity, dripping, dustiness of the air, aggressiveness of the environment, air velocity, vibration and shock loads, etc. For example, the average annual operating temperature (° C) of air in mines can be adopted: in the main workings 12; in the faces 15; in substation chambers 18.

Mine electrical equipment is designed and manufactured in various versions: when placed on a surface under a canopy (for example, U2: climatic version U, placement category 2); in underground workings (U5); in areas with a cold climate: on the surface under a canopy XJI2, in underground workings XJI5.

Along with the indicated indicators, the voltage quality has a significant impact on the reliability indicators of electrical equipment. Indicators of voltage quality are frequency deviation, voltage deviation and fluctuation, non-sinusoidal voltage waveform, frequency fluctuation, neutral offset and voltage unbalance of the fundamental frequency.

Operating conditions for electromechanical equipment of mining enterprises

Operating conditions are usually defined as a set of external factors (physical quantities) that can affect it during operation. External factors are divided into two groups: climatic and mechanical.

In underground mining, climatic factors have the greatest impact on humidity, temperature, dust, and corrosive substances. From mechanical factors - vibration, sharp shocks and shocks, and for the outlet ends of electrical equipment, in addition, tensile and bending forces, torque, twisting, which are possible during the installation of electrical equipment.

The high humidity (up to 100%) in underground workings of coal and ore mines is explained by the presence of groundwater, and the increased temperature (according to the MakNII, in some workings it reaches + 40C0 even with air conditioning) an increase due to a positive gradient in the depth of development and (to a lesser extent) heat release from operating electrical equipment.

The corrosiveness of mine waters is significant. The content in them of cations and anions of acids and alkalis, carbon dioxide, as well as other chemically active elements reaches 50 g per 1 liter.

Humidity, temperature, dust, aggressive agents, mold fungi, acting on the shells and insulation of electrical equipment, reduce their reliability and, therefore, lead to premature failures.

With open-pit mining of mineral deposits, climatic factors affecting electrical equipment are much greater. In addition to higher (+ 45 ° C and above) and low (-50 ° C and below) temperatures, its changes during the day (40 ° C and more) are influenced by such factors as solar radiation, wind, rain, frost, etc.

Allocate three characteristic of the kind impact temperature on work electrical equipment in quarries: prolonged increase or decrease; temperature fluctuation; episodic increase or decrease. The reason for the premature failure of electrical equipment with prolonged exposure to elevated temperature - inconsistency of the selected insulation of live parts with the degree of heating. Changes in temperatures and, as a result, periodic heating and cooling of electrical equipment are caused by daily fluctuations and the cyclical operation of the equipment itself. Changes in temperatures with zero crossing at high humidity are especially unfavorable, since frost occurs on the contacts, freezing of the relay armatures and disruption of the operation of control systems due to this.

At low temperatures (-30 ° C and below), work is especially difficult power grid equipment. For example, transformer oil thickens so much that it causes complete failures of oil switches. Replacing them for these conditions with vacuum ones is the most effective measure of increasing operational reliability.

Adversely affects the operation of electrical devices filled with

transformer oil, humidity, since, being hygroscopic, the oil absorbs moisture and loses its dielectric properties. In this regard, the period for replacing transformer oil in devices is about 3 months.

Corrosion in open pit works is associated with contamination of the moisture layer, occasional appearing on the surface of electrical equipment, by various chemical

substances deposited from the air. The electrolyte formed during this intensively destroys the elements of electrical equipment.

Solar radiation has a significant effect on career electrical equipment: under the sun's rays, decay processes are sharply accelerated

electrical insulating materials (PVC, fluoroplastic, rubber, etc.), and paint and varnish cracks and collapses. Additional heating of surfaces of openly installed equipment by direct sunlight reaches 30 ° C. The high-voltage adventure points (HVs) located on the work boards are exposed to this effect.

Dustiness of mine workings depends on the method of destruction of minerals (mechanical, drilling and blasting), type of transport (electric, conveyor, automobile), structures of loading and unloading devices and structures. Downhole electrical equipment is most exposed to dust in mines and quarries. Accumulating on the surface of live parts

electrical equipment, the dust layer becomes electrically conductive and breakdown usually occurs through it. Getting into electrical equipment, dust particles accelerate the abrasive wear of its elements, are the cause of bearing seizure. There is a correlation between the dust content of the open pit air and the operating time before the overhaul of electrical equipment, which must be used in the development of new dustproof structures of electrical equipment.

Mechanical influences (shock, vibration, tensile forces, etc.) are experienced by electrical equipment - when moving most of the machines during operation (shearers and roadheaders, excavators, etc.) and periodic movement of electrical installations (conveyors, drilling rigs, substations,

distribution and switching points, etc.).

Switching points and other power supply equipment at when transported along unprepared routes, they experience significant vibration loads (vibration frequency up to 180 Hz, amplitude 0.2-0.5 mm, acceleration 15g). Vibration loads often cause destruction of support and bushing insulators, breakage of rods and misalignment of contact systems, loss of rigidity and strength of welded structures, damage to devices, protection relays, etc.

In addition to climatic and mechanical factors of the external environment, the state of electrical equipment is affected by mining and geological factors.

This is manifested in the nature of the operating modes of mining machines, the totality of which most fully reflects the conditions of their operation.

Reasons for failure of mine electrical equipment

Collecting statistics in progress exploitation miner electrical equipment and its analysis make it possible to identify the most typical causes of failures of electric motors, starting protection equipment, transformers and transformer substations, cables.

Studies have shown that the largest number of failures in combine motors falls on the stator winding and inlet boxes contaminated with coal dust, gear oil, bearing grease and flooded with water.

In the stator windings of such electric motors, the main part of the breakdowns of the insulation of the sections on the case falls on the corners of the sections near their exit from the groove. The groove part of the section wears out more than the frontal parts due to electrodynamic shocks and thermomechanical friction against the groove walls. Breakdowns of coiled insulation are noted only in the frontal parts and are absent in the slotted part at any stage of insulation aging. It should be noted that the melting of aluminum rotor windings in EDK motors, for example, is observed 2 times less often than in EDCO motors with a higher rate of temperature rise.

The misalignment of the rotor and stator that has appeared during operation can lead to a "paste" of the rotor against the stator.

The most typical damage to bearings of combine electric motors during normal operation is fatigue damage and brinelling of rolling surfaces. Ingress of coal and rock dust, metal particles into the bearing grease leads to the formation of dents on the rolling surface. Abrasive wear occurs, gradually leading to fatigue chipping. Under the influence of temperature and mechanical load, the bearing grease gradually ages, its viscosity decreases, which can lead to its runout, jamming and rotor paste.

For electric motors of the VAO series, the most characteristic type of damage is charring of the coil insulation due to thermal effects. Turning closures are characteristic of the frontal part of the stator winding from the side of the section connection.

Phase-to-phase and turn-to-phase short-circuits occur at the connections of the sections and at the outlet ends of the winding head parts. Other typical damages include case short-circuits, jamming of bearings, fan on the casing, network breakage, etc.

The main failures of mine explosion-proof electrical devices (switchgears, circuit breakers, magnetic stations, starters, etc.) should include failures of remote control circuits, free release mechanisms, power contacts, trip coils.

Failures in remote control circuits are caused primarily by failures of its individual elements due to the influence of harsh environmental conditions and poor quality of the supply voltage. Resistors and semiconductor elements have an open circuit failure, a capacitor has a short circuit, and chokes and stabilizers have a turn circuit. Up to 95% of failures are due to poor-quality connections or soldering.

The reasons for failures of various kinds of relays are misalignment of contacts, formation of a non-conductive film on their surface due to corrosion and pollution, welding of contacts. Low-power relays are characterized by false alarms under the influence of shock and vibration loads. However, the majority of failures occur in the closing coils.

The reason for failures of chokes, transformers is the destruction of winding insulation, which occurs under the influence of high temperature and humidity, vibration and shock loads.

When analyzing the failures of transformer substations and transformers, it was found that the largest number of failures of substations falls on automatic switches and protection units BZP-1A. In these devices, the most characteristic is the wear of the contacts, breakdowns of the insulation of the HV winding on the case, turn short circuits of the HV winding, turn closures of the tripping coil of the circuit breaker. The failure rate is on average 13.3 10-5 1 / h (mean time between failures - 7500 h).

Failures of mine flexible cables most often occur due to mechanical damage to the insulation (up to 85%). However, due to wetting of the insulation, electrical breakdowns and a decrease in insulation resistance are also observed in end cuts, couplings and couplings. This explains the rather limited lifespan of flexible cables.

For armored cables with paper insulation, failures are typical due to breakdown of insulation in bushings and lead-in couplings, due to mechanical damage in workings by falling pieces of rock, vehicles and during workings fastening.

For cables with voltage higher than 1000 V, the following data on failure rate (per 100 m), 1 / h can be recommended: stem λs = 2.4 · 10-5; in inclined workings λн = (6.5 ÷ 9.0) · 10-5, in horizontal workings λg = (3.7 ÷ 6.7) · 10-5.

For cables with voltage up to 1000 V, the data is much higher and amount to, 1 / h: for flexible combine λк = 58.0 · 10-5; flexible in lavas λl = 29.2 · 10-5; flexible in workings λw = 12.5 · 10-5; armored 10.0 10-5.

Lecture number 4

ECONOMY AND RELIABILITY. RANDOM GOODS.

Lesson plan:

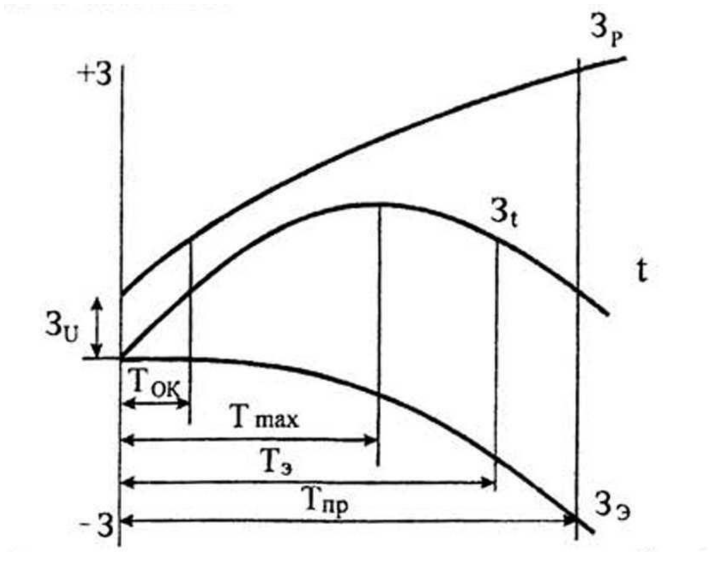
1. Relationship between reliability and economy
2. The economic expression of reliability
3. Random variables

The question of the impact of reliability on the economy of an enterprise or a sector of the national economy will be discussed in detail below. Here we will restrict ourselves to general remarks.

The modern level of development of technology allows you to achieve almost any level of quality and reliability of products and therefore costs are an important criterion for achieving a specific goal. In some cases, they can be so large that they do not compensate for the effect of increasing reliability and the overall result of operating such a system will be negative.

The task is to choose a rational solution when the costs of measures to improve the reliability will be commensurate with or significantly less than the profit received during the operation of the system.

When comparing various options, they usually proceed from the condition of the greatest total economic effect, taking into account the costs of manufacturing and operation and the positive economic effect that the use of the object gives for its intended purpose.



Rice. 2. Change over time in the economic efficiency of the operation of a hypothetical product

In fig. 2 shows the change in the total costs of manufacturing a new object ZU (initial costs) and the cost of operating it ZE (including maintenance, repairs and spare parts) as a function of time. It can be seen that the costs of ZU + Ze are negative in the balance of efficiency and increase over time due to the aging of individual elements of the object and the need to invest more and more funds to restore the lost properties.

During operation, the object is gives positive economicthe effect of RR is a profit that tends to ecrease the growth rate due to an increase in the cost of repair and maintenance (MOT) as the object wears out.

By thisFor this reason, the curve of total efficiency Зt = ЗU + Зэ + ЗР has a maximum and crosses the abscissa axis t twice. After a time interval t = TOC, the total costs will equalize (ЗР = ЗU + ЗЭ) and the object will pay for itself, that is, it will return the costs of its production.

Starting from the moment of time t = CURRENT, the object will be profitable. The increase in the effect will gradually decrease due to the increase in operating costs up to t = Тпр, when again ЗР = ЗU + ЗЭ. For t> Tpr, the operating costs will be greater than the economic effect that the facility can provide. The economic feasibility of operation is in the interval TOC <TE <Тпр, where Тпр is the maximum service life.

The choice of a variant of an object, taking into account the reliability factor, is made by comparing the costs of its development, manufacture and operation with the economic effect that it can provide.

Material damage caused by interruptions in work due to failures is also considered as a measure of the efficiency of the functioning of an object.

Material damage can manifest itself in the form of costs to restore the operational state of the facility, in the form of an increase in the cost of manufactured products or a decrease in labor productivity, as well as in additional capital investments.

In some cases, failures of technical systems lead to violations of the conditions for their safe use, and then the consequences can manifest themselves in the form of fires, explosions, etc., and even lead to the death of people.

The economic expression of reliability EMC failures lead to interruptions in the operation of technological equipment, to violations of the power supply regime and other facts that cause material damage due to the termination of the functioning of the main or all production links of the enterprise.

The above indicators of reliability make it possible, with a certain degree of accuracy, to obtain an economic expression of reliability, i.e. submit material damage due to EMC failures in monetary terms.

Most simply, material damage is determined in the event of failures of the restored products. If N products of the same type were in operation during the time Te, the FBG P (Te) of which is known, and the cost of each product C, p., Then the mathematical expectation of the loss M (UB) excluding the cost of replacing the failed products will be

$$M (Ub) = N [1 - P (Te)] Si, \tag{35}$$

and the mathematical expectation of losses, taking into account the costs of C3 for the purchase of new products
to replace the failed ones and the costs of C for the actual replacement will be

$$M (Ub) s = N [1 - P (Te)] (Cu + Cs + Cn). \tag{36}$$

If the average IR of non-recoverable products is known, then the FBG for the time Te will be $P (Te) = \exp (-\lambda avTe)$.

From formulas (35) and (36) it can be seen that in this case the duration of downtime and losses due to disruption of the technological process are not taken into account.

In case of violations of the technological process due to EMC failures, a loss Yp occurs due to product losses as a result of a decrease in the volume of its output and the cost increases due to an increase in its conditionally constant component due to forced downtime, which is expressed in the form of a loss of UPV. The total loss will be

$$M (YO) = YNS + Upv = AC (\beta + \gamma - 1), \tag{37}$$

where $\beta = C / C$ is the ratio of the price of C to the cost of C per unit of production; A = QgTgpKivPo (E) KVTS.

Here Qg - hourly productivity, units. h; Tgp is the number of hours of operation per year, h / year; Kiv - coefficient of use of EMC for the production of products (Kiv = 0.3 - 0.7); Ro (E) - total probability of downtime; KBTC - coefficient of influence of technological connections on losses in case of failures; γ - the share of conditionally fixed costs in the cost of production.

It is convenient to determine the downtime probability by the formula

$$RO(E) \approx \sum_{i = 1}^{n} \overline{Pi}(NS), \tag{38}$$

where n is the number of elements. Here, the downtime probability of one element is determined by

ratioP (E) = λWedta.wed, where λWed - the average failure rate of the element; ta.wed - the average

downtime to failure, h

Formula (37) is convenient to use to determine losses during breaks power supply, when a failure in the system leads to a downtime of a technological link or section. The data for the calculation are given in the Appendix.

When calculating EMC and power supply systems (SES) for reliability, other approaches are also possible. One of them is based on determining the expected under-supply of electricity due to EMC and SES failures.

If the total expected power consumption Eabout for a certain period of time

is known, then her shortage in the same time will be ΔE = EaboutRO(NS). If the cost1 kWh

is a, p. / kWh, then the loss will be Δ3h = EaboutRO(E) a, p.

For the economic justification of the adopted technical solutions for the development It is important for SES to know the costs of improving reliability. These costs are determined by comparing the costs of improving reliability and economic losses from interruptions in power supply.

Random Variables

Failures of electromechanical systems are random events. The time intervals between failures will also be random. All the consequences of failures are of the same nature - product losses, downtime, etc. Thus, when studying all processes related to the reliability of products, objects or systems, one has to deal with random events and random variables.

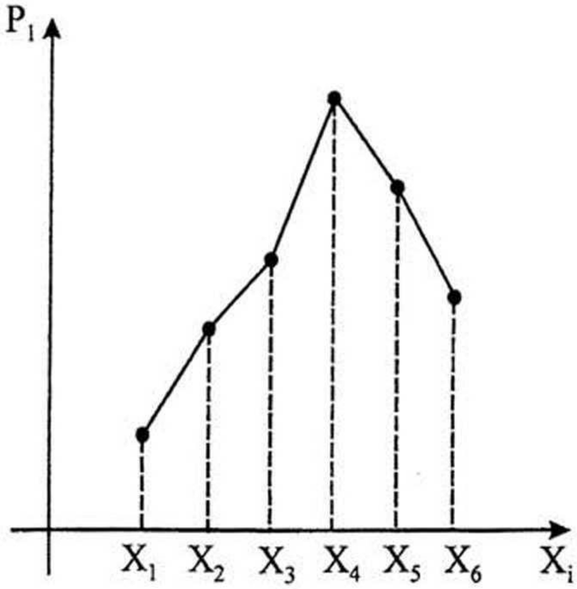
An event is a fait accompli. A random event is any fact that may or may not happen. In the theory of probability, events are divided into reliable, equally possible, joint, inconsistent, dependent and independent [2, 8].

A random variable (SV) is a variable that can take on its own value in each of the n tests (observations). The set of SVs is called a random function (random process).

Random variables are divided into discrete and continuous.

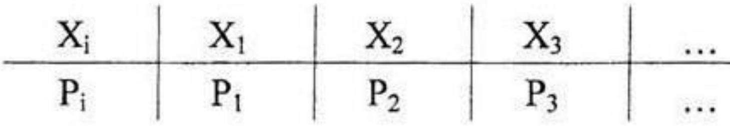
Discrete RVs can take values corresponding to a natural number series (n people, d apples, k insulators, etc.), continuous ones - any values on the number axis (the time of failure-free operation of the same type of elements, the duration of their repair or restoration, etc.).).

To describe the SV, it is necessary to know the probability of accepting different values by it, i.e., the distribution law. The SV distribution law is the relationship between the possible values of this quantity and the corresponding probabilities.



Rice. 3. Distribution polygon

To describe a discrete SV, a table is used, which is called a series distribution. In the upper row of the table, the values of random variables are recorded, and in the lower row - the corresponding probabilities of the appearance of these random variables. An example table is shown below.

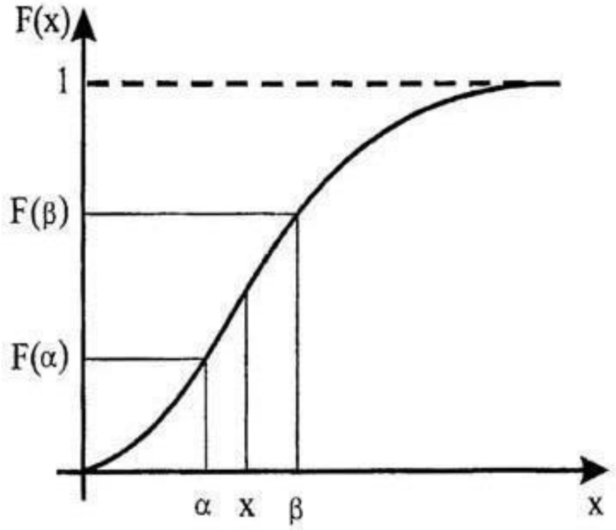


X_i	X_1	X_2	X_3	…
P_i	P_1	P_2	P_3	…

For visibility row maybe to be presented graphically. The vertices of the obtained ordinates are usually connected by straight line segments (Fig. 3). The resulting shape is called the distribution polygon.

For continuous RVs, it is impossible to compile a list of all possible values, and therefore they are described using a distribution function. The distribution function or the integral law of distribution of RV X is called setting the probability of the inequalities $X < x$, considered as a function of the argument x, i.e., $F(x) = Ver(X < xi)$ or $P(\alpha < x < \beta) = F(\beta) - F(\alpha)$; $F(x) = P(X < x)$. A graphic representation of the function is given in Fig. 4.

Basic properties of the cumulative distribution function:



Rice. 4. Distribution function

the function F (x) is in the range $0 \leq F(x) \leq 1$;

values $F(0) = 0$; $F(+\infty) = 1$; the probability of occurrence of an event in

a semi-closed interval is equal to: $P(\alpha < x < \beta) = F(\beta) - F(\alpha)$.

Function distribution continuous SV is her exhaustive characteristic. Its disadvantage is that it is difficult to judge from it the nature of the SW distribution in the vicinity of any point on the numerical axis. More visual

an idea of the nature of the SW distribution

in the vicinity of various points is given by

the probability distribution density

$$F(x) = \int_{-\infty}^{x} f(x)dx \text{ ;}$$

or a differential distribution law f (x), and $f(x) = dF / dx = F'(x)$ (Fig. 5).

The most important properties of the function f (x): integral function the probability of a continuous RW X hitting the section (α, β) is equal to the integral of the distribution density taken over this section, i.e.

$$P(\alpha < x < \beta) = \int_{\alpha}^{\beta} f(x)dx ,$$

i.e., the shaded area under the curve in Fig. 5.

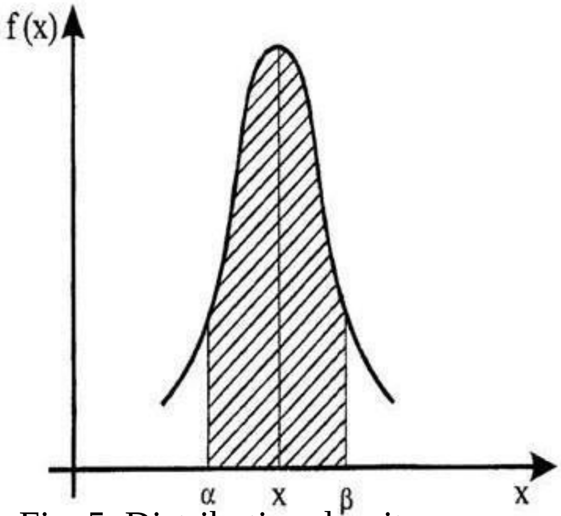


Fig. 5. Distribution density

Lecture number 5 NUMERICAL CHARACTERISTICS OF RANDOM VALUES

Lesson plan

1. Purpose of numerical characteristics
2. Laws of distribution of discrete quantities

The main purpose of numerical characteristics is to express the most significant features of a particular distribution.

The mathematical expectation M [X] CB X is the sum of the products of all its possible values by the probabilities of these values. For discrete quantities

The mathematical expectation is approximately equal to the arithmetic mean:

$$M[X] = m = \sum_{i=1}^{\infty} x_i P_i .$$

$$m^* = \frac{\sum^{n} x_i}{n},$$

where n is the number of realizations of CB X.

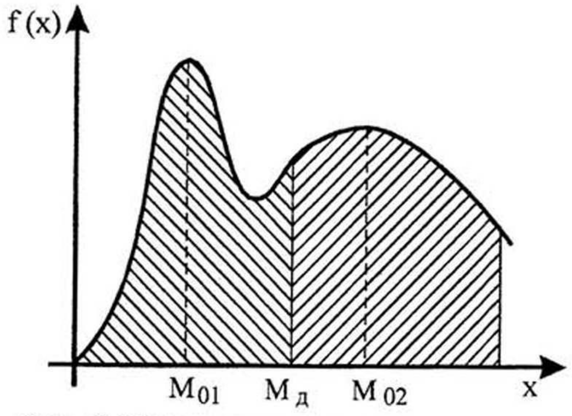


Рис. 6. Двухмодульное распределение

Dispersion D [x] characterizes scattering of SW. It shows how closely the random variables are grouped around the center of scattering. Variance is the mathematical expectation of the square deviation of the value xi from its mathematical expectation m.

For a continuous value

$$D[x] = \sigma^2 = \int_{-\infty}^{+\infty} \left[(x_i - m)^2\right] f(x) dx .$$

The value is often used, which is called the standard deviation and is defined as follows:

$$\sigma = \sqrt{D[x]} .$$

The M0 CB mode is its largest random value. In fig. 6 shows a bimodal continuous distribution (modes M01 and M02).

The median MD is such a value of SV, relative to which it is equally probable to obtain a larger or smaller value of SV, i.e., P (x <MD) = P (x> MD).

In fig. 6 shows shaded areas each equal to 0.5. The coefficient of variation V is the ratio of the standard deviation to the mathematical expectation, i.e. $V = \sigma / m$.

Distribution laws of discrete quantities

These laws find application in technical applications, the most widespread are the binomial law and the Poisson distribution law.

The binomial distribution law (Bernoulli's formula) is used when repeating tests. Let us assume that independent experiments are carried out n times; the probability of occurrence of the expected event in each experiment is constant and equal to p, and the probability of its non-occurrence $q = 1 – p$. Then the probability of occurrence of this event is determined exactly one time from ratios

$$P_{k,n} = C_n^k p^k (1-p)^{n-k} = \frac{n!}{k!(n-k)!} p^k q^{n-k}.$$

Basic properties of binomial distribution: range of values - positive integers from 0 to n; the probability p can be any value between 0 and +1; at p = 0.5, the distribution law is symmetric; n is a positive integer; mathematical expectation is defined as m = np; and the standard deviation according to the formula

$$\sigma = \sqrt{npq}\ .$$

(6)

Poisson distributions are found in technical retest problems where the probability of an expected event is small. Typical examples of a random variable with a Poisson distribution are: the number of calls at the telephone exchange in time t, the number of complex equipment failures in time t, the number of atmospheric interference during radio transmissions, the number of rare components per unit area or volume, etc.

The Poisson distribution law is interpreted as follows: it is required to find the probability Pn =P (x = n) that exactly n points will fall on a segment of length t, assuming that the points are distributed along the entire axis with an average density (Fig. 7).

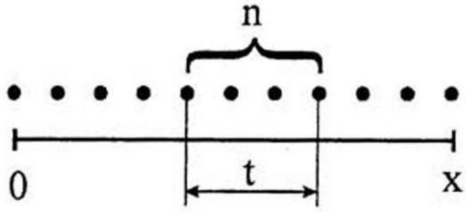
We denote this density, i.e., the average number of points per unit length, by λ. Then Poisson's law will be written as follows:

$$P_n = \frac{(\lambda t)^n}{n!} \exp(-\lambda t).$$

If we denote λt = a, then

$$P_n = \frac{a^n}{n!} \exp(-a),$$

where a is the mathematical expectation.



Rice. 7. Towards the definition of the Poisson distribution

Poisson distribution properties:

- distribution depends on one parameter a, which is mathematical expectation (m = a);
- standard deviation $\sigma = \sqrt{a}$;
- the distribution is asymmetrical, the asymmetry is especially pronounced at small values of a.

For discrete random variables, the distribution function has the form:

F(x) = P(X = xi),

where xi - values of a random variable; P - the probability of the appearance of this value. When the current variable x passes through one of the possible values of the discrete quantity X, the distribution function changes abruptly, and the magnitude of the
jump is equal to the probability of this value. The sum of all possible jumps of the function F
(x) is equal to one. The graph of the distribution function of a discrete random variable is a stepped curve (Figure 1.1, b)

In reliability problems from discrete distributions, the most commonly used binomial and Poisson distribution.

Binomial is the distribution law of a discrete random variable of the number x of occurrence of events K times in n independent tests, in each of which the probability of occurrence of events is P.

The probability that the event will occur exactly K times (no matter what sequence) is determined by the Bernoulli formula: P K C K
pK qn K
n n
or PK n! pK qn K
n K!
n K !

where q = 1 - p is the probability of non-occurrence of the event in each test.

If the number of trials n is large, and the probability of occurrence of events P in each
aKe a
test is small, then the formula is used Pn K K
!

where a = nP is the average number (mathematical expectation) of events in n tests. The distribution of a discrete random variable X described by the last formula is called
the Poisson distribution.

For example, failures of recoverable objects within a given period of time have a binomial distribution.

Example. The mine has six conveyors with turbo couplings. Probability of failure-free operation of one turbo coupling for four months q = 0.8. Find the probability of failure in four months zero, one, two, three and four

couplings:0 1 0.8 0.26
R6 0.20 6 2;
R 0.8 0.85
61 1 0.21 5 6! 0.21 0.328;
1! 6 1 !
R 6! 0.2 0.245
62 20.84 ;
2! 62!
R 6 6! 0.2 0.081
3 3 0.83 ;
3! 6 3!
R 6! 0.2 0.8 0.015
64 4 2 ;
4! 64 !

R6 6! 0.24 0.015
4 0.82 ;
4! 6 4 !

Lecture number 6

DISTRIBUTION LAWS OF CONTINUOUS RANDOM VALUES

Lesson plan

1. Gauss's law
2. Exponential distribution
3. Predicting change resistance isolation electrical equipment

To describe continuously distributed RVs, the normal, truncated normal, logarithmic-normal, exponential laws, the Weibull-Gnedenko law and other distribution laws are used.

The normal or Gaussian distribution law (Fig. 8) is characterized by the distribution density according to the ratio

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x_i - m)^2}{2\sigma^2}\right]$$

and distribution function

$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{+\infty} \exp\left[-\frac{(x_i - m)^2}{2\sigma^2}\right] dx.$$

In relations (9) and (10), m is the mathematical expectation, and σ is the standard deviation. The normal law (NZ) is widespread in technical problems, and indeed in nature in general. It manifests itself in all cases when RV X is the result of the impact of a large number of interdependent RVs, the influence of each of which is small (ie, there are no dominant RVs).

The main feature of the normal law is that it is a limiting law, which is approached by other distribution laws.

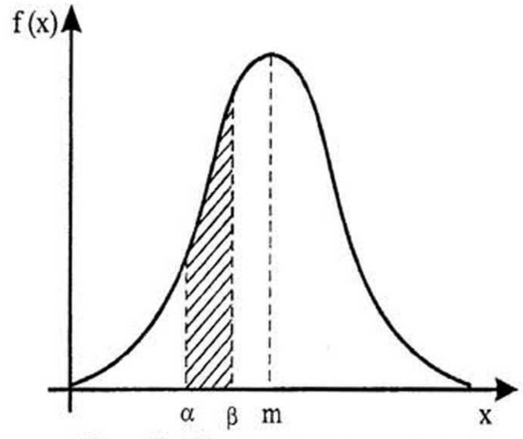


Рис. 8. Кривая плотности нормального закона

The probability that RV X takes values belonging to the interval (α, β), i.e., falls into this interval will be

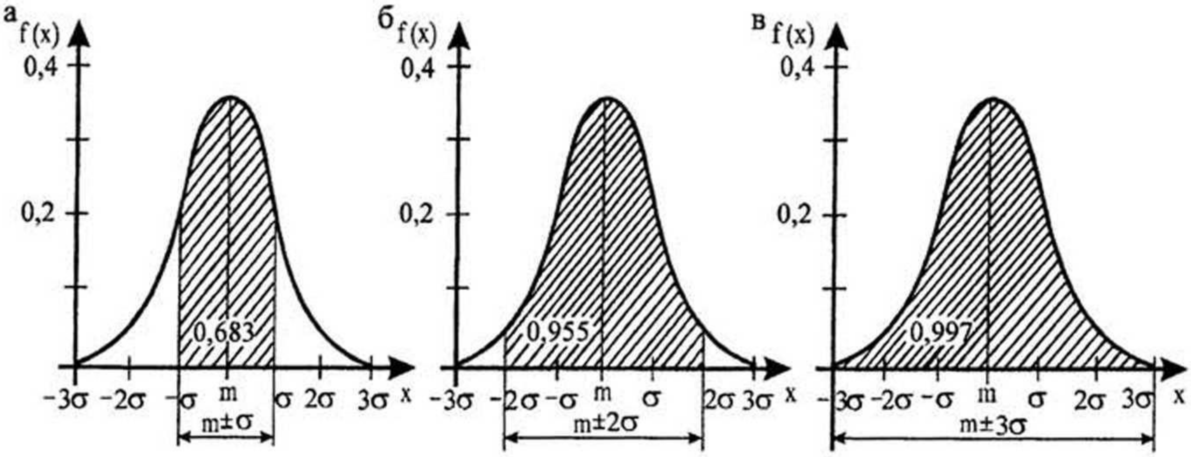
$$P(\alpha < x < \beta) = \frac{1}{\sigma\sqrt{2}} \int_{\alpha}^{\beta} \exp\left[-\frac{(x_i - m)^2}{2\sigma^2}\right] dx.$$

In fig. 8 this area is shaded.

In the practical application of NS, one of its features is of great importance, which is that the probabilities of hitting SV X in the intervals [(m - σ), (m + σ)], [(m

- 2σ), (m + 2σ)] and [(m - 3σ), (m + 3σ)] are known and amount to 0.683, 0.9554, and
0.997. This feature of NS is called the "three sigma rule". It means that 68.3% of the SV values are contained in the m ± σ range, where m is the mathematical expectation,
95.5% of the values are in the m ± 2σ range, and 99.7% are in the m ± 3σ range,
i.e. practically all values of the considered or investigated random

magnitudes. In fig. 9 sequentially shows the probabilities of hitting the SW in the interval m ± σ (Fig. 9, a), m ± 2σ (Fig. 9, b) and m ± 3σ (Fig. 9, c).



Rice. 9. The probability of hitting the SW with a normal distribution (area under the curve) in the intervals: a - (m ± σ); b - (m ± 2σ); c - (m ± 3σ)

The exponential distribution (ER) has a distribution density:

$$f(x) = \lambda \exp(-\lambda x) = \frac{1}{m}\exp(-\frac{x}{m}),$$

where λ is the distribution parameter; λ. = 1 / m; m - mathematical expectation.

Distribution function:

$$F(x) = 1 - \exp(-\lambda x) = 1 - \exp(-\frac{x}{m}) .$$

The CB dispersion is obtained from the relation

$$D = 1/\lambda^2,$$

and the standard deviation

$$\sigma(x) = \sigma = \sqrt{D(x)} = \frac{1}{\lambda} = m,$$

that is, with ER, the standard deviation is equal to the mathematical expectation of SV. In applied matters of reliability, it is often

use the function P (x) = 1 - F (x), which is called the reliability function

Taking into account formula (15), we obtain

In fig. 10 shows the ER density f (x) and the reliability function P (x).

One of the most important for the practical application of the properties of the ER is that for the case when the SV X is equal to the mathematical expectation, i.e., x = m, the reliability function has the value P (x) = exp (-m / m) = exp (-l) = 0.368,

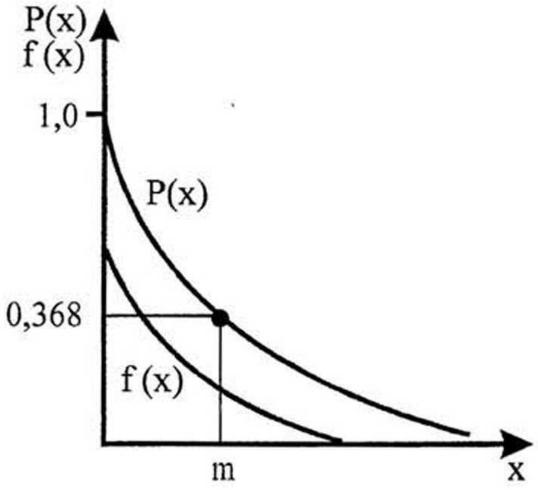


Рис. 10. Плотность ЭР и функция надежности

that is, the average value of SV corresponds to the probability of its occurrence in 38.3% of cases (Fig. 10).

Note that when the product λx << 1, i.e., when the RV is much less than its mean value, then relations (12), (13), and (16) can be simplified by replacing exp (-λx) with the first two terms of the expansion in the power series exp (-λx). In this case, expression (16) takes the form

$$P(x) \approx 1 - \lambda x = 1 - x/m.$$

The resulting error does not exceed 0.5 (λx) 2.

The Weibull - Gnedenko (RVG) distribution is also widely used in reliability theory to describe the functioning of systems that have a running-in period or are subject to wear (aging).

The distribution density of this distribution has the form:

$$f(x) = abx^{b-1}\exp(-ax^{b}),$$

and the distribution function:

$$F(x) = 1 - \exp(-ax^{b}).$$

This is a two-parameter distribution, where the parameter b determines the form of the distribution density; parameter a - its scale (another name: b - shape parameter, and - scale parameter). So, at b <1, the RVG can approach the ER (Fig. 11), and at b = 1 it can coincide with it. For b> 1, RVG can approach HP (Fig. 11.6) or degenerate into ER.

In addition to the SW distributions considered above, which are widespread in the theory of reliability, in some cases, other distributions can be used, information about which can be obtained from the special literature, for example [1].

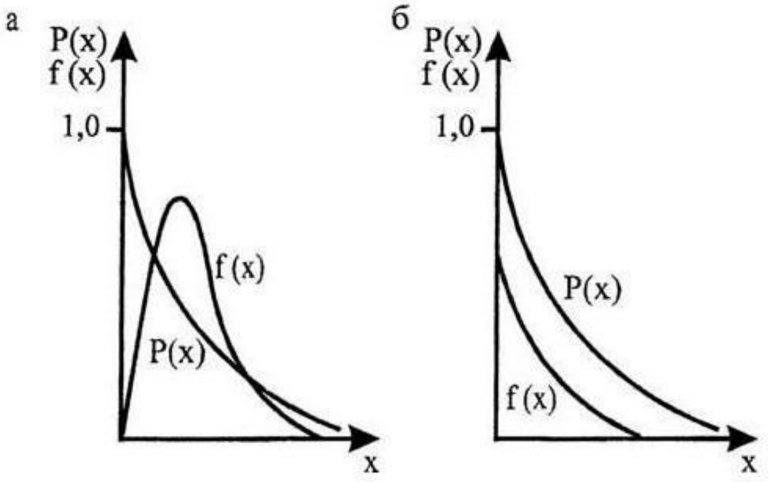


Рис. 11. Распределение Вейбулла – Гнеденко при b > 1(а) и b < 1 (б)

With the help of SV distribution laws in the theory of reliability, they most often characterize reliability indicators, for example, operating time or uptime, recovery time, etc. The distribution laws in this case are called statistical reliability models.

Quantiles are often used to describe a continuous distribution. The quantile corresponding to a given level of probability p is such a value x = xp, at which the distribution function takes on a value equal to p, that is, F (xp) = p. Some quantiles have a special name. So, for example, the median of the MeX distribution is called the quantile, corresponding to the value p = 1/2. Quantiles corresponding to p = 1/4 and p = 3/4 are called the lower and upper quantiles, respectively. If, for example, pn = 90, pb = 95, then we get 90% and 95% quantiles, respectively. The indicated quantiles are, respectively, 10%, 5% upper points of the distribution, and the quantiles corresponding, for example, to the values p = 0.10, p = 0.05, -10%, 5% lower points distribution

Example. The MTBF of the scraper conveyor turbo coupling is distributed ok with parameters a = 500 h and = 100 h

Determine the probability of failure-free operation for operating time t1 = 200 h and t = 700 h:

$$Z1 \quad \frac{200\ 500}{100} \quad 3;\ Z2 \quad \frac{700\ 500}{100} \quad 2$$

Φ (–3) = –Φ (3) = –0.4987; F (2) = 0.4772;

R(200) = 1 - F(200) =
1 - (0.5 - 0.4987) = 0.9987;
R(700) = 1 - F(700) =
1 - (0.5 + 0.4772) = 0.0228.

Log normal distribution developments have many non-recoverable products such as rolling bearings. With this distribution, the logarithm of the random variableNS distributed according to the normal law.

$$\text{Probability density: } f\,(x) \quad \frac{M}{x\ 2\sqrt{\ }}\, e^{\frac{\lg x\ \ \lg a\ 2}{2\ 2}}$$

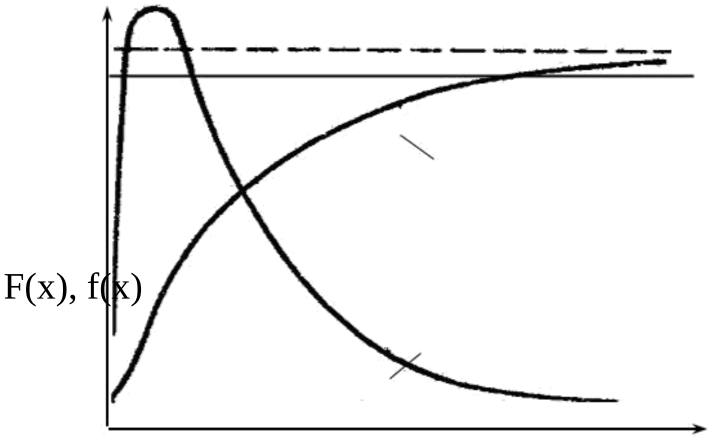
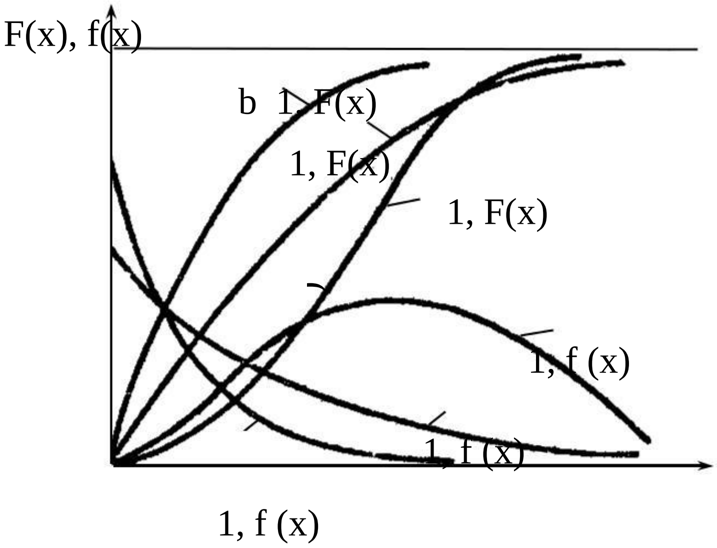


Figure 1.3. Log-normal distribution random variable



0 NS

Figure 1.4. Weibull distribution

lg x
lg a 2
1
Or f (x) _____ e 2 2
x 2 √

where M = 0.43; - standard deviation of the logarithm of a random variable.

Range of possible values NS lies in the interval (0, +). The mathematical expectation and variance of a random variable NS with a log-normal distribution (Figure 1.3):

a 2
M (x) e 2 ; D(x) 2 e 2 .
e2a 1

Weibull distribution have some objects that fail due to fatigue failure, many semiconductor devices.

The Weibull distribution (Figure 1.4) has the function distribution

x2 x b
F(x) 1 e ; F(x) 1 e a

x2 x b
b x b 1
f
(
and the probability density f (x) 1e x aa
F(x) xd ;) ...

Parameter influences the form of the distribution function and the density

probabilities.

Exponential distribution. Weibull distribution at b = 1 has a probability density

x
f (x) e1

a
x
_

and the distribution function F(x) 1 e a

This distribution is called exponential and is of particular importance in reliability theory.

The MTBF of many non-recoverable products (automation and electronic equipment, etc.), in which the phenomenon of wear and aging is poorly expressed, are exponentially distributed.

Probability of uptime

P(t)   1 _
F(t) e a

Failure rate
1
(t)   const
a ...

Therefore, the probability density and the distribution function with an exponential distribution are written in the form

1

f (t) e t   ...   .
Distribution   function   F   .
(t) 1 e   .

Dimension s-1 is the number of failures per unit of time.

It can be shown that the mean time to failure T0 1/ and variance D 1/ 2 ...

Example... Combine hydraulic pump failure rate = 0.0006 h-1... Define probability of pump failure-free operation in 300 hours and MTBF.

Probability of uptime in 300 hours

P(t) 1 F(t) e 0.0006 300 e 0.18 0.835.

Mean time to failure

_   ____1   16
0.   67

00 h
06

The probability of failure-free operation with this distribution depends only on the length of the considered time interval t and does not depend on the moment in time from which

the countdown begins.

Gamma distribution. If the device consists of one worker and n reserve elements, each of which is switched on after the failure of the previous one, then the device will fail at the moment when the element fails n + 1.

If all items are exponentially distributed with failure rates

, then the operating time to failure of the entire device will have a -distribution with parameters and

m = n + 1.

The distribution density of a random variable (Figure 1.5) is determined from the expression

mm
1 1 λte
G
m
t ,

where Γ - designation -functions if m Is an integer, then Γ (m) = = (m - 1)! The gamma distribution of operating time and recovery time may have some other objects, in this

casem can be either an integer or a fractional number.

Figure 1.5. Gamma distribution

m = 1

At m = 1 The -distribution has a probability density

f (t) λe λt ,

those. exponential distribution is a special case -distributions.

The mathematical expectation and variance of a random variable having -distribution

Lecture number 7

RELIABILITY INDICATORS

Lesson plan

Indicators of durability of machines

Indicators of maintainability

Indicators of persistence

Complex indicators of reliability

Indicators of reliability of restored objects:

probability of failure-free operation P(t);

failure flow parameter (t) Is the density of the probability of failure the restored object, determined for the considered moment in time;
MTBF T - the ratio of the operating time of the restored object to

the mathematical expectation of the number of its failures during this operating time.

The probability of failure-free operation is determined in the same way as for non-recoverable objects. However, it should be borne in mind that the distribution functions of the operating time between the start of operation and the first failure, the first and second failure, and so on, may be different. Therefore, the probability of no-failure operation should be determined through the corresponding distribution function. During the operation of mining equipment, information on reliability is collected separately for new and for objects that have been overhauled.

The moments of failure form the flow. The characteristic of the failure flow is the leading function (t) Is the mathematical expectation of the number of failures in the time t:

(t) = Mn(t).

For the time interval (t1, t2)

Mn(t1, t2) = (t2) - (t1).

Function

The parameter of the flow of failures is the average number of failures per unit of time. It is sometimes referred to as the average failure rate.

MTBF is defined as the ratio of the amount of operating time of recoverable objects to the total number of failures of these objects for a certain period:

Durability indicators

Resource - operating time of the object from the start of operation to reaching the limit states.

Average resource Is the mathematical expectation of the resource.
Average resource between medium (overhaul) repairs - average resource between adjacent medium (capital) repairs.
Gamma Percentage Resource - operating time during which the object does not reach

limit state with a given probability (%). If, for example, =80%, then the corresponding resource should be called eighty percent.

Table 1.5 shows the standard resource values for some types of mining equipment.
If the resource allocation function is known Fd(t), then percent resource

is determined from equation 1 - Fd(t) = /100.

Table 1.5

Equipment durability indicators (standard)

Equipment	Resource, thousand tons (service life, months)	
	Until the first overhaul	Between capital repairs
Shearers		
1K101	210 (12)	168 (10)
2K52M	270 (12)	216 (10)
1GSh68	360 (12)	288 (10)

End of Table 1.5

Equipment	Resource, thousand tons (service life, months)	
	Until the first overhaul	Between capital repairs
KSH1KG	215 (12)	172 (10)
KSh3M	450 (12)	360 (10)
Scraper conveyors		
SP63M	300 (12)	240 (10)
SP130	420 (12)	336 (10)
SP87P	420 (12)	336 (10)
KM8102BM	480 (12)	384 (10)
SUOKP70	500 (12)	400 (10)

Repairability indicators

The probability of recovery at a given time - the probability that the time

restoration of the object's performance does not exceed the specified one.

Average recovery time - mathematical expectation of recovery time performance.

Mathematical definition of the probability of restoration of the object's performance:

probabilistic

Pv(t0) = P(0, t0) = P{ t0} = Fv(t0), where - random time of object restoration;

Statistical
Pv(t0) = n(t0), ____

N (0)

where n(t0) - the number of objects, the repair of which has ended by the time t0; N(0) - the number of objects, the repair of which was started at the initial moment of time t = 0.

Thus, the probability of recovery is the frequency of the event that

that the implementation of the repair time of the object is less t0 (set time).

Determination of the average recovery time:

probabilistic:

Tv M tf (t) dt tdFv (t) 1 Fv (t) dt ,

00 0

where Tv - the mathematical expectation of the recovery time;

Statistical:

1 (1) i N (0)
(2) n ()1
i
____ n ____
N(0) v N(0)

1

where iv - recovery time i-th object; N(0) - the number of recovered objects. In general, the random recovery time

i i1 i2 i3 i4 ,

where i1 - time of failure detection; i2 - repair time (failure elimination); i3 - time

testing the machine after eliminating the failure; i4 - waiting time for repair.

Repairability indicator Tvdefined taking into account all four terms, characterizes as the fitness of the design for fast

detection of failures, their elimination and testing after the elimination of the failure, and the level of organization of the repair service, provision of labor, spare parts, i.e. maintainability in specific operating conditions.

Persistence indicators

Persistence - property of the object to continuously maintain serviceable and efficient condition during and after storage and (or) transportation. It is characterized by the following indicators:

the likelihood of a failure during storage;

storage time for failure;

average shelf life;

gamma-percentage shelf life - shelf life, which

will be reached by the object with a given probability (%).

These indicators can be determined if the distribution function is known Fc(t)

random variable with, where with - random time of object storage until failure (between failures).

For example, the probability of a failure occurring over time t:

Pwith(t0) = Pwith(0, t0) = P{ with t} = 1 - Fwith(t).

If you set the number of objects as a percentage ( ) that will persist for time tc, then the shelf life tc can be determined from the equation

1 - Fwith(t) = /100.

If, for example, = 90%, then the corresponding shelf life should be called 90% shelf life.

Comprehensive reliability indicators

Availability ratio - the probability that the object will be operational

at an arbitrary point in time, except for the planned periods during which the use of the object for its intended purpose is not allowed.

Technical utilization rate - ratio of mathematical expectation

the time the object remains in a working state for a certain period of operation to the sum of the mathematical expectation of the time that the object is in a working state, the time of downtime due to maintenance, and the repair time for the same period of operation.

From the last expression it follows thatK G characterizes the reliability and maintainability of the facility.

The technical utilization factor is statistically determined by the ratio of the total residence time of the observed objects in a working state to

the product of the number of observed objects for a given operating time: $\hat{K}$and .

If the specified operating time Tthe ex is different for each product, then this formula will change:

Unlike KG, Kand takes into account the time spent on scheduled maintenance and therefore always KT.I. KG...

The greater the value Kand and KG, the better the object is adapted for technical service.

Lecture number 8

METHODS TO ENSURE RELIABILITY OF MINING MACHINES

Lesson plan

Formation of reliability in design

Formation of reliability in the manufacture of an object

Calculation of a node from redundant elements by transition probabilities

Ensuring the reliability of a machine cannot be considered in isolation from its operating conditions. Depending on the purpose of the machine, the requirements for reliability may be different. In cases where they are not guided by economic considerations, they usually strive for maximum reliability. Where economic objectives are put first, the equipment should have optimal reliability (Figure 2.1).

Reliability is formed and maintained at three stages of the life cycle of technical objects: development and design, manufacturing, and operation.

Formation of reliability in design

The main methods of forming the required level of reliability of mining equipment at this stage include:
choice of rational constructive, kinematic and technological schemes

work;

full accounting of external and internal loads;

application of perfect methods for calculating operating parameters;

redundancy of elements, functions, strength and power; analysis of reliability indicators;

choice of methods for fast and high-quality restoration of working capacity.

Before calculating the reliability indicators of the product, a calculation scheme is drawn up. First, the work of the product is described - how it works for a given time, how the elements work. As a result, a list of properties of a serviceable product and a range of changes in its operating parameters are drawn up.

Then the possible failures of elements and the entire product are listed and described, the impact of failures of each of the elements on the performance of the product is evaluated, after which a logical model of its failure-free operation is drawn up. To do this, consider the behavior of the product in the event of failure of each of the constituent elements.

The level of reliability is also determined by the method of connection or interaction of the constituent elements of the object. In the theory of reliability, there are sequential, parallel and mixed interactions of elements.

If the object consists of elements A, V and WITHinteracting sequentially, then

it is functional when each of these elements is in working order. The failure of any element is a necessary and sufficient condition for the failure of an object as a whole. The probability of failure-free operation of the product as a whole is determined by the multiplication theorem for the probability of failure-free operation of elements

P = PARVRWITH...

Hence, it can be seen that with an increase in the number of successively interacting elements, the reliability of the product decreases rapidly.

If the product consists of parallel interacting elements and its operability will be ensured while maintaining the operability of at least one element (A, V or WITH), then the probability of failure-free operation of such a product is determined by the probability addition theorem.

With a large number of parallel interacting elements, the probability addition theorem gives a very complex calculated dependence. Therefore, it is more convenient to determine the probability of product failure and through it - the probability of failure-free operation.

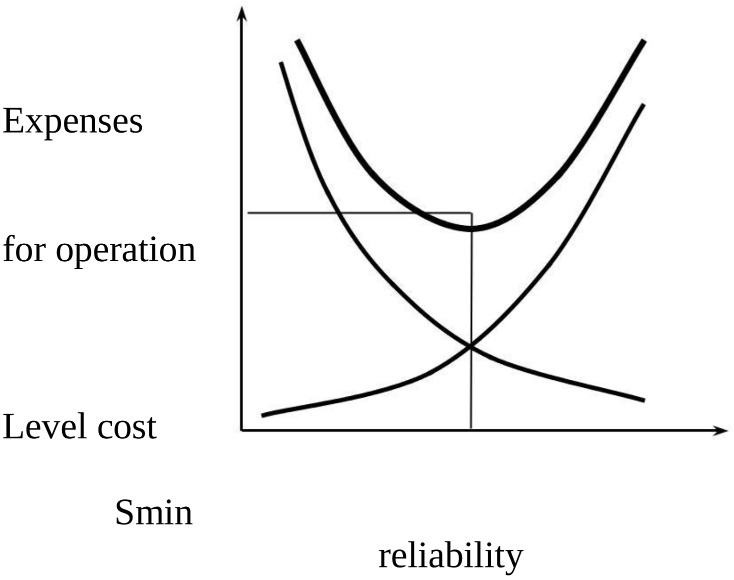
Probability of non-failure operation of the product with parallel interaction elements is greater than or equal to the probability of failure-free operation of the most reliable element. Moreover, it increases with an increase in the numberm parallel interacting elements.

In a mixed interaction of elements, product reliability is determined using dependencies for serial and parallel interaction.

In the theory of reliability, a number of methods have been developed that increase the reliability of systems. One of them is the creation of reserves of one kind or another, which increase the likelihood of failure-free operation. So, for example, the system includes redundant elements, redundant in relation to the minimum necessary for its operation. This results in a higher probability of uptime than a single element.

It should be noted that the introduction of a backup element is not the only way to improve reliability. The same effect can be achieved by increasing the level of reliability of the working elements of the system. They reserve the strength of parts (safety margin), machine power (power reserve). One of the approaches to improving reliability in design is the use of the "worst case" criterion, which provides for the normal operation of the product with a combination of the worst values of any factors during operation. This leads to a stability margin for the product.

The introduction of redundancy in the machine leads to a deterioration in its weight, dimensions, cost and other indicators. There are mathematical methods and algorithms that allow you to find the design solutions that would best meet various, often conflicting, requirements. They can be used to formulate and solve the problem of achieving the maximum likelihood of failure-free operation of a product under given constraints (in terms of cost, size, weight, etc.) or achieving the minimum value of one of the indicators at a given level of probability of failure-free operation.



Reliability level

Formation of reliability in the manufacture of an object
At the manufacturing stage increased reliability and durability of machines achieved by applying high quality materials and advanced technological processes of processing, perfect process technology assembly, installation and tests, strict compliance technological regulations.
Significant role in implementation

The planned level of product reliability is played by ensuring the stability of the dimensions and shape of the parts, increasing the wear resistance and fatigue strength, the quality of the processed surface and the physical and technical properties of the manufactured parts. The finished products are accepted by the factory quality control department and then factory and industrial tests are carried out.

With large batches of products, carrying out a complete inspection is expensive. In this case, only some products from the batch are subject to inspection, and the inspection itself is called selective or statistical. Accelerated tests are used to reduce the number of tests and their duration. The main idea of accelerated reliability testing is that, without changing the physical essence of the process of changing the reliability, significantly reduce the testing time and, after assessing the quality of products, in a relatively short time bring their reliability to the target level. Acceleration of tests is achieved:

toughening of load conditions or characteristics of the external environment;

extrapolation of the characteristics of the random process of the occurrence of failures;

modeling the process of deterioration and aging of an object using various instruments and analog modeling.

Accelerated test results should be systematically compared with field observations.

Restoration of reliability during the operation of the facility

The analysis of the operational reliability of mining machines shows that the most significant influence on the level of operational reliability is exerted by the correct organization of the use of the equipment of working faces, the provision of its spare parts and the frequency of preventive maintenance. Units and parts of mining equipment show the range of operating times to failure, therefore, the choice of preventive replacement intervals for various groups of parts is of great importance. Replacing parts after a period equal to the minimum operating time is not economically justified. Therefore, the question arises about the choice of the optimal frequency of planned replacement of parts. The average cost of preventive replacement of the elements of the treatment complex simultaneously with the reassembly of the complex after the completion of the column is lower than during the period of the development of the column.

The number of gradual failures of downhole equipment elements is significantly influenced by the overhaul period and the manpower of the repair shift.

For various types of downhole equipment, there is a limit to the increase in the average turnaround time due to the increase in the labor resource of the repair shift. This limit depends on the complexity of the equipment used. So for daily maintenance, the probability of wear failures in the KM-87D complex does not exceed 0.01, and the probability of their occurrence with one repair shift per week increases to 0.61 even with a significant increase in the labor resource of the repair shift. Rational repair periods should be selected taking into account the complexity and operational reliability of the downhole equipment.

Prompt and high-quality maintenance of preventive work can be carried out only on the basis of the use of computers, which will allow you to simultaneously monitor a large number of equipment, prescribe one or another type of prevention and monitor the work performed.

Carrying out restoration work, even with their optimal organization, does not exclude the possibility of wear and sudden failures of machine elements. Therefore, it is very important to determine and timely supply the required number of spare parts to replace the failed elements in the periods between scheduled maintenance.

Lecture number 9

RESERVATION

Lesson plan

Method - reservation

Block diagrams of connections of elements

Reliability of types of connections

Redundancy is a method of increasing the reliability of an object by introducing redundancy. Redundancy - additional funds and capabilities in excess of the minimum required for the object to perform the specified functions.

Redundancy:

the presence of redundant elements of the object structure; use of extra time in excess of the minimum; use of additional information;

ability of elements to perform additional functions, except directly installed;

the ability of the elements to carry out additional loads.

Redundancy is one of the ways to maintain the level of equipment reliability. Reliability indicators depend on the scheme and methods of redundancy. There is a concept of "state" of the system, which is characterized by the performance of one of the elements and the entire system as a whole. The system states are described using graphs of transitions from one state to another. On the basis of the transition graphs, systems of differential equations are compiled, the solution of which makes it possible to determine the probability of failure-free operation of the machine with various options for the layout and redundancy of the object's elements.

Structural diagrams of connections of elements

Distinguish between general and separate structural redundancy. With a general reservation, the object as a whole is reserved. With a separate reservation, individual elements of the object (parts, assemblies, blocks, aggregates), diagrams, etc. are reserved. Mixed redundancy is often used.

Split backups are much more efficient than shared backups. Efficiency increases with decreasing redundancy, i.e. the smaller part of the object is reserved as a whole, the more P (t) of the object.

Permanent structural redundancy is one in which the backup elements function on a par with the main ones during the entire operation time and are in the same mode with it.

Structural redundancy by replacement is a redundancy in which the functions of the main element are transferred to the backup only after the failure of the main element. The transfer of the functions of the main element to the reserve one can be done manually or automatically.
If the system consists of n elements, of which one is primary and n-1 is backup, then

(
t)
n —

——
n!

those. probability of failure in case of backup substitution in n! times less than with permanent redundancy, since the redundant elements are not under load. Reliable transfer of functions to the backup element must be ensured.

Let's consider the effectiveness of different methods of structural redundancy. System

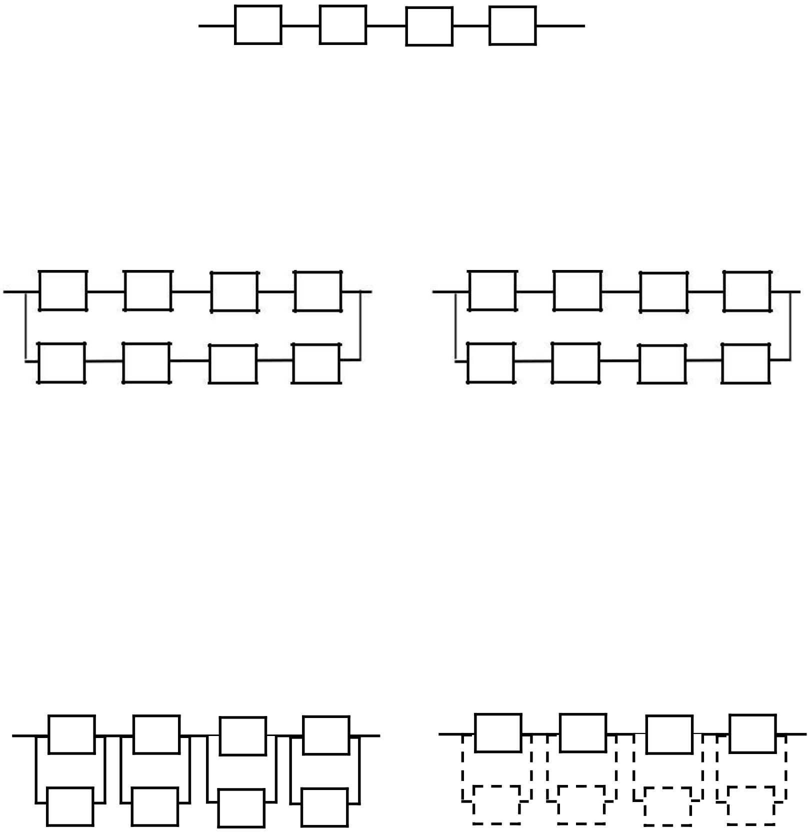


Figure 2.2. Structural schemes various species redundancy: a -
of four elements connected in series (Figure 2.2, a). Probability of no-failure

work P (t) = 0.9, the probability of failure q (t) = 1 - 0.9 = 0.1,

P (t) = P4 (t) = 0.94 = 0.66; Q (t) = 1 - P (t) = 1 - 0.66 = 0.34.

Total permanent redundancy of the system (Figure 2.2, b):

Q (t) = 0.342 = 0.12; P (t) = 1 - 0.12 = 0.88.

Total system redundancy by substitution with reliable switching

Q2 (t)
0.342

Q (t)
(Figure 2.2, pc ____
c): 2! 2!

Ppc(t) 1 Qpc(t) 1 0.06 0.94.

Separate permanent redundancy of each element of the system (Figure 2.2, d):

.
.
.

(
1
t q2 4 1 0.12
) (t) 4 0.96;
(

1
(Pp
t c
) 1 0.96 0.04.

Separate redundancy by replacing each element of the system (Figure 2.2, e):

q2
(t)
Ppc(t____ 4 __
) 1

Qpc(t) 1 0.98 0.02.

Obviously, separate redundancy is much more efficient than general redundancy, and replacement redundancy in reliable switching is more efficient than constant redundancy.

The impact of the scale of redundancy can be estimated as follows. Probability of no-failure operation of one Pi pipeline. Probability of no-failure

work (Figure 2.2, a) P1 = 1 - (1 - Pn i)m.

The probability of failure of two parallel conveyors (Figure 2.2, b) (1 - Pi) m.

Probability of no-failure operation P1 = 1 - (1 - Pi) m.

Consider three groups of two conveyors connected in series. Then the probability of failure-free operation of the system (Fig.2.2, b) P2 = [1 - (1 - Pi) m] n;
with n = 3, m = 2 and Pi = 0.9:

P1 = 1 - (1 - 0.93) 2 = 0.93; P2 = [1 - (1 - 0.9) 2] 3 = 0.993 = 0.97.

From this it is clear that the circuit in Fig. 2.2, b is more reliable.

Reliability for various redundancy schemes is calculated using the following formulas.
General permanent redundancy of the system (Fig. 2.2, b)

= 1 - (1 - Pin) m; P = 1 - (1 - Pi4) 2.

General redundancy of the system by replacement with a reliable connection (Figure 2.2, c)

Total permanent reservation of each element (Fig.2.2, d) P = [1 - (1 - Pi) m] n.

General redundancy by replacing each element (Figure 2.2, e)

Reliability of connection types

Calculation of the reliability of a product consisting of a number of elements is possible after the formation of its structural diagram. At the same time, it is considered that the elements of the product interact sequentially if the failure of any of them leads to the failure of the entire system. In this case, the system is operable if both element A and element B are operable, etc. The conjunction "and" predetermines the application of the probability multiplication theorem. The system is in a state of failure if either element A or element B fails, etc. In this case, the probability of failure is determined by the addition theorem for the probabilities of failure of elements.

The elements of the product interact in parallel if its operability is ensured while maintaining the operability of at least one element, i.e. workable or A, or B, etc. The probability of failure-free operation of such a product is determined by the theorem of addition of probabilities for joint events. With a large number of parallel connected elements, the use of the probability addition theorem leads to a very cumbersome calculated dependence. Therefore, it is more convenient to determine the probability of product failure by the theorem of multiplying the probability of failure and only then the probability of failure-free operation:

P = 1 - Q = 1 - i 1qi = 1 - i 1(1 - pi).

It should be noted that the concepts of parallel and serial communication

from the point of view of the theory of reliability, they do not correspond to the connection of elements in the physical sense.

For example, on the drain lines from the sump of the

factory, two valves are installed, physically

connected in series (Figure 2.3). From the point of view

of the theory of reliability, these valves interact

sequentially when the drain is opened (the normal

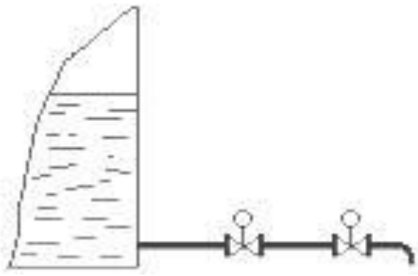
position of the valves is closed) and in parallel when

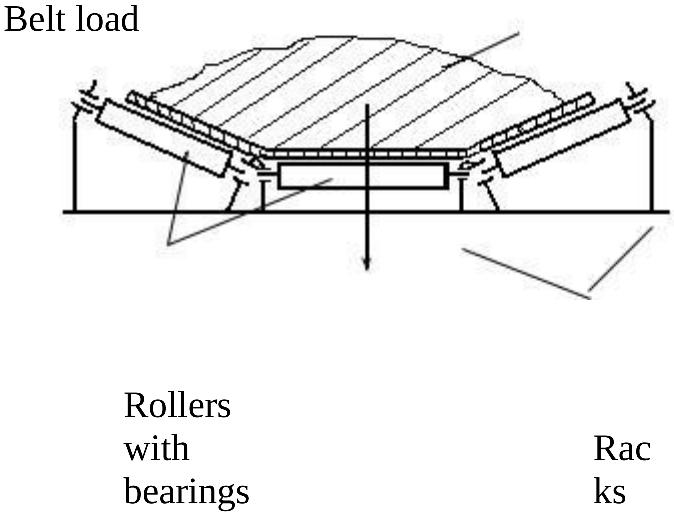
the drain is closed (the normal position is open).

Thus, when forming a structural diagram of the interaction of elements of any system

a preliminary analysis of its normal operation is required. It is recommended to use functional analysis tools for this.

First, the main function of the product is formulated, and then the main ones, which ensure the performance of the main function and allow you to highlight the main structural elements of the product. After that, the sequence of the passage of the most important flow (material or field) through the structural elements is established. Exactly





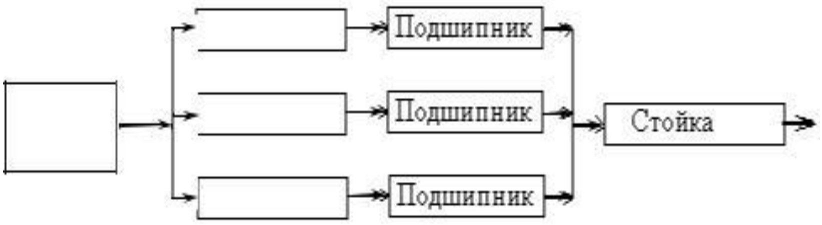
this subsequence sets character interaction of elements - parallel, consistent or mixed. Consider the example outlined construction methodology structural diagram product interaction.

There is a roller support for the cargo branch of the belt conveyor (Figure 2.4). The load lies on the belt, which is placed on three rollers with bearings resting on the struts. It is necessary to build a structural diagram

Rice. 2.4 cargo roller support of the conveyor.

roller supports. The main function of the roller support is to reduce the resistance to the movement of the belt with the load. Main functions: provide a low coefficient of friction; maintaining the belt with a load; groove of the cargo flow section.

The first main function is performed by rollers with bearings, the second - by stands with rollers, the third - by a set of rollers. Since the main function is associated with the flow of forces (field flow), it is necessary to consider the sequence of this flow passing through all the elements of the product. The resistance to movement is created by the forces of the weight of the load and the strap. These forces from the belt with a load (element of the super system) pass sequentially through the rollers with bearings, racks, the frame of the conveyor train (element of the super system). Thus, we obtain a block diagram of the conveyor roller support (Figure 2.5).



Video clip

Video clip

ribbon

Video clip

Bearing

Bearing

Bearing

Rack

Figure 2.5. Block diagram of the roller support

The structural diagram of the interaction of the elements of the roller support has a mixed form. After a mathematical description in the form of an equation of the reliability indicator of the roller support, depending on the reliability indicators of its structural elements, it is possible to analyze the operation modes of the roller support.

For m successively interacting elements, the probability of failure-free operation is determined by the dependence

m

P = i 1pi,

where pi is the probability of failure-free operation of the i-th element.

If all elements have the same probability p, then P = pm.

For n parallel interacting elements, the probability of failure of the ith element is qi = 1 - pi, and the probability of failure of m elements
nn

Q = i 1qi = i 1(1 - pi).

Probability of failure-free operation of the entire product

n

P = 1 - Q = 1 - i 1 (1 - pi). For

identical elements P = 1 -

(1 - p) p.

If the product consists of m elements interacting in series and forming n parallel interacting chains, then the probability of failure-free operation of the entire product

m

P = 1 - j 1 (1 - i 1 pi).

With the same elements P

= 1 - (1 - pt) p.

Lecture number 10

CALCULATIONS OF FBG WITH SEQUENTIAL AND PARALLEL CONNECTING ELEMENTS

Lesson plan

Calculations for serial connection of elements

Calculations for parallel connection of elements

Calculation of a node from redundant elements by transition probabilities

Calculations when connecting elements in series

EMC reliability calculations are performed to determine the reliability and maintainability indicators at the design stage or before conducting reliability tests to compare design and actual indicators.

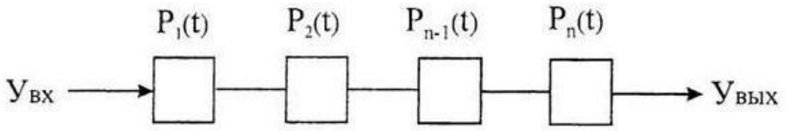
Determination of the reliability of complex systems is carried out as follows: the system is divided into constituent elements or groups of elements and the reliability of each of them or a group is established or calculated, and then the reliability of the entire system is determined. For this purpose, a structural diagram is drawn up. The structural reliability of a system is called the resulting reliability for a given structure (method of connecting elements) and known reliability values of all elements or their groups included in it.

The breakdown of the system into elements is carried out on the basis of the principle of the unity of functioning, taking into account the fact that the reliability of an individual unit or group of elements differ from each other. When drawing up a structural diagram, two types of connection of elements are used - sequential (main) and parallel.

When the elements are connected in series, the system failure occurs when any of the elements fails. It is like breaking a chain made up of links located one after the other. They are depicted in the form of rectangles with indicators of reliability (Fig. 1).

When connecting elements in series, it is assumed that the operational state of each of them is an independent event. Then the probability of the system's operational state can be determined by the probability multiplication theorem:
P0(t) = P1(t) P2(t) ... Pn(t),(nine)

where Pi(t) - FBG of the i-th element.



Rice. 1. Serial connection of elements

With an exponential law of distribution of the operating time of each of the elements, the reliability (FBG) of the system will be:

$P0(t) = \exp(-\lambda 1t)\ \exp(-\lambda 2t)\ldots\ \exp(-\lambda nt) = \exp(-\lambda 0t)$,   (ten)

where $\lambda 0 = \lambda 1 + \lambda 2 + \lambda n$

or

$$P_0(t) = \prod_{i=1}^{n} P_i(t). \qquad \text{(eleven)}$$

In some cases, it is convenient to calculate not the FBG of the system, but its operating time, if the operating time of the elements is known. In this case, it is necessary to take into account the type and properties of the distribution law of the operating time of individual elements, if they differ from each other.

So, if the operating time of some elements are distributed according to one law, and the operating time of others according to another, then the operating time of the system (product) is determined from the ratio

where T_i- MTBF of the i-th element; n is the number of elements.

For non-recoverable products, this formula is valid only when exponential law.

If an element of a non-recoverable product has an MTBF that obeys the normal law, and the MTBF of the remaining elements is distributed exponentially, then the MTBF is determined as follows:

distributed according to the Weibull - Gnedenko law with the same scale parameters ($a_1 = a_2 = a_3 = \cdots a_n$) and forms ($b_1 = b_2 = b_3 = \cdots b_n$), the MTBF of the product is equal to.

In other cases, various combinations of laws determine the MTBF

by the method of approximate calculations.

When determining the indicators of the durability of products, those failures of prefabricated elements that require major repairs are taken into account.

With a series connection of elements for the exponential law, the product reliability indicators:

where T, Ti - MTBF of a product and its assembly elements (units) i-th type; P (t),Pi(t)

the probability of failure-free operation of the product and its assembly element (unit) of the i-th type; Ni

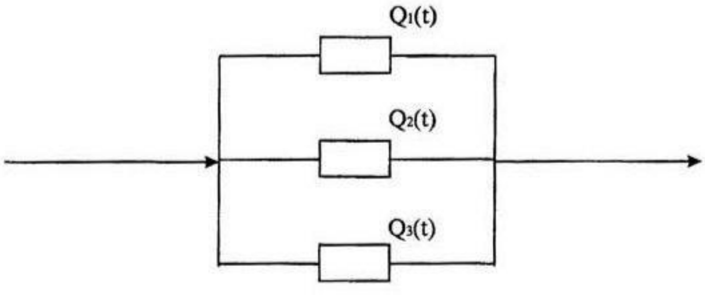
the number of assembly units of the i-th type; Ai - the share of failures of assembly units the i-th type in the

total number of product failures.

If one assembly unit is characterized by several types of failures, then the reliability indicators for each type of failures are calculated separately, and the product as a whole is represented by several series-connected assembly elements, each of which is characterized by only one type of failure.

Calculation with parallel connection of elements

Parallel connection of elements (Fig. 2) is used for redundancy or duplication (backup cables, power lines for powering consumers of the first category, etc.), as well as to ensure the transmission capacity of power lines, etc.



Rice. 2. Parallel connection of elements

In case of parallel connection, it is assumed that the inoperable states of the elements are independent events, and therefore they operate with the probabilities of failures Q (t) = 1-P (t), i.e. failure is the opposite of a healthy state. The sum of the FBG and the probability of failure corresponds to the full group of events: P (t) + Q (t) = 1.

The resulting reliability of a group of n parallel connected elements will be:

$$P0(t) = 1 - Q0(t) = 1 - Qi(t) \qquad (17)$$

$i = 1$

where $Qi(t)$ is the probability of failure of the i-th element in time t.

In real structural diagrams, there is a mixed or parallel serial connection of elements. An example is the systems automatic control, radio and electronic circuits, etc.

In power supply systems, common or separate redundancy is most widespread (Fig. 3).
With general redundancy, there are several (from two or more) systems of the same type that perform the specified functions. The probability of failure-free operation of such a system is equal to:

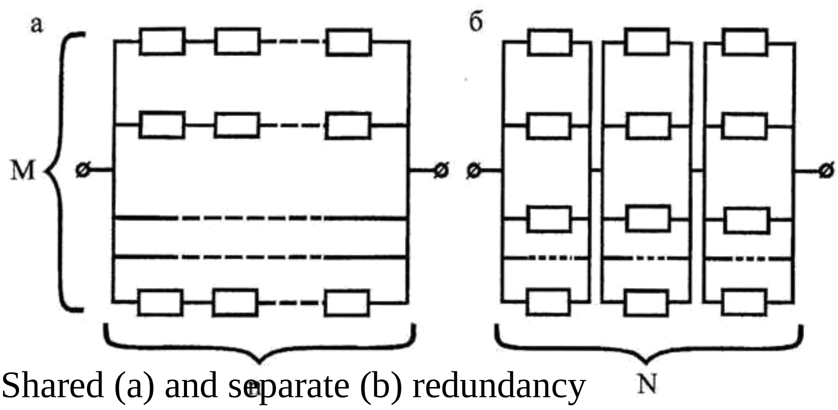
$nk = 1$

$$P (t) = 1 - (1 - Pi (t))$$

(eighteen)

$i = 1$

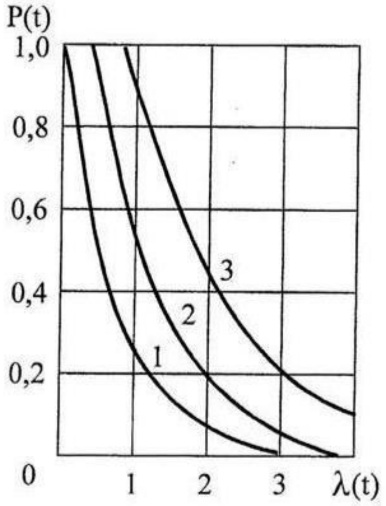
where $k = (n - m) / n$; k is the multiplicity of redundancy; n is the total number of systems (elements), including standby ones; m is the number of working systems (elements) required for normal functioning; $(n - m)$ is the number of spare elements.



Rice. 3. Shared (a) and separate (b) redundancy

In fig. 4 shows the change in the probability of no-failure operation depending on the redundancy ratio.

However, high reliability with shared redundancy is costly and therefore may not be economically viable. With split redundancy (sometimes referred to as overridden redundancy), the reserve element is brought into operation manually or automatically as needed. With the same FBG of each element



Rice. 4. Dependence of P (t) on the redundancy rate: 1 - at K = 0/1 (non-redundant system); 2 - K = 2/2; 3 - at K = 3/1.

the reliability of the group is calculated by the formula

$Pgr(t) = 1 - [1 - P (t)]M$, (19)

where M is the number of parallel circuits.

Reliability of the entire system

$Pgr(t) = \{1 - [1 - P (t)]M\}N = \{1 - [1 - Qgr(t)]\}$, MN

(twenty)

In more complex cases, when calculating structural reliability, it is convenient to use the following algorithm: calculate the reliability of the chain (if there are series-connected elements), then the reliability of several groups (parallel connection), then the reliability of the subsystem (groups connected in parallel), and so on from simple to more complex and finally to the resulting reliability.

If the failed element is restored immediately (on site), then the reliability of the redundant system increases. The operating time of the system in which

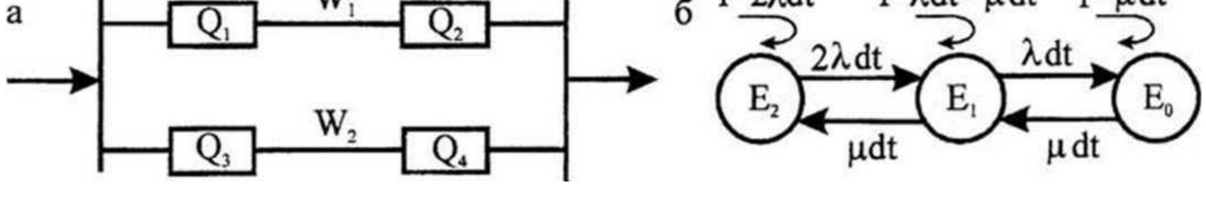
the element restored after failure is transferred to the reserve, can be determined by the formula where Tv - recovery time; T - time to failure of one element.

With parallel connection in order to increase the capacity of the lines

we have a serial connection of elements, and the calculation of such a system is carried out by analogy with the above.

Calculation of a node from redundant elements by transition probabilities

Calculations using formulas (19), (20) and (21) usually give approximate, sometimes significantly overestimated results. For accurate calculations, it is convenient to use the homogeneous differential equations of probabilistic transitions (Kolmogorov differential equations). Let there be two elements mutually reserving each other, one of which is in work, and the other is in reserve. It can be two power lines W1 and W2 shown in fig. 5, a. In the event of a failure of a working element (for example, W1), a backup (W2) is put into operation, and if during the recovery of the failed one it does not fail, then the node works normally. If during this time a failure occurs, then the node as a whole is in an inoperative state. This is called an active (hot) spare.



Rice. 5. Scheme of switching on the active reserve (a) and the transition graph (b)

The transition graph of such a system is shown in Fig. 5, a and 5, b. In Fig. 5, b, the states E1, E2 and E0 mean: E2 - both elements are operational; E1, - one of the elements is working normally, and the other has failed and is being restored; E0- both elements are inoperative and one of them is being restored.

The rule for drawing up differential equations is stated above [clause 2.5].

Here it is necessary to take into account that from the E2 state under the influence of the failure rate 2λ, the system passes in the time dt to the E1 state. Double failure rate is taken due to the fact that we have two elements and any of them can fail. Under the influence of the stream of restorations μ, the system again passes to the E2 state. System of differential equations

$$\frac{P2(t)}{t} = 2\lambda P2(t) + \mu P1(t),$$

$$\frac{P1(t)}{dt} = 2\lambda P2(t) + \mu P0(t) - (\lambda + \mu) P1(t), \qquad (22)$$

$$\frac{P0(t)}{t} = \lambda P1(t) - \mu P0(t). \qquad \}$$

States E2, E1and E0 form a complete group of events, ie, P2 (t) + P1 (t) + P0 (t) = 1, and therefore the initial conditions will be P2 (0) = 1; P1 (0) = 0; P0 (0) = 0.

The equations of system (22) are solved using the Laplace transform. Probability of state E0 (both elements failed):

$$P0(t) = \frac{2\lambda 2}{(\lambda + \mu)2 + \lambda 2}\left[1 + \frac{1}{\sqrt{\lambda 2 + 4\lambda\mu}}(S2\exp S1t - S1\exp S2)\right], \qquad (23)$$

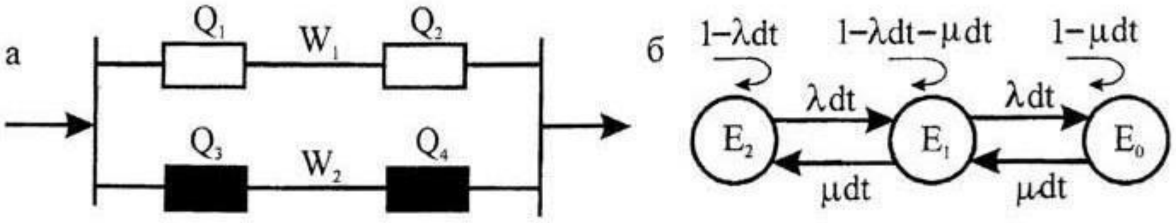
where

$$S1 = -\frac{3\lambda + 2\mu - \sqrt{\lambda 2 + 4\lambda\mu}}{2}, \quad S1 = -\frac{3\lambda + 2\mu + \sqrt{\lambda 2 + 4\lambda\mu}}{2}, \qquad (24)$$

The probability of an operable state of a node is PΣ (1) = 1 - P0 (t). At t ∞, the transition process is stabilized and the probability PΣ (t) ceases to depend on time, and then we have

$$P\Sigma(\infty) = KG = 1 - \frac{2\lambda 2}{(\lambda + \mu)2 + \lambda 2} = \frac{(\lambda + \mu)2 - \lambda 2}{(\lambda + \mu)2 + \lambda 2} \qquad (25)$$

An example of passive (cold) redundancy is shown in Fig. 6, a. It shows that line W1 is on load and line W2 is on standby (switches Q3 and Q4 are off). The transition graph is shown in Fig. 6, b.



Rice. 6. Scheme of passive (cold) switching on the reserve (a) and the transition graph (b)

Kolmogorov differential equations:

$$\frac{dP2(t)}{dt} = -\lambda P2(t) + \mu P1(t),$$

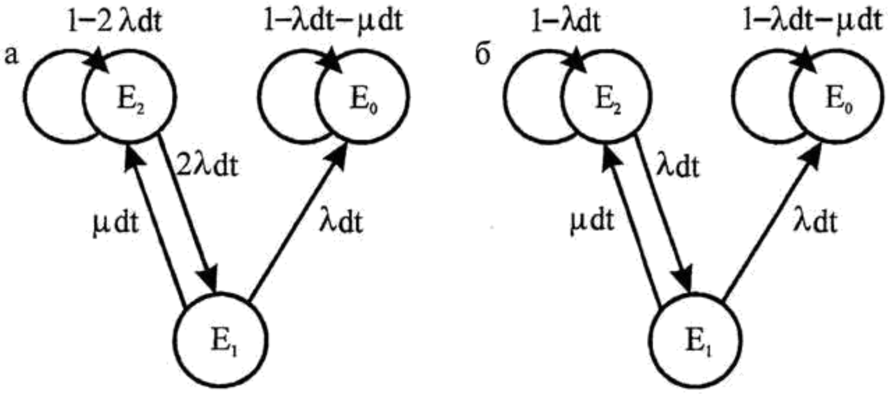
$$\frac{dP1(t)}{dt} = \lambda P2(t) - (\lambda + \mu)\,P1(t) + \mu P0(t),$$

At t ∞ availability factor

$$\pi(\infty) = KG = 1 - \frac{\lambda 2}{(\lambda + \mu)2 - \lambda\mu} = \frac{(\lambda + \mu)\mu}{\lambda 2 + \lambda\mu + \mu 2} \ldots \quad (29)$$

To determine the FBG and the average operating time, the state graphs will change. They are shown in Fig. 7, a and b.

Under the initial conditions P2 (0) = 1, P1 (0) = 0, P0 (0) = 0, one can obtain the FBG in the form of the well-known relation P (t) = exp [-t / Tcp],



Rice. 7. Transition graphs for active (hot) and passive (cold) redundancy to determine the reliability indicator

Mean time between failures of a node with active redundancy

$$Tep2 = \frac{1 + 3\rho}{2\rho} Tep; \quad \text{(thirty)}$$

with passive redundancy

$$Tep2 = \frac{1 - 2\rho}{\rho} Tep; \quad (31)$$

where ρ = λ / .

In conclusion, note that with the help of transition graphs one can various tasks of redundancy or functioning of electromechanical systems.

Considered in practical exercises No. 2, No. 3 to the calculation of the reliability of EMC, having a serial or parallel connection of elements, allow you to calculate almost any system consisting of a set of different elements.

Lecture number 11

TECHNICAL DIAGNOSIS OF OBJECTS

Lesson plan

Prediction of technical condition

Diagnostic parameters

Technical diagnostics covers methods and means for determining the state of a technical object. The process of determining the state of a technical object is called

diagnosing... A distinction is made between working diagnostics, in which working influences are applied to the object, and test, in which test influences are applied to the object. Diagnostics are performed with the aim of either monitoring the performance of an object, or searching for a defect, or generating a forecast of a further change in state, or combinations of these goals. The diagnostic process is carried out using a set of measuring instruments, special equipment and measurement programs. As a result, a diagnosis of the state of the object is obtained. The state of the object is assessed by diagnostic criteria - parameters or characteristics that reflect the change in the object during operation. The general concept of diagnostics is operability, which makes it possible to designate classes of object states.

Diagnostic systems in computers are used to inspect complex technical systems. Due to the complexity and high cost of diagnostic tools, this method is used in special cases.

Forecasting the technical condition of objects

During operation, diagnostics are performed either continuously or periodically to assess the condition and predict its changes in the near future. With continuous diagnostics, the parameters are evaluated in the operating mode of the object or are switched for a short time to a special diagnostic. Periodic diagnosis is performed at regular or random intervals.

The following diagnostic methods are usually used: according to the parameters of working processes (cutting speed, power consumption, developed pressure, etc.), according to the parameters of related processes (the amount of heat generated, the level of vibration, noise, etc.), according to structural parameters (gaps in joints, spread of error values, etc.)

The forecasting process model includes three stages: retrospection, diagnosis, forecasting. At the first stage, the operating experience of the facility is analyzed by comparing the operating conditions and the resulting malfunctions. As a result, the possible directions of changes in the state of the object, the most informative parameters and diagnostic programs are established. At the second stage, test effects on the object are set and research data are accumulated in the form of tables, graphs, spectrograms, etc. At the third stage, the received information about the state of the diagnosed object is processed. As a rule, for a single object, the accumulated information is of a random nature. For a group of objects of the same type, changes in operating parameters become statistical in nature, having the properties of smoothness and monotony (trend). Forecasting is possible if there are uniform patterns in the change in parameter values, which is reflected in the trend. The resulting forecasting model must undergo "training" - the calculation of predictive characteristics, comparison with the actual ones and making adjustments to the model.

Technical diagnostics are carried out using technical means. The system of technical means of diagnostics is a set of equipment, programs and an object that carries out an examination according to the rules established by the relevant documentation. Distinguish between test systems diagnosing (innings specially organized impacts fromfunds diagnostics) and functional diagnostics (supply of working influences).

Test diagnostic systems usually solve the problem of checking the health and functionality of an object, as well as troubleshooting. Test influences should not interfere with the normal functioning of the object. Functional diagnostic systems are used to check the correct operation of the facility and troubleshoot. These systems work when the object is used for its intended purpose.

There are three types of forecasting:

Analytical, based on the methods of extrapolation of the values of the predicted variable for some future period; the greatest efficiency is provided by the method of group accounting of arguments (MGHA), which uses an external criterion to assess the accuracy of the regression equations;

probabilistic, based on the theory of probability, which makes it possible to determine

the probability of finding the predicted parameter in a given range; statistical classification based on the theory of pattern recognition; at

this substantiates the assignment of an object to one of the known classes on the basis of the similarity measure.

Forecasting contributes to the creation of durable objects by identifying items for urgent restoration, justification of the number of spare parts, the period of maintenance and repairs.

Diagnostic parameters

The assessment of the state of the object is carried out according to diagnostic criteria, which are used as the parameters of the object or characteristics. Parameters include physical quantities that have specific values, and characteristics - the dependence of one physical quantity on others. If the values of diagnostic signs are within the limits allowed by the technical documentation for the object, then the object is in a working condition. If at least one sign is out of range, then the object is in a state of failure (inoperative).

Distinguish between direct and indirect diagnostic parameters. TOdirect refer to the working parameters of the object, the values of which are measured and assessed in the process of diagnostics (movement speed, traction force, radiation brightness, developed pressure, etc.), to indirect - parameters that allow indirectly assessing direct parameters (concentration and size of metal particles in gear oil, magnetic permeability of the material, heat release, wear of working surfaces, etc.). Table 3.1 shows the classification of forecasting parameters.

When using a characteristic of the form y = f (x) as a diagnostic feature (here x is an input parameter, y is an output parameter), the performance is assessed by the magnitude of the deviation of the current characteristic from the nominal one. In this case, it is required to assign a quantitative criterion to assess the difference between the current and nominal characteristics of the object. There are several criteria for this: mean deviation, root mean square, mask [3].

Table 3.1

Parameters for predicting object states

Parameter view	Parameter examples
Kinematic	Time, speed, acceleration, angular velocity and acceleration, frequency, phase, etc.
Geometric	Length, area, perimeter, volume, curvature, planar angle, solid angle, etc.
Static and dynamic	Mass, force, pressure, power, coefficient of friction, coefficient of resistance, coefficient of elasticity, work, energy, power, moment of force, moment of inertia
Thermal	Temperature, heat flux, heat capacity, coefficient

	heat transfer, heat of combustion, heat of phase transformation, etc.
Acoustic	Sound pressure, acoustic impedance, pitch, timbre, volume, etc.
Electrical and magnetic	Charge density, potential, capacity, current, voltage, resistance, magnetic flux, induction
Radiation	Radiation flux, spectral density of radiation by wavelength and frequency, illumination, brightness, reflectance, etc.
Atomic energy	Dipole moment, ra dose diation, nits radioactivity, etc.
Universal physical permanent	The speed of light in vacuum, gravitational constant, Planck's constant, Faraday number, etc.

Lecture number 12

PROBABLE METHODS FOR DETERMINING SERVICE AND REPAIR FREQUENCIES

Lesson plan

1. Collection and processing of information about the reliability of objects
2. Determination of distribution parameters
3. Models of machine prevention
4. Optimization of overhaul periods

To maintain the design level of reliability, it is necessary to analyze the results of mining machines. The most important source of reliability information is where mining equipment is used. It is necessary to have an idea in which departments of the mining enterprise you can get information on reliability. The information obtained must be statistically processed - the law of distribution of a random variable is established and the statistical characteristics of the main parameters of reliability indicators are calculated. The choice of the distribution law is made according to the type of histogram with verification of statistical reliability, using the goodness-of-fit criteria (Pearson's test) and other methods. After that, the reliability indicators are calculated.

Collection and processing of information on the reliability of objects

Collection of information on reliability is necessary to establish numerical values of reliability indicators, to determine their compliance with standard values, as well as to determine the frequency, causes and consequences of failures. Thus, the purpose of the collection is:

setting of numerical indicators of reliability;

determination of the frequency of causes and consequences of failures;

clarification of standards, instructions and other materials of TO, TR and KR;

checking the effectiveness of measures to improve reliability.

To build a strategy for servicing machines and installations, it is necessary to have data on the duration of their operation between repairs, on the types and causes of failures, measures to restore operability, the amount of repair costs and the elimination of the consequences of an emergency failure.

Reliability data can be obtained from the following sources of information:

normative and technical documentation (work programs to ensure reliability of the facility, safety measures during the operation of equipment, requirements for the performance of the machine, etc.);

test results in simulated conditions (research and qualification tests, acceptance tests);

results of operational tests (timing observations, data on failures, reliability tests).

The accumulation of data is carried out in various ways, including by keeping a log of failures, replacement and repair of machine elements, analysis of accounting records of the movement of spare parts in the warehouse, accounting records, etc. Then the data is processed by the methods of mathematical statistics and the information is presented in two forms: for the administrative management and for the engineering services. For the administration, data on the number of failures by elements, assemblies, systems for a certain period of time, measures to eliminate failures, economic data should be provided. For the mine's engineering service - more detailed information for drawing up a plan of measures for servicing machines, timing of repairs, determining the professional and quantitative composition of the repair team, and financial costs.

Information collection methods:

timing observations in production conditions; logbooks of cars;

list of defects and accounting of remanufactured and manufactured parts;

Acts on the condition of equipment after a certain period of time;

acts of claims, acceptance, testing of equipment, laboratory and bench tests.

All this information about reliability is probabilistic in nature. Numerical characteristics are used for the probabilistic description of random variables. The main ones are mathematical expectation, variance, standard deviation, variance, standard deviation, coefficient of variation. Knowing the specific form and analytical expression of the distribution function of the investigated random variable, it is possible to calculate the probabilities of no-failure operation and failures of objects for any operating time values.

The main methods of obtaining information are timekeeping observations, laboratory and bench tests.

Scheduling Time Observations... Timekeeping materials must reflect the results of such a number of observations that the reliability indicators can be determined with the degree of accuracy proposed in Table 3.2.

Table 3.2

Assessment of the accuracy of time-keeping observations

Character Research	An object research	Trust probability	Relative error no more
Level assessment overall reliability by industry	Complex	0.9	0.1
	Individual machines	0.8	0.1
	The main Assembly units	0.8	0.2
Reliability assessment for certain conditions	Complex	0.8	0.1
	Individual machines	0.9	0.2

The calendar duration of time-keeping observations is determined from

expressions; K [n]T 0 / K NS N tp / S tp tin tyo te., about

tisp

where T0 - estimated mean time between failures; KNS - coefficient of continuous operation of the facility; tR - working hours; tin - time spent on auxiliary operations; tyo

- time spent on elimination of failures; te. about - downtime for various reasons.

To ensure the specified accuracy, it is necessary to have the number of timing observations not less than those indicated in Table 3.3.

Observations are carried out over a group of homogeneous objects operating in approximately the same operating conditions.

Duration of tests of one object

[n]T0 ,

tisp NKoKNS

where N - the number of objects of the same type; Ko - coverage ratio, Ko = 0.6 - for an experimental batch; Ko = 0.3 - for serial cars; Ko = 1 - for prototypes.

Table 3.3

The number of observations for the basic distribution laws

Law distribution	Initial parameters			Necessary number of observations
			Coefficient variations V	
Exponential	0.8	0.2	1	22
	0.8	0.1	1	80
	0.9	0.2	1	55
	0.9	0.1	1	200
Normal	0.9	0.1	0.2	6
	0.8	0.1	0.3	eight
	0.9	0.2	0.3	5
	0.8	0.1	0.2	16
Logarithmically normal	0.9	0.2	0,4	7
		0.2	0.7	26
		0.1	0,4	27
		0.1	0.7	78
Weibull	0.8	0.2	0.6	ten
		0.2	0.8	eighteen

0.8	0.1	0.5	23
	0.1	0.8	56
0.9	0.2	0.6	twenty
	0.1	0.8	125

For non-refurbished or non-refurbished objects

[n]T1 ,

tisp KNS

where [n] - the minimum required number of objects; T1 - the estimated value of the mean time to failure.

One-time duration of time-keeping observations is usually equal to the duration of the work shift. Required number of shifts m t ...

isp

tcm

The duration of one-time time-keeping observations must be more than 3T0 / KNS , a

number of shifts of continuous timing observations

4T0

...

mn 1 $\underline{\text{KNS}}$

tcm

To obtain reliable data on the distribution law, the

condition tisp (70 -100)T0 ...

Determination of reliability indicators is associated with the solution of two main problems of mathematical statistics - estimation of unknown parameters of a sample and testing statistical hypotheses.

An analogy of the mathematical expectation mNS random variable NS

is his statistical estimate (arithmetic mean):

1

$\hat{m}$x xi n...

n i 1

Number of intervals

$$K \quad \frac{xmaxxmin}{L},$$

where L Is the length of the interval. Number of intervalsK should be at least 5-6 and no more than 10-12.

Number of values ni random variable NS in each interval must be at least 5.

Example... We accept tmin = 0 for n = 300, tmax = 400 min, then

400 43

1 $\underline{\quad 3,3\text{lg}}$ minut

L 300 es

Processing of statistical information... Due to the limited sample of

the general population (of the entire set of machines of the same type), the statistical distribution function always contains elements of randomness. Therefore, the values of the

parameters for the general population can be obtained only with a certain probability. These

parameter values are called estimates. The estimate of the distribution function of the

general population is the statistical distribution function.

The distribution law, if unknown, is determined as follows. The entire range of the obtained values of the random variable $\hat{t}$ is split into intervals. For the convenience of calculations, it is advisable to take the intervals equal.

The approximate size of the interval

$$\frac{\hat{t}_{max}\ \hat{t}_{min}}{1\ 3.3\lg n},$$

where n - the number of received values of the random variable $\hat{t}$...

In each interval, the number of values of of a random variable must be at least 5-10.

If the number is smaller, the intervals are of different lengths. For each interval, the following are calculated:

the number of values of a random variable falling into this

interval ni; attitude ni/n (frequency of the event).

n

Sum ni should be equal to one. This is an indicator of the correctness of the calculations.

i 1 n

Confidence interval is called an interval that with a probability covers the estimated value of the distribution parameter. Probability value called

confidential probability. If, as a result of the experiments, a statistical estimate is obtained parameter $\hat{M}(t)$ and found that the difference between the parameter M (t) and its estimate does not exceed some value with probability , i.e.

$\{\hat{M}(t)\ M\ (t)\ \ \hat{M}(t)\ \ \}$,

then the interval $\hat{M}(t)$; $\hat{M}(t)$ will be the confidence interval for the estimate $\hat{M}(t)$; the bounds of the interval are called confidence bounds. The coefficient of variation V / m ...

If the distribution law is unknown before the start of observation, then it is assumed that the MTBF and recovery time are distributed according to the exponential law, and the resource and service life - according to the logarithmically normal, i.e. in this case, the maximum number of observations is required.

Confidence is related to the marginal absolute error condition

$$P \left| x0\ \ \hat{x}0 \right| \ ,$$

where x0 - the general average value of the studied trait; $\hat{x}0$ - grade x0 according to the results of the

experiment.

Relative marginal error $/\ \hat{x}_0$...

Then a theoretical distribution curve is plotted on the histogram f(t), which must retain the essential features of the statistical distribution.

When fitting a theoretical curve f(t) between it and the statistical distribution some discrepancies are inevitable.

The correctness of the choice of the theoretical curve is established using the criterion

consent 2 0 (Pearson criterion):

ni np i
2 k 2
0 ______,
i 1 npi

where k - number of intervals of statistical distribution; ni - number of values random variable in i-th interval; n - the total number of values of the random variable; Ri -

theoretical probability of hitting a random variable in i-th interval, equal to the increment of the distribution function in this interval.

Distribution 2 depends on the number of degrees of freedom:

r = k - s - 1,

where k - the number of intervals; s - number of links, for exponential distribution s = 1, for normal s = 2.
For distribution 2 there is Table 3.4, which lists the roots of the equation

P 20 2 ,

where - the level of significance (the probability of rejecting the correct hypothesis).

In practical calculations, take = 0.05. Table 3.4 gives the values of the quantity 2 depending on the number of degrees of freedom r and level of significance .

y and r find 2 ... If2 , the hypothesis is rejected, since the divergence
2 measure 2
0 0
0 2 , - the hypothesis is
hit the critical zone. If 2 accepted.

Determination of distribution parameters. Distribution parameters are determined
before and after the choice of the distribution law based on the analysis of the histogram.

For any distribution law of the studied quantity, the estimate of the mathematical expectation is taken equal to the arithmetic mean:
n ——

Under the normal distribution law, the obtained estimates of the mathematical expectations ˆand standard deviation are distribution parameters.

With a log-normal distribution, the parameter estimates

or parameter estimates can be obtained through the mathematical expectation and the standard deviation (through the √ coefficient of variation):

With exponential distribution, mathematical expectation and variance
respectively, equal

To determine the values NSi in the analyzed distribution is constructed histogram of the empirical distribution density of a random variable. Axis the abscissas are the intervals t random variable and on each of these
intervals are plotted pr f(tI am) mtenO
3coalnn2and=1To5 with an area equal to the frequency of occurrence of a random
quantities in a given and4n, 0terval. The heights of the rectangles are proportional to the frequencies
appearances NSi random variable in each interval.

The length of the intervals is recommended to be determined by the formula

t tmax tmin ,

1 n3i=, 3tenlg N

where tmax and tmin - respectively, the maximum and minimum values of the random variable in the variation series.

An example of plotting a histogram and a smoothing empirical curve is shown in Figure 3.1.

Criterion application scheme 2 in assessing the consistency of theoretical and statistical distributions is reduced to the following:

60 80
50 200 400 0 0 t

1)for each of the studied distributions, the measure of discrepancy is determined 2;

2) for each of the distributions, the number of degrees of freedom is calculated

r = k - s - 1,

where s - the number of independent connections equal to the number of determined parameters of the law
distribution;

3) by r and calculated values 2, using Table 3.4, find the level of significance goodness-of-fit criterion for each investigated distribution law, and
must be at least 0.01;

4) as the theoretical distribution function, the one for which
the level of significance turned out to be the highest.

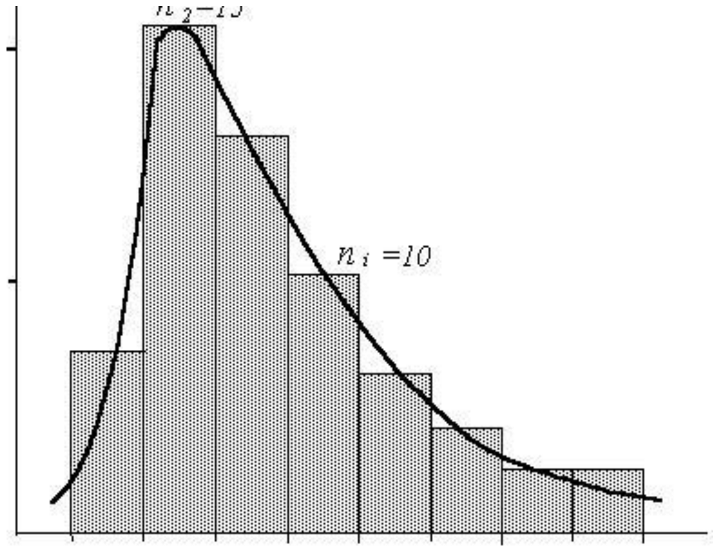


Figure 3.1. Histogram and theoretical distribution function

Machine Prevention Models

Consider the four main models of machine prevention:

with emergency repairs;

with scheduled repairs in case of unscheduled emergency repairs without transfer terms of the next maintenance (PM);

with scheduled repairs in case of unscheduled emergency repairs with a postponement next scheduled preventive maintenance;

with scheduled repairs.

Emergency repairs are widespread. It is assumed that failure is detected instantly at the moment of occurrence. During the entire period of emergency repair, the machine is idle. At the end of the repair, the whole process of the machine functioning and its maintenance is repeated.

Obviously, with the described prevention model, the criterion can be calculated K, however, finding its minimum is pointless.

Let's denote: t3 - average duration of emergency repairs; 3 - medium costs of emergency repair (repair due to failure); 1 - average damage per unit of downtime or average damage from failure of the device to perform a unit work; 2 - average damage from device failure.

Hereinafter, we will assume that the effect of operating the machine is proportional to time of its work (operating time).

Then

$$K \quad \frac{3 \quad 1t3 \;\; 2}{TO} \quad \frac{Aaw}{TO},$$

where Aaw - average costs associated with emergency repairs; To - mean time to failure, T o P t dt ... 0

Scheduled repairs for unscheduled emergency repairs. Such a system is widely used for servicing mining and transport vehicles. We assume that it is possible to carry out scheduled preventive maintenance and emergency repairs, and the failure is detected instantly. Restoration work is carried out in the following order. If the machine has not failed by the appointed time, then a scheduled repair is performed, if the system failed earlier, then at the time of failure, emergency repairs begin. After an emergency repair, the time of the next scheduled repair does not change. We assume that the machine is inoperative during scheduled and emergency repairs.

Let's denote: t1 - the average duration of scheduled repairs; 1 - medium
the cost of carrying out scheduled repairs; (T1) Is the leading function of the flow of failures - the mathematical expectation of the number of failures over time T1 - the required time for the frequency of scheduled repairs (without the time spent on emergency repairs t3 (T1)).

Average costs associated with one scheduled repair over timeT1,
are equal Apl = 1 + 1 t1... Costs associated with conducting (T1) emergency repairs will be equal Aaw (T1). Total costs for the periodT1 make up A = Aaw (T1) + Apl... Optimization criterion

Aaw (t1)
Aaw (t1) Apl or K Apl ...
K
T1 T1
R(t)dt
0

Scheduled repairs during unscheduled emergency repairs with the postponement of the time of the next scheduled repair. After an emergency repair
the next scheduled repair is postponed so that the time between the end of the last emergency repair and the next scheduled repair is equal to T1... Such a preventive model is appropriate for large, expensive units with a long service life (belt conveyor drives, components of combines,

electric motors of electric locomotives, etc.). IfR(T1) Is the probability of failure-free operation over time T1, then the average costs of carrying out scheduled repairs during the regeneration period are equal to AplR(T1).

Probability of failure over time T1 equals 1 - R(T1). Average costs for
emergency repairs Aaw[1 - R(T1)]. Average operating time during the regeneration periodT1

T1
equals P(t)dt ...
0

Optimization criterion

Aaw 1 R(T1)Aa (A A)R(T
AplR(T1))
v aw pl 1 ...
K
T1
R(t)dt T1
R(t)dt
0 0

Scheduled repairs. In the practice of the mining industry, it is possible to use only scheduled repairs scheduled according to calendar time (for example, mine electric locomotives). In this case, the failure can only be detected during scheduled repairs. From the moment of failure until the end of the next scheduled repair, the machine will not be able to perform its functions.

If R(T1) Is the probability of failure-free operation over time T1 (the required time for the frequency of scheduled repairs), then the average costs associated with carrying out

scheduled repair during the regeneration period T1are equal AplR(T1), the average costs associated with

emergency repairs are equal Aaw[1 - R(T1)], the average damage from downtime due to failure to detect a failure in the time interval from the moment of failure to the next

replacement is

T1
1 T1 P(t)dt ,
0

T1
since the average operating time of the machine during the regeneration period T1 is equal to P(t)dt ...
0

For a given service strategy, the optimization criterion

T1
AplR(t) Aaw 1 R(t)
T1 R(t)dt
K 0 ...
T1
R(t)dt
0

After choosing the optimal replacement period for various parts, they can be grouped according to the timing of their replacement and, depending on the complexity of the repair, maintenance, current or overhaul repairs can be assigned. It is desirable that the structure of the repair cycle be multiple, i.e. for each subsequent type of repair, parts and assembly units of all previous groups were replaced.

For example, for the SP-63 conveyor turbo coupling, the following structure of the repair cycle can be adopted, day:

N RO RO T1 RO RO T2 RO RO K RO RO Spisanie

0 1 2 3 4 5 6 7 eight 9 10 11 eighteen

Optimization of overhaul periods

Units and parts of mining machines have a scatter of operating time to failure, therefore, it is necessary to choose the correct preventive replacement intervals for various groups of parts.

Preventive replacement of parts after a period equal to the minimum operating time to failure is economically unjustified, since many parts will still have a sufficient resource during replacement and, in addition, costs for premature replacement will be required, while the technical utilization of the machine will decrease. With the maximum replacement time, the risk of an emergency failure associated with possible severe consequences will increase. It is necessary to choose the optimal intervals for planned replacement of parts, i.e. plan the timing of repair services.

The optimal intervals between planned replacement of parts are determined based on various criteria:

maximum coefficient of technical utilization;
minimum maintenance costs, etc.

In the mining industry, the most common criteria are economic.

Optimization of the frequency of planned replacement of parts should be approached taking into account not only the operating costs, but also the effect of using the machine.

Such an organization of replacements will be rational, in which the maximum effect will be obtained from each unit of costs.

In general, the optimization criterion

k l
C mi iti m j jtij
(T)i 1 j 1 min
K ,
NS T
(T)
j(t)dt
0

where C (T) and E (T) - respectively, the total costs and the total effect during the operation T; j(t) Is the mathematical expectation of the instantaneous value of the effect from use of the machine; k - the number of types of maintenance work; mi - number

maintenance work i-th type; i - average costs per unit of time when conducting i-th type of maintenance work; ti - average duration i-th type of maintenance work; l - the number of reasons for downtime; mj - the number of downtime jth reason; j - average damage per unit of downtime for j-th cause or damage from failure to complete a specific task; tj - average downtime for jth reason. It can be shown that when the

minimum is reached by the optimization criterionK

at the same time, a minimum of total costs, a minimum of unit costs associated with the operation of the device, a maximum of a technical utilization rate and a maximum of an availability factor are obtained.

Determination of the optimal service life of machine elements can be performed only for the adopted prevention model. After carrying out any of the possible replacements, it is considered that the reliability indicators of the element are fully restored, and the next scheduled replacement is assigned after a periodT...

The task is to find such a value for this period (hours, days), at which the value of the optimization criterion will be minimal.

Let us consider the methodology using the example of a prevention model with planned and emergency repairs.

The value of the optimization criterion for this model:

AplR(T) Aaw 1 R(T) AplR(T) Aaw 1
R(T)
K ,
T T
R(t)dt tf (t)dt TP(T)
0 0

T where tf (t)dt TP(T) Is the mathematical expectation of the operating time under the condition of replacing the element, if 0
its operating time will reach the value T...

Dividing the left and right sides of the equation by Aaw, we get

P(T) [1 P(T)] P(T) [1
K P(T)]

,

Aa T T
w tf (t)dt
P(T)dt TP(T)
0 0

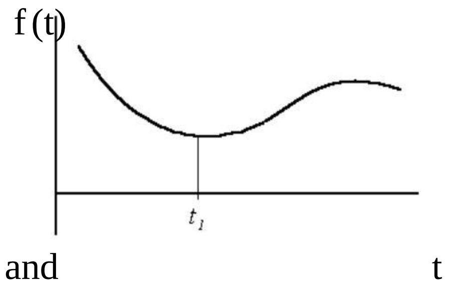
where = Apl/Aaw - cost coefficient.

By adopting d 0 , we get
dT

f (T) 1 f (T)1
T T
1 P(T P(T)P(t)dt 1 P(T)tf (t)dt TP(T)
) 0 P(T) 0 (T)
P(T f (T)tf (t)dt TP(T) (1
) T) 1.
P(T)
0

Localization of the roots can be made from the following considerations:

1. With a normal distribution R(T) the equation has only one root, which with a probability of 0.997 is in the interval [tWed - 3 ; tWed + 3]. Since this root can be only positive, then the interval [0; tWed + 3]. HeretWed - mathematical expectation of operating time; - standard deviation.
2. With the Weibull distribution with the parameter b 1 equation has only one root, which with a probability of 0.982 is in the interval [0; 4a].
3. When -distribution, the equation has only one root provided that 1 - 1/m... If eleven/m, then the equation has no roots. When finding a root, one should consider an interval 0; 4 .m
4. With a log-normal distribution, the curve = f(T) (Figure 3.2) has minimum and maximum. Therefore, the equation for a fixed has two roots or even has no roots. The lower limit of the root localization interval is 0, the upper one must be found by successive expansion of the interval.



Half division method:

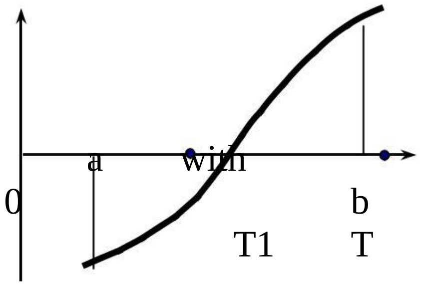


Figure 3.2. Function extrema

Figure 3.3. Finding the root of an equation

(T) 1 ε P(T) ...

T

P(T)P(T) f (T) P(t)dt

0

The two roots of the equation are positive and negative. Suppose we know the interval [a; b], inside which is the root of the equation (Fig.3.3). Let's calculate the values (a) and
(b). If (a) (b) 0, this means that the function crosses the axis T and the desired root available in the studied interval. If (a) (with) 0, then the root of the equation is in interval [with; b]; if (a) (with) 0, then the root is in the interval [a; with].

The localization interval of the root can be narrowed to any limits. The calculation accuracy is set [b - a] . In this interval, any
meaning T...

Lecture number 13

CALCULATION OF SPARE PARTS

Lesson plan

Spare parts kits

Guaranteed availability of spare parts

Overhaul period

During operation, any part or assembly may fail. To ensure high efficiency of the object, it is necessary to replace the failed part with a new one as soon as possible. This work is carried out with sufficient stock in the warehouse of the established nomenclature of spare parts. There are single, group and repair kits of spare parts.

A single set is designed to maintain the product in good working order by the maintenance personnel. A single kit is developed for each object and comes with it once. In the future, it should be replenished in a timely manner through additional purchases.

The group kit is developed for a group of products of the same name and is intended for preventive maintenance of facilities by the repair department of the enterprise. Supplied by the manufacturer once together with a group of objects, the composition is determined by the operating conditions and the requirements of technical documentation.

A repair kit is developed by the manufacturer for a group of objects of the same name for their repair at a specialized repair company, as well as for replenishment of group kits. Supplied separately from equipment.

The task of calculating a set of spare parts is to substantiate their quantity and range.

Average number of failures of a set of N elements

Nt

nWed

T1 ,

where t is the considered period of operation; T1 - operating time to the 1st failure.

The number of consumed elements Z during the time or operating time t is equal to the number of failures n. The probability that exactly Z spare elements are required during time t can be determined by the Poisson formula

N
t
T
Pz (t) (Nt) e 1
z
T12
Z! ,

where Z = 0, 1, 2,… i,… .

The average number of spare elements consumed during the overhaul period tmr is equal to the average number of failures,

Ntmr
Z Wed T1 ...

Due to the randomness of the occurrence of failures, more or less spare elements may be required than Zav. With a stock of elements Nz equal to the average expected consumption Zav, i.e. if the safety factors K Ns / ZWed 1, the need for spare parts will be satisfied with a guaranteed probability of 0.5, which is not enough. It is necessary to calculate the number of spare elements with a given guaranteed probability of their presence Pв, equal to 0.9; 0.95; 0.99. The sufficiency level is taken depending on the consequences of failure:

in case of failure to fulfill the specified functions Pв = 0.9-0.92;

in case of failure with large losses from downtime Pв = 0.95-0.97;

In case of failure with serious consequences (threat to life) Pв = 0.99.

The probability that no more than N of spare elements will be required for the overhaul time tmr can be found from the expression

Ntmr
Ns (Ntmr
T)
P () e
N ztmr1 —— 2
Z 0 T1
Z! ...
R (t)

Probability Nz mr must be at least the accepted guaranteed probability P provision of spare parts, i.e.

RN (t) R ...
z mr

Formula for guaranteed probability of spare parts availability:

N sZ 2
PN (t) e
z mr ZWed Wed P
Z 0 Z! ...

To ensure a high probability of eliminating failures by the factor of the availability of spare parts in stock, it is necessary to have not Zav, but Nz spare parts.

Always Kz 1, and with an increase in the average expected number of failures Zav, i.e.
when providing a margin for a larger number of elements or for a longer service life, the safety factor decreases.

A decrease in Kz with an increase in Zav indicates the advisability of concentrating machines of the same type at one enterprise or centralizing the supply of spare parts for a group of enterprises with the same type of equipment.

Example. There are six SP-63M conveyors in operation, equipped with drives with KOF-32-4 electric motors. The probability of failure-free operation for the period of prevention is P = 0.8. Determine the required number of standby electric motors to satisfy
need for them with probability P = 0.9.

Solution. Find the probability of failure Z = 0; 1; 2; ...; 6 electric motors:

R WIT 1 0.8 0 0.8 0.8
6 0 H60 6 1 0.2 0 6 0.262;
R WI TH 1 0.8 0.8
6 1 6 1 0.8 5 6 0.2 1 5 0.394;
1
R
6 2 WITH2 2 0.8 0.8
6 1 0.8 4 15 0.2 2 4 0.246;
R 0.
6 3 WITH3 3 0.8 twe 2 0.8
6 1 0.8 3 nty 3 3 0.082;
R 4 WITH4 4 0.82 15 0.24
6 6 1 0.8 0.82 0.015;
R WIT 1 0.8 0.8 0.25
65 H56 5 2 6 0.81 0.002;
R 6 WITH6 6 0.8 0.2 0.0000
6 6 1 0.8 0 16 0.80 6

1,000

So, if there are two electric motors in reserve, the demand will be satisfied with a probability of 0.262 + 0.394 + 0.246 = = 0.902, with three standby electric motors, the demand will be satisfied with a probability of 0.984, i.e. almost three standby motors will always be sufficient to meet the T1 overhaul requirements.

The average number of electric motors that fail over the overhaul period T1,

Zav = 0 0.262 + 1 0.394 + 2 0.246 + 3 0.082 +

+ 4 0.015 + 5 0.002 + 6 0.00006 = 1.2.

During the overhaul period, the stock must be replenishedon average one or two electric motor.

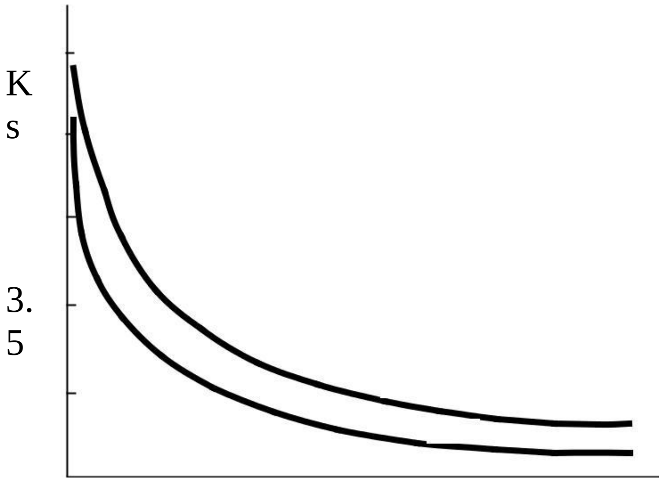
Safety factor

Ns 2

ZWed 1.65

Ks = 1,2 5

at P 0.9.



Depending on the from numbers simultaneously operated facilities coefficient stock changes in 3.0 significant limits:

Figure 3.4. Dependence of the safety factor on the number of machines

ZWed	1	2	3	4	5	6	7	
Ks	1.80	1.65	1.57	1.50	1.47	1.40	1.37	(R = 0.9)
Ks	2.60	2.30	1.83	1.75	1.67	1.63	1.60	(R = 0.95)

With an increase in the average number of refusals, i.e. when providing a margin for a larger number of elements or for a longer service life, the safety factor decreases (Figure 3.4).

Therefore, it is economically more profitable to purchase spare elements for all operated complexes.

The total operational number of spare elements

Nz.e = Nz + Nr.z + Nxp + Nпр,

where Nz is the number of spare elements to eliminate failures; Nr.z - the number of elements for regulated replacements;

Nxp - consumption of elements during storage; Npr - consumption of elements

Lecture number 14

FORMATION OF A STRATEGY MAINTENANCE OF MINING MACHINES

Lesson plan

1. Determination of operating time distribution parameters
2. Planned and emergency replacements
3. Construction of repair schedules

When forming a strategy for servicing mining equipment, the following sequence of actions is recommended.

1. Determination of the distribution parameters of the MTBF. For building a strategy for servicing machines and installations, it is necessary to have data on the duration of their operation between repairs, on the types and causes of failures, measures to restore operability, the amount of repair costs and the elimination of the consequences of an emergency failure. The data is processed by methods of mathematical statistics. Knowing the specific form and analytical expression of the distribution function of the investigated random variable, it is possible to calculate the probabilities of no-failure operation and failures of objects for any operating time values.

When fitting the distribution between the theoretical curve and the statistical distribution, some discrepancies are inevitable for various reasons. It is possible to estimate the error and justify the choice of the theoretical curve using one of the goodness-of-fit criteria (Pearson, Student, etc.)

2. Determination of the optimal replacement time elements of mining machines. Choice the optimal timing of repairs can be made only for the adopted strategy of servicing the mining equipment of the site. Economic, technical, environmental and other indicators are used as a criterion for calculating the optimal timing. You can also use as a criterion the ratio of the cost of replacing an assembly (part) to the duration of the overhaul period.

Distinguish between the costs of the planned replacement of the submarine of the machine unit and the emergency Aav (that is, the costs of eliminating the consequences of an accident in the event of a sudden failure of a unit or part). Then the attitude

$$E = \frac{A\text{pl}}{A\text{pl} \quad A\text{aw}}$$

will be called the cost factor. From this ratio it can be seen that with an increase in replacement costs in an emergency situation, the cost coefficient E tends to zero, and in the general case its value is in the range 1> E> 0. Based on the numerical solution of the equation reflecting the dependence of costs on the replacement period, the optimal terms and the probability of their achievement are determined based on the accumulated information on the reliability of mining equipment. Based on the results of the calculations, a qualitative analysis of the data is carried out and the terms and types of repairs are assigned.

3. Appointment of types of maintenance and repair. For supporting the operational state of the machines during their operation, they plan to periodically carry out maintenance and repairs. Maintenance and repair service of mining machines is a system of measures for the maintenance, maintenance and restoration of the working capacity of mining machines, which is established on the basis of the recommendations of the system of scheduled preventive maintenance (PPR) and the estimated values of overhaul periods. The Regulations on the planned preventive maintenance and repair system for equipment in coal and shale mines establish the types, regulations and principles for organizing maintenance and scheduled repairs, the nomenclature of the main technical documentation for establishing repair standards, principles for organizing the accounting, storage and movement of spare parts and equipment, and dr.

The essence of the system of scheduled preventive maintenance consists in the preparation and implementation of the established types of maintenance and scheduled repairs in accordance with the structure of the repair cycle. The scope of work for specific operating conditions of mining equipment systems is developed by the energy-mechanical service of associations and mines.

4. Construction of repair schedules. To build a repair schedule first a time axis is built and the total service life of the Tsl equipment is plotted on it. For each node on the axis, the time for replacing the Topt node is postponed if the probability of achieving the optimal operating time w exceeds 0.9, and Tav, if this value is less than 0.9. If necessary, closely spaced repair periods of units are combined into one. Depending on the complexity of the work, the type of repair is assigned.

In the final version, the repair schedule is recalculated in daily terms (i.e., the time for repair shifts during the day is subtracted).

5. Calculation of the number of spare units (elements). Mining equipment belongs to systems of repeated action, which must perform specified functions for a long time. During this time, a random number of failures can occur in the system, due to the unreliability of its individual elements. The calculation of the number of spare parts should be made taking into account the number of planned replacements and emergency failures. safety factors are used depending on the number of serviced machines of the same name and the probability of reaching the planned repair time.

Lecture number 15

METHODS FOR TESTING MINING EQUIPMENT AND DETERMINING INDICATORS OF ITS RELIABILITY AT THE STAGE OF DESIGN

Lesson plan

1. Methods for testing mining equipment
4. Test stages
5. Test methods

For testing, an interdepartmental commission (IAC) is appointed, which includes representatives of: customer; production association; enterprises where acceptance tests are carried out; developers of technical specifications; basin research institute; developer of design documentation; leading design and engineering institute; manufacturer; head research institute; MakNII or VostNII (if necessary); State Sanitary Inspection; technical inspection of the trade union of the industry in which the product will be used.

Acceptance testing is based on a methodology that, taking into account the specific features of the equipment under test, is developed on the basis of the Standard Procedure for Acceptance Testing of Equipment Complexes. The test procedure includes the following sections: goals and objectives; an object; organization and procedure for conducting; conditions and scope; content and methodology for conducting observations; conclusions and recommendations based on the results.

In accordance with the main goal in the testing process for each sample of the complex and the main elements included in its composition, the following tasks must be solved: determination of the actual indicators of the technical characteristics, assessment of the correctness of their choice and compliance with the design indicators; checking the compliance of the main machines of the complex with the existing GOSTs; determination of the actual degree of mechanization and automation of production processes; checking the functionality of the complex; identification of the advantages and disadvantages of the design; checking the operational reliability of the complex and its main parts; assessment of the correctness of the choice of the technological scheme of the complex operation; verification of work safety conditions; assessment of dustiness, ease of passage, temperature conditions during the operation of the complex; determination of technical and economic indicators of the operation of the main machines and the complex as a whole and the establishment of the economic efficiency of its application; assessment of the quality level of equipment; clarification of the scope of the complex; establishing the feasibility of continuing work on fine-tuning the structure.

The organization and procedure for conducting tests should provide for: checking the completeness of the complex that arrived at the test site; control assembly of machines; testing them in work; training of service personnel. After the control assembly, the complex is dismantled and lowered into the mine.

The tests are carried out in two stages. At the first stage, the complex and the interaction of its main parts (excavation machine, face conveyor, mechanized support, etc.) are mastered, adjustment is carried out. At the same time, the organization of work is being worked out, safety rules are being clarified. The timing of the first stage of testing is established by the IAC.

Mining-geological and mining-technical conditions selected for testing should correspond as much as possible to the boundary, most unfavorable conditions established by the technical characteristics of the complex, i.e .:

power and powerful; dip angle - maximum dip angle; the stability of the roof and its class of collapse - respectively, the least stable roof and the highest class of collapse; resistance of soil and roof to indentation - the minimum in terms of technical characteristics; coal cutting resistance - the maximum limit of this resistance.

The safety conditions for the operation of the complex and its elements are identified, and the assessment of dust suppression means, ease of repair and operation is given. When assessing the reliability of the equipment of the prototype of the complex, the following is established: a complete list of all failures (separately for the combine, conveyor, support), including failures of electrical equipment; reliability indicators of the complex as a whole and separately of the shearer, longwall support conveyor and interface support and their main parts and assemblies; a list of nodes for which it is necessary to continue monitoring after completion of tests in a given volume (nodes that did not fail during the test period and for which reliability indicators were not determined).

In the process of testing, the following indicators of the reliability of machines and assemblies should be determined: mean time between failures, availability factor, specific labor intensity of overhaul maintenance and scheduled maintenance.

Bench tests of machine parts and assemblies play an important role in determining reliability indicators (Figure 3.5). In order to save time and money, these tests must be performed as many times as necessary to obtain reliable results. To determine the required number of experiments, the theory of their planning is used. Samples are tested on special stands. According to the test results, the fatigue curve is plotted, the parameters of the fatigue limit distribution are estimated, and the machine life under operational loads is determined.

Figure 3.5: P - drive; IU - test unit; UN - load node. The advantage of the stand with a direct power flow is low power consumption, the disadvantages are its complex design and high manufacturing cost.

The feedback signal from the measuring amplifier enters the control amplifier, where it is compared with a given control signal received from the driver. The difference between the given electrical signal and the feedback signal (the actual value is taken from the diameter) is amplified in the regulating amplifier and, as an error signal, is fed to the servovalve, which corrects the flow of the oil supplied to the cylinder cavity. The specified and true load value can be observed on an oscilloscope. The pressure source is the hydraulic unit. The testing complex is equipped with a computer. The control signal is input from a magnetic record, which records the actual loading process.

There are three main methods for high-cycle fatigue testing:

one-stage tests (regular loading);
multistage (block loading) - 6-8 steps;
tests under accidental loading.

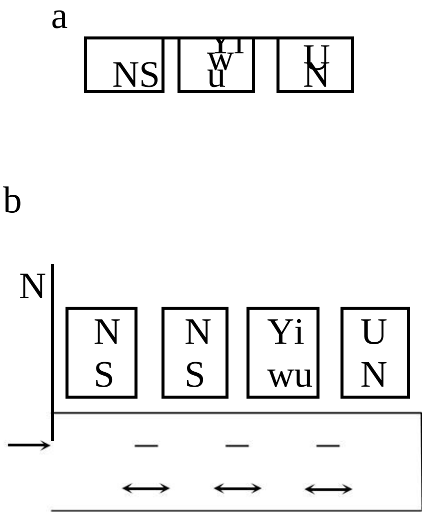


Figure 3.5. The test circuit stand:

Recently, tests under random loading have received the greatest development due to the creation of electrohydraulic tracking systems. There are types of loading:

Reproduction tests (by copying);

Simulation tests real process.

To calculate the probability of failure-free operation Pm (t), the machine must be divided into separate elements: systems, nodes, details. Failure of one element should not influence the reliability of others.

All elements of the machine can be divided into three groups. The elements of the first group can be determined by calculation, the second - by analogs, the third - at the stands.

The system availability factor is determined from the expression

1
KG nN
S T
1 vi
i 1 Tabouti ...

Reliability tests are carried out in accordance with GOST 17510-79.

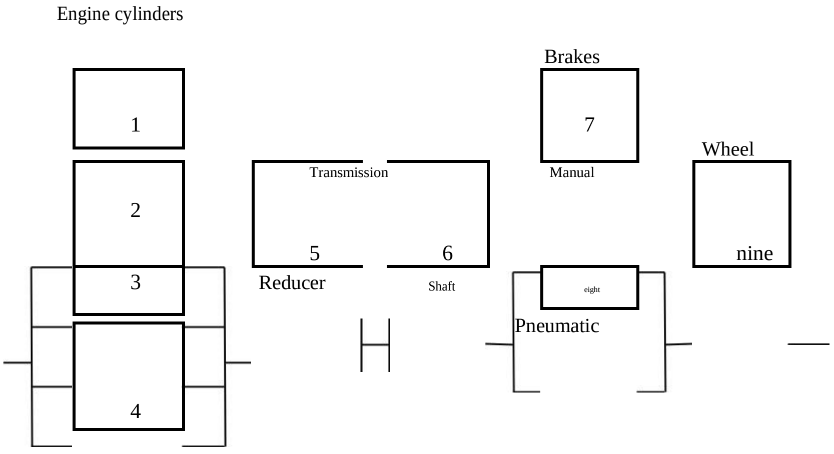
Lecture number 16

CALCULATION OF RELIABILITY INDICATORS OF COMPLEXES MINING MACHINES

Lesson plan

1. Analysis of the process of functioning of the object
2. Stages of calculating the reliability indicators of a complex of mining equipment

Before calculating the reliability at the design stage, a calculation scheme is drawn up for



basis analysis process functioning object. Then formulated it possible structural fortunes and are described possible failures. Calculation of indicators reliability

produced by addition and probability multiplication theorems. For increase reliability, various redundancy schemes are used. With the help of laboratory and industrial tests, the correspondence of the calculated and actual indicators is established. When organizing trials, a factorial design of experiments is used.

Problem A. A car can be represented by a diagram (Fig.4.1).

Based on the structural diagram, find the probability of no-failure operation car w_a if the probability of failure-free operation of each element is wi ...

1. The likelihood of failure-free operation of the car is wa... Find the probability trouble-free operation of each element, if they are the same.
2. The likelihood of failure-free operation of the car is equal to wa... Probabilities of no-failure work in series wNS elements are the same, connected in parallel wNS

- 20% less and also the same. Find the probabilities of failure-free operation of all elements of a given system.

4. Probability of failure-free operation of each element connected in series is equal to wNS, and each connected in parallel is 20% less wNS... Determine the probability of system uptime.

Calculation data: option 1 - wi = 0.9; option 2 -wa = 0.6; option 3 -wa = 0.51; wNS = 0.73; option 4 -wNS = 0.73.

Solution. Option 1: wa = [1 - (1 - 0.9)4] 0.9 · 0.9 [eleven - 0.9)2] 0.9 = 0.72164.

Option 2. This is the opposite problem to the previous one, wi = 0.849.

Option 3. The equation for calculating the probability of failure-free operation of the vehicle has the form

wa = [1 - (1 - 0.8wi)4]wi 3[1 - (1 - 0.8wi)2].

For serial connection wi = 0.8342, for parallel connection wi = 0.6674.

Option 4. The equation for calculating the probability of no-failure operation of the car has view

wa = [1 - (1 - wNS)4] (0.8wNS)3 [eleven - wNS)2]; wa = 0.3145.

Problem B... During the period of normal operation of the machine, characterized by a constant failure rate, the probability of failure-free operation of the machine after T hours of work is wm... Determine the failure rate . Calculation data:T = 2500; wm = 0.9. For the conditions of the problem, the probability of failure-free operation is determined by the formula

wm = e- t,

hence the failure rate

= -Ln (wa) /t = -Ln0.9 / 2500 = 0.4214 ten-4

Lecture number 17

CALCULATION AND CONSTRUCTION OF MAINTENANCE SCHEDULES

MINING MACHINES

Lesson plan

Determination of the optimal service life of the elements

Calculation of the number of spare parts for each unit

V calculated work reviewed probabilistic way organization preventive maintenance based on the analysis of statistical information on reliability. The purpose of the calculations is to determine the optimal service life of the elements of mining machines, at which the minimum costs for scheduled and emergency repairs are achieved, the construction of a strategy for the maintenance of mining equipment and the determination of the required number of spare parts.

Work order:

1. Determination of the parameters of the distribution laws of random operating time of nodes and

machine parts.

2. Selection of the most probable distribution laws of the operating time of each node

cars.

3. Calculation of the optimal replacement period for each unit of the machine, determination of the timing and

types of repairs, the choice of the number of spare parts.

4. Construction of repair schedules.

Determination of the parameters for the distribution of operating time 1st node is done by statistical processing of accumulated data on a computer. The following results were obtained:

	Tav =	=
Normal law	1780	650
	A =	l =
Logarithmically	4.8124	0.2

		36
normal law		
Weibull's law	A = 1884 B = 5.006	
Gamma distribution	= 0.00252	m = 10. 41

To construct a diagram and an experimental curve for the distribution of the operating time of the 1st node, we determine the length of the interval
t Tmax Tmin

1 3.3 lg N ,

where Tmax and Tmin are respectively the maximum and minimum operating time of the 1st machine unit according to statistical data,

262
9
840
1
3.3
2

Figure 4.2 shows the results of plotting the diagram and the operating time distribution curve for the 1st node.
The most probable distribution law of the operating time of each node is selected with

using Pearson's 2 test of goodness:

The laws First Second Third Quarter Fifth knot

distribution knot th knot

Normal	13 .4 5	14.90 23.46		18.86 13.58
Logarithmically normal	28 .4 0	26.33 16.32		17.28 33.80
Weibull	4. 64	4. 4 7	1 6 . 8 6	2 0 . 1 6
Gamma	10 .0 8	34.056 10.39		4 . 2 3

According to the value of the goodness-of-fit criterion, the distribution laws were selected: the first, second, fifth nodes - Weibull's law; the third, fourth nodes are gamma distributions.

As a criterion for calculating the optimal timing of replacements, we use the ratio

the cost of replacing the node to the duration of the overhaul period Ssp and the coefficient of the cost of the node E, the value of which is given in the initial data. As a result of calculations on a computer, the values of the optimal replacement times Topt, the average values of the operating time Tav,

□□

the likelihood of reaching the optimal replacement time and unit costs of substitutions Ssp:

Nom ep knot	Topt		T cr	Su d	□	E	
		1 8 4 0 6 1 0 0 3 0 7					0 2 8 5 0 2 7 3 0

			0.00014	0.510	0.533
0.00005	0.945	0.185	0.00017	0.279	0.444
0.00004	0.967	0.119	0.00013	0.296	0.644

According to the condition of the problem, if the probability of reaching the optimal replacement period is more than

0.9, the term for replacing Topt is accepted, otherwise - Tav. Accepted replacement dates are highlighted in bold.

To calculate the number of spare parts for each unit, you must assign replacement models. The type of model is selected based on the analysis of the unit replacement cost Ssp and the unit cost factor E. High Ssp values make it necessary to extend the overhaul period to maximize the use of the unit resource, and small values of the cost factor show the severity of the consequences of an emergency failure.

Analysis of the values of these parameters allows us to give the following recommendations:

for 1st node - regulated model, i.e.

without postponing the planned repair period in the event of an emergency failure, since Ssp has a small value relative to other nodes and E <0.3;

for 2nd node - regulated model;

for 3rd node - basic model, i.e. node is working

to failure, since the consequences of an emergency are not severe, and Ssp is relatively large;

for 4th node - an individual model, i.e. with

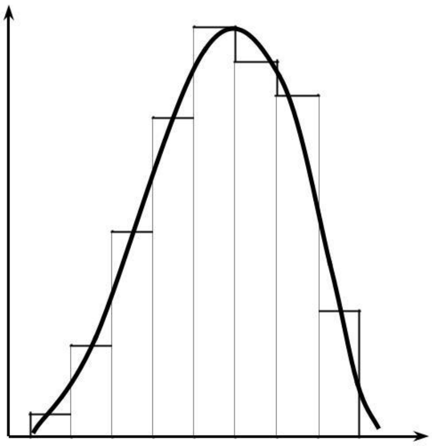
the postponement of the planned repair period when replacing the unit due to an emergency failure (the highest value of Ssp);

for 5th node - basic model.

Planned number of repairs
z NTsl

Wed TR ,

where N is the number of cars on the site; Tsl is the service life of the site; Tr is the overhaul period.



To build a repair schedule, first build a time axis and postpone for

it is the total service life of the equipment Tsl = 12900 h. As the time for replacing the unit, we take the Topt value if the probability of achieving the optimal operating time w exceeds 0.9, and the Tav value if this value is less than 0.9.

We postpone these values on the axes of each node (Figure 4.3). It can be seen from the graph that the replacement of nodes 3, 4 and 5 can be carried out in one repair shift, since the largest difference in the timing of replacements is small (for the 3rd and 5th nodes), i.e. no more than 12% of the replacement period for the 5th node. We assign the term for replacing these three nodes to 153 days (2750/18 = 153), since this maximizes the resource of the most expensive of the replaced nodes (4th), and a possible emergency failure of the 3rd or 5th nodes is not will entail serious consequences.

Further from this period, we postpone the replacement of the 3rd, 4th and 5th nodes again. Now you can see

that replacements of all five nodes have become close. For this period, we assign a major overhaul of the machine, since it is close to the middle of the service life of the site and the total labor intensity of the repair is maximum.

In the same way, we continue to build the repair schedule until reaching Tsl, taking as the starting point for the replacement of all units, the period for overhaul. After that, we translate the terms of repairs from the hourly measurement to the daily one, since it is customary in mines to designate three shifts as mining, and the fourth as repair. This results in a working period of 18 hours every day. On the final schedule, we postpone replacement times and assign types of repairs. We believe that the professional training of the site repair personnel is sufficient to replace unit 1. To replace nodes 4 and 5, one could use

specialists of the energy-mechanical service of the mine (i.e. to appoint T1), but the cost of replacing node 3 at the same time allows us to increase the repair status to T2 (with the involvement of specialists from local repair enterprises).

Lecture number 18

FACTORS AFFECTING THE RELIABILITY OF THE MINING ELECTRICAL EQUIPMENT

Lesson plan

1. Factors affecting the reliability of mine electrical equipment
2. Operating conditions of electromechanical equipment of mining enterprises
3. Reasons for failure of mine electrical equipment

Factors affecting the reliability of mine electrical equipment

GOST 18311-80 defines the operating conditions of electrical equipment as a set of values of physical quantities that are external factors and affect its operation.

The main influencing factors of operating conditions are: temperature; relative humidity and dustiness of the air; temperature changes; Atmosphere pressure; air speed; vibration and shock loads; displacement during operation.

The operating conditions of electrical equipment are determined by the category of use of electrical devices, voltage quality, number of starts, operating mode of electrical installations, etc.

Analysis of the causes of failure of electrical equipment operating in coal and ore mines showed that climatic and mechanical factors, as well as operating conditions, have a significant impact on its reliability.

In accordance with GOST and a number of industry regulatory documents, the operating conditions of electrical equipment are classified according to degrees of severity. 15 degrees of hardness have been established for positive temperature, 9 for negative temperature, 20 for vibration loads, 4 for shock loads, 8 for relative humidity, etc.

High reliability and efficiency of electrical equipment can be ensured when the technical solutions (technical parameters,

Design, manufacturing technology, types of tests) correspond to strictly specified conditions (degrees of severity) of operation.

In accordance with this, the development takes into account the operating and limiting temperature, air humidity, dripping, dustiness of the air, aggressiveness of the environment, air velocity, vibration and shock loads, etc. For example, the average annual operating temperature (° C) of air in mines can be adopted: in the main workings 12; in the faces 15; in substation chambers 18.

Mine electrical equipment is designed and manufactured in various versions: when placed on a surface under a canopy (for example, U2: climatic version U, placement category 2); in underground workings (U5); in areas with a cold climate: on the surface under a canopy XJI2, in underground workings XJI5.

Along with the indicated indicators, the voltage quality has a significant impact on the reliability indicators of electrical equipment. Quality indicators voltages are frequency deviation, voltage deviation and fluctuation, non-sinusoidal voltage waveform, frequency fluctuation, neutral offset and fundamental frequency voltage unbalance.

Operating conditions for electromechanical equipment of mining enterprises

Operating conditions are usually defined as a set of external factors (physical quantities) that can affect it during operation. External factors are divided into two groups: climatic and mechanical.

In underground mining, climatic factors have the greatest impact on humidity, temperature, dust, and corrosive substances. From mechanical factors - vibration, sharp shocks and shocks, and for the outlet ends of electrical equipment, in addition, tensile and bending forces, torque, twisting, which are possible during the installation of electrical equipment.

The high humidity (up to 100%) in underground workings of coal and ore mines is explained by the presence of groundwater, and the increased temperature (according to the MakNII, in some workings it reaches + 40C0 even with air conditioning) its natural increase due to a positive gradient along the depth of mining and (to a lesser extent) heat release from operating electrical equipment.

The corrosiveness of mine waters is significant. The content in them of cations and anions of acids and alkalis, carbon dioxide, as well as other chemically active elements reaches 50 g per 1 liter.

Humidity, temperature, dust, aggressive agents, mold fungi, acting on the shells and insulation of electrical equipment, reduce their reliability and, therefore, lead to premature failures.

With open-pit mining of mineral deposits, climatic factors affecting electrical equipment are much greater. In addition to higher (+ 45 ° C and above) and low (-50 ° C and below) temperatures, its changes during the day (40 ° C and more) are influenced by such factors as solar radiation, wind, rain, frost, etc.

Allocate three characteristic species impact temperature on work electrical equipment in quarries: prolonged increase or decrease; temperature fluctuation; episodic increase or decrease. The reason for the premature failure of electrical equipment with prolonged exposure to elevated temperature - inconsistency of the selected insulation of live parts with the degree of heating. Changes in temperatures and, as a result, periodic heating and cooling of electrical equipment are caused by daily fluctuations and the cyclical operation of the equipment itself.

Changes in temperatures with zero crossing at high humidity are especially unfavorable, since frost occurs on the contacts, freezing of the relay armatures and disruption of the operation of control systems due to this.

At low temperatures (-30 ° C and below), work is especially difficult power grid equipment. For example, transformer oil thickens so much that it causes complete failures of oil switches. Replacing them for these conditions with vacuum ones is the most effective measure of increasing operational reliability.

Adversely affects the operation of electrical devices filled with transformer oil, humidity, since, having hygroscopicity, oil absorbs moisture and loses its dielectric properties. In this regard, the period for replacing transformer oil in devices is about 3 months.

Corrosion in open pit works is associated with contamination of the moisture layer, occasional appearing on the surface of electrical equipment, by various chemical substances deposited from the air. The electrolyte formed during this intensively destroys the elements of electrical equipment.

Solar radiation has a significant effect on career electrical equipment: under the sun's rays, decay processes are sharply accelerated electrical insulating materials (PVC, fluoroplastic, rubber, etc.), and paint and varnish cracks and collapses. Additional heating of surfaces of openly installed equipment by direct sunlight reaches 30 ° C. The high-voltage adventure points (HVs) located on the work boards are exposed to this effect.

Dustiness of mine workings depends on the method of destruction of minerals (mechanical, drilling and blasting), type of transport (electric, conveyor, automobile), structures of loading and unloading devices and structures. Downhole electrical equipment is most exposed to dust in mines and quarries. Accumulating on the surface of live parts electrical equipment, the dust layer becomes electrically conductive and breakdown usually occurs through it. Getting into electrical equipment, dust particles accelerate the abrasive wear of its elements, are the cause of bearing seizure. There is a correlation between the dust content of the open pit air and the operating time before the overhaul of electrical equipment, which must be used in the development of new dustproof designs of electrical equipment.

Mechanical influences (shock, vibration, tensile forces, etc.) are experienced by electrical equipment - when moving most of the machines during operation (shearers and roadheaders, excavators, etc.) and periodic movement of electrical installations (conveyors, drilling rigs, substations, distribution and switching points, etc.).

Switching points and other power supply equipment at when transported along unprepared routes, they experience significant vibration loads (vibration frequency up to 180 Hz, amplitude 0.2-0.5 mm, acceleration 15g). Vibration loads often cause destruction of support and bushing insulators, breakage of rods and misalignment of contact systems, loss of rigidity and strength of welded structures, damage to devices, protection relays, etc.

In addition to climatic and mechanical factors condition external Wednesday electrical equipment is affected by mining and geological factors. This is manifested in the nature of the operating modes of mining machines, the totality of which most fully reflects the conditions of their operation.

Reasons for failure of mine electrical equipment

Collecting statistics in progress exploitation miner electrical equipment and its analysis make it possible to identify the most typical causes of failures of electric motors, starting protection equipment, transformers and transformer substations, cables.

Studies have shown that the largest number of failures in combine motors falls on the stator winding and inlet boxes contaminated with coal dust, gear oil, bearing grease and flooded with water.

In the stator windings of such electric motors, the main part of the breakdowns of the insulation of the sections on the case falls on the corners of the sections near their exit from the groove. The groove part of the section wears out more than the frontal parts due to electrodynamic shocks and thermomechanical friction against the groove walls. Breakdowns of coiled insulation are noted only in the frontal parts and are absent in the slotted part at any stage of insulation aging. It should be noted that the melting of aluminum rotor windings in EDK motors, for example, is observed 2 times less often than in EDCO motors with a higher rate of temperature rise.

The misalignment of the rotor and stator that has appeared during operation can lead to a "paste" of the rotor against the stator.

The most typical damage to bearings of combine electric motors during normal operation is fatigue damage and brinelling of rolling surfaces. Ingress of coal and rock dust, metal particles into the bearing grease leads to the formation of dents on the rolling surface. Abrasive wear occurs, gradually leading to fatigue chipping. Under the influence of temperature and mechanical load, the bearing grease gradually ages, its viscosity decreases, which can lead to its runout, jamming and rotor paste.

For electric motors of the VAO series, the most characteristic type of damage is charring of the coil insulation due to thermal effects. Turning closures are characteristic of the frontal part of the stator winding from the side of the section connection. Phase-to-phase and turn-to-phase short-circuits occur at the connections of the sections and at the outlet ends of the winding head parts. Other typical damages include case short-circuits, jamming of bearings, fan on the casing, network breakage, etc.

The main failures of mine explosion-proof electrical devices (switchgears, circuit breakers, magnetic stations, starters, etc.) should include failures of remote control circuits, free release mechanisms, power contacts, trip coils.

Failures in remote control circuits are caused primarily by failures of its individual elements due to the influence of harsh environmental conditions and poor quality of the supply voltage. Resistors and semiconductor elements have an open circuit failure, a capacitor has a short circuit, and chokes and stabilizers have a turn circuit. Up to 95% of failures are due to poor-quality connections or soldering.

The reasons for failures of various kinds of relays are misalignment of contacts, formation of a non-conductive film on their surface due to corrosion and pollution, welding of contacts. Low-power relays are characterized by false alarms under the influence of shock and vibration loads. However, the majority of failures occur in the closing coils.

The reason for failures of chokes, transformers is the destruction of winding insulation, which occurs under the influence of high temperature and humidity, vibration and shock loads.

When analyzing the failures of transformer substations and transformers, it was found that the largest number of failures of substations falls on automaticswitches and protection blocks BZP-1A. In these devices, the most characteristic is the wear of the contacts, breakdowns of the insulation of the HV winding on the case, turn short circuits of the HV winding, turn closures of the tripping coil of the circuit breaker. The failure rate is on average 13.3 10-5 1 / h (mean time between failures - 7500 h).

Failures of mine flexible cables most often occur due to mechanical damage to the insulation (up to 85%). However, due to wetting of the insulation, electrical breakdowns and a decrease in insulation resistance are also observed in end cuts, couplings and couplings. This explains the rather limited lifespan of flexible cables.

For armored cables with paper insulation, failures are typical due to breakdown of insulation in bushings and lead-in couplings, due to mechanical damage in workings by falling pieces of rock, vehicles and during workings fastening.

For cables with voltage higher than 1000 V, the following data on failure rate (per 100 m), 1 / h can be recommended: stem λs = 2.4 · 10-5; in inclined workings λн = (6.5 ÷ 9.0) · 10-5, in horizontal workings λg = (3.7 ÷ 6.7) · 10-5.

For cables with voltage up to 1000 V, the data is much higher and amount to, 1 / h: for flexible combine $\lambda\text{к} = 58.0 \cdot 10-5$; flexible in lavas $\lambda\text{l} = 29.2 \cdot 10-5$; flexible in workings $\lambda\text{w} = 12.5 \cdot 10-5$; armored 10.0 10-5.

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DEPARTMENT "MINING BUSINESS"

INSTRUCTIONS FOR USE

for practical work in the discipline *"Reliability of mining machines"*

Almalyk 2021

Practical work No. 1

Calculations of indicators of reliability of elements.

Reliability - property of the object to perform the specified functions, keeping in time the values of the established performance indicators within the specified limits,

corresponding to the specified modes and conditions of use of the facility, repair, storage and transportation.

Reliability includes:

reliability;

durability;

Maintainability;

preservation.

Reliability - property of the object to continuously maintain operability for some time or some work.

Failure is an event that disrupts the performance of an object. The signs (criteria) of failures are established by the NTD for a given object.

Sudden failure is a failure characterized by an abrupt change in one or more specified parameters of an object.

Gradual failure is a failure characterized by a gradual change in one or more specified parameters of an object.

Failure is a self-correcting failure resulting in short-term operational disruptions.

Production failure is a failure resulting from a violation of the established manufacturing process or repair of an object.

Operational failure is a failure resulting from violation of established rules and (or) operating conditions or the influence of unforeseen external influences. Complete failure is a failure, after the occurrence of which the use of an object for its intended purpose is impossible until its operability is restored.

Partial failure is a failure after which the product can be used for its intended purpose, but with less efficiency.

The reason for the failure is the phenomena, processes, events and conditions that led to the occurrence of the object's failure. The occurrence of a failure can be caused by errors or a low level of design of the facility, non-compliance with the technology during production, violations of operating rules, various types of damage, natural processes in the facility itself (material fatigue, wear, corrosion, etc.).

Indicators of reliability of non-recoverable objects:

probability of failure-free operation P(t0) Is the probability that an object will not fail within a given operating time;

failure rate (t) Is the conditional density of the failure occurrence, determined for the considered moment of time, provided that the failure did not occur before;

mean time to failure T0 Is the mathematical expectation of the operating time to the first failure.

Mathematical definition uptime probability from the start of operation to t0 (Figure 1.1):

probabilistic

P(t0) P(0, t0) P   t0 1 F(t0),

where - random time of operation (operating time) of the object to failure (between failures); F(t0) - distribution function of a random variable ;

Statistical

N (t0)   (0

N   ) nt()   (t

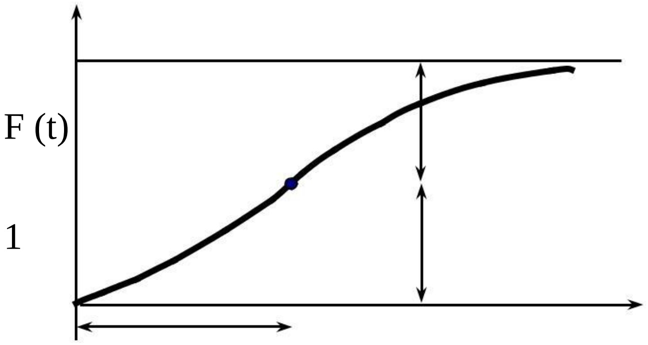
0

Pˆ (t0)   N

N (0)   (0)   (0)

where N (t0) - the number of corrected objects at a time t0; N (0) - quantity fixed objects at time t = 0; n(t0) Is the number of object failures during

t0...



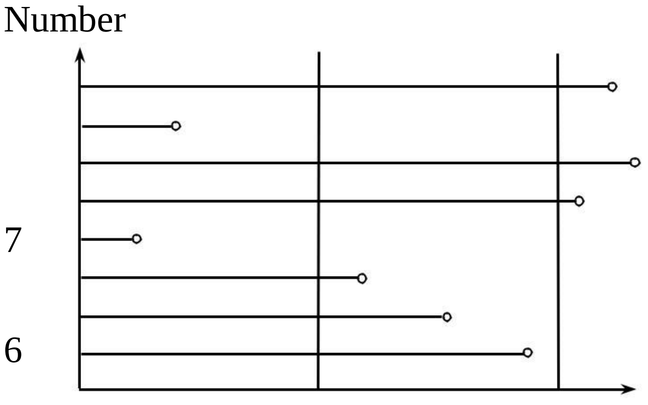


Figure 1.1. Definition of reliability:a - probabilistic;

b - statistical

If the operating time is counted from an arbitrary moment t, then the probability

trouble-free operation in the time interval from t before t + t0 can be determined based on the probability multiplication theorem.

Really,

P(t t0) P(t)P(t, t t0).

probabilistic way of determining:

F
P((t t)
t, t t) C
0 F
(t),

where P(t, t t0) Is the probability that the object will work flawlessly for a given time t0 starting from the moment in time t, or the conditional probability that the random runtime to failure will be longer t + t0 provided that the object has already worked flawlessly up to the point in time t... Statistical way of determining:

N(t t N(
) / t t0)
Pˆ 0 N0
(t, t 0t) N(t) / N(
N0 t),

where N(t) - the number of objects corrected by the time t... With the

probability of failure in the time interval from 0 tot0:
probabilistic definition:

Q(t0) Q(0, t0) P t0 F(t0),

where Q(t0) Is the probability that the object will fail within a given time t0starting work at t = 0, or the fact that the random time of operation of the object to failure will be less given time t0; it's obvious thatQ(t0) = 1 - R(t0), since the events are inconsistent;

Statistical definition

$\hat{Q}$ (t0) n(t0)

N (0).

With the probability of failure in the time interval from t before t + t0:

probabilistic definition:

P(t t)
Q(t, t t0) 1 P(t, t t0) 1 0

P(t);

statistical definition:

N(t t) N(t) N(t
t) n(t, t)
Q(t, t 0
t0) 1
(t) N(t) (t),

where n(t, t0) Is the number of general failures exactly in the time interval (t, t + t0).

Task. Put to the test N0 products. During time t hour n (t) pieces are out of order

products. For the next time interval t out of order n(t) products. Necessary

–

calculate the probability of no-failure operation (P (t) in time t, the failure rate a t and –

–

failure rate t on the interval t ... Initial data for solving the problem are shown in Table 1.

Table 1. Initial data for task 1

Var. No.	N0	t, hour	t ,hour	n(t)
1	60	twenty	twenty	eight
2	75	40	35	7
3	50	70	50	6
4	55	55	50	eight
5	65	75	75	nine
6	80	85	80	ten
7	85	90	80	eight
eight	45	5	5	5

Solution

Probability of uptime (P (~~t~~):

–

(N0 n(t)) / N0 = (45-5) / 45 =

t) 0.888888889

Failure

rate a t o the interval t :

t) n(t) / (N0 t) = 5 / (45 * 5) =

0.022222222 Bounce Rate t on the interval t :

(t) a(t) / P(t) = 0.022222222 / 0.888888889 = 0.0250000

Practical work No. 2

Calculations of FBG and mean time between failures of elements.

Indicators of reliability of restored objects:

probability of failure-free operation P(t);

failure flow parameter (t) Is the probability density of the failure of the restored object, determined for the considered moment in time;

MTBF T - the ratio of the operating time of the restored object to the mathematical expectation of the number of its failures during this operating time.

The probability of failure-free operation is determined in the same way as for non-recoverable objects. However, it should be borne in mind that the distribution functions of the operating time between the start of operation and the first failure, the first and second failure, and so on, may be different. Therefore, the probability of no-failure operation should be determined through the corresponding distribution function. During the operation of mining equipment, information on reliability is collected separately for new and for objects that have been overhauled.

For the failure rate:

* probabilistic definition. From the definition of the failure rate by the theorem multiplication of probabilities we have:

$$tf(t)\ P(t)(t)\ t$$

or

$$(t)\ \frac{f(t)}{P(t)}\ \frac{1}{1\ F(t)}\frac{d}{dt}P(t)\ \frac{d\,P(t)}{p(t)}\ \frac{d\,Q(t)}{1\ Q(t)},$$

where f(t) Is the probability density of the object failure at the time t provided that before at this point, the product did not fail;

* statistical definition:

$$\hat{}\,(t)\ \frac{n(t,t\ t)\,/\,N(0)\,t}{N(t)\,/\,N(0)}\ \frac{n(t,t\ t),}{N(t)\,t}$$

where n - great; t - few; ˆ(t) Is the ratio of the number of failures in the time interval (t, t + t) to the product of the number of corrected objects at the moment of time t on a long interval

time t (the number of failures of one object per unit of time, provided that before that the moment the product failed).

For MTBF:

* probabilistic definition for continuous production:

$$T0 \quad M \quad \underset{0}{tf\,(t)\,dt} \quad \underset{0}{P(t)\,dt}\,,$$

where T0 - mathematical expectation of operating time before the first failure;

* statistical definition:

$$\hat{T}_0 \quad \frac{1\;\;(1)\;\;(2)\;\;\dots\;\;N(0)}{N(0)}\;1 \qquad \frac{}{N\;0}\;\overset{N(0)}{\underset{i\;1}{}}\;()_{i}\,,$$

where $\hat{T}0$ Is the arithmetic mean of the implementation of the object's operating time to failure. If one of the functions is knownP(t), Q(t), f (t), (t), then through it you can

determine the rest (Table 2.1).

Tableitza 2.1 Functional relationship between reliability indicators

known and I function I am	Formulas for the other three functions			
	$P(t)$	$Q(t)$	$f(t)$	(t)
$P(t)$	-	$1 - P(t)$	$\frac{d}{dt}P(t)$	$\frac{1}{P(t)}\frac{d}{dt}\;-\;P(t)$
$Q(t)$	$1 - Q(t)$	-	$\frac{d}{dt}\;Q(t)$	$\frac{1}{1\;\;Q(t)}\frac{d}{dt}Q(t)$
$f(t)$	$\underset{0}{}\;f(x)dx$	$\overset{t}{\underset{0}{}}\;f(x)dx$	-	$\frac{f(t)}{\underset{t}{}\;f(x)dx}$
(t) exp	$\overset{t}{\underset{0}{}}\;(x)dx\;1\;\;\text{exp}$	$\overset{t}{\underset{0}{}}\;(x)dx\;\;(t)\;\text{exp}$	$(x)dx\;\overset{t}{\underset{0}{}}$	-

Let's find the addiction P(t) from (t). From the definition of failure density and intensity

refusals we
have:

d
d P(t 1 p
(t)) P(t ; — (t)dt
dt) p ;
t
ln
ln P(t) P(0) (t)dt 1, ln
— —— 0 , P(0) P(0)0 0,

hence,

t (t
)dt
P(t) e 0 ...

Definition indicators reliability for recoverable objects
is performed in the same way as for non-recoverable objects.

Task. The product consists ofN elements, the average failure rate of which is Wed ...

It is required to calculate the probability of no-failure operation over time t and average

operating time to the first failure. The initial data for solving the problem are given in table 2.2.

Solution

Probability of uptime P (t):

P (t) = e- s *t ,

Where, with - average failure rate;

with = N * cp ,

with = 189000 * 1.4 * 10-6 =

0.2646; P (t) = e-0.2646 * 2 = 0.589076.

Mean time to first failure TWed:

TWed = 1 / with

TWed = 1 / 0.2646 = 3.779289.

Table 2.2. Initial data for task 2

Var. No.	*N*	*Wed* , *1 hour*	*t, hour*
1	200,000	$2 * 10^{-6}$	7
2	190,000	$2.7 * 10^{-6}$	5
3	195,000	$3 * 10^{-6}$	6
4	200,000	$1.7 * 10^{-6}$	7
5	205,000	$1.7 * 10^{-5}$	eight
6	180,000	$2.1 * 10^{-5}$	5
7	197,000	$2.8 * 10^{-6}$	4
eight	189,000	$1.4 * 10^{-6}$	2

Practical work No. 3

Building graphs of element reliability indicators

Let the operating time of an element until failure is subject to an exponential distribution law with the parameter ... It is required to calculate quantitative characteristics

P(t), a(t),
T cp at value t. Build dependency graphsP(t),
element reliability a(t)
from t. The initial data for solving the problem are shown in
Table 3.

Table 3. Initial data for task 3

Option No.		t_1	t_2	t_3
1	2 * 10-6	700	800	900
2	2.7 * 10-6	780	850	900
3	3 * 10-6	500	700	800
4	1.7 * 10-6	400	600	800
5	1.7 * 10-5	450	650	850
6	2.1 * 10-5	600	700	900
7	2.8 * 10-6	650	750	850
eight	1.4 * 10-6	400	500	600

Solution

Probability of no-failure operation P (t):

P (t) = e- *t

P (t1) = e - 0.0000014 * 400 = 0.999440157; P

(t2) = e - 0.0000014 * 500 = 0.999300245; P (t3

) = e - 0.0000014 * 600 = 0.999160353.

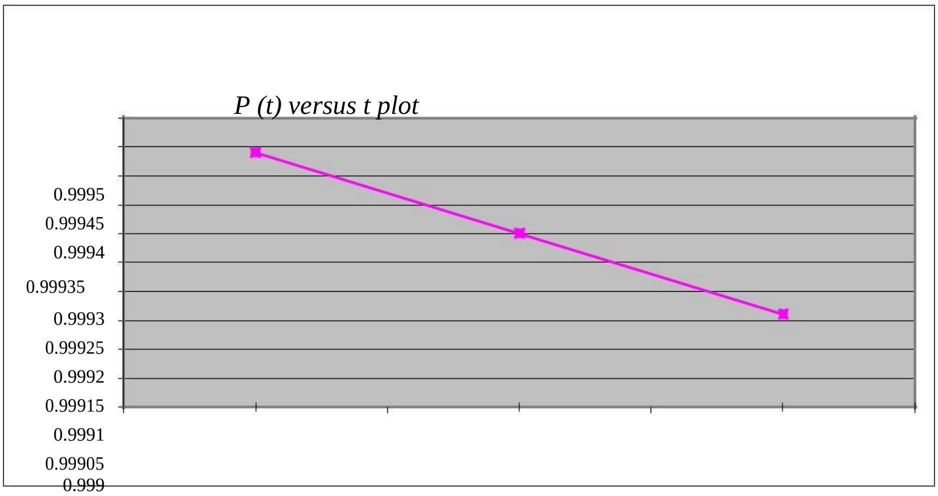
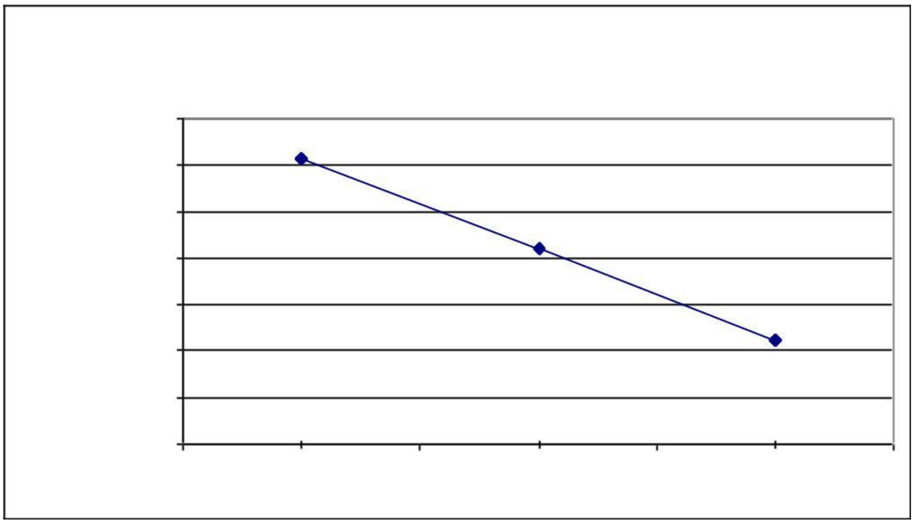


Figure 3.1. The graph of the dependence of the probability of no-failure operation on time

$$a\ (t3\ ) = 0.0000014 * e - 0.0000014 * 600$$
$$= 0.0000013988.$$

Graph of a (t) versus t



Practical work No. 5

Determination of the failure rate at a two-sided confidence interval.

Physical processes in almost any area are random. This is due to the reasons for their occurrence and course. Therefore, research in the theory of reliability is carried out on the basis of methods of probability theory and mathematical statistics. These methods are based on the concepts of an event, a random variable, addition and multiplication theorems for probabilities for reliability assessment.

Failure rate
1
(t) const

a ...

Therefore, the probability density and the distribution function with an exponential distribution are written in the form

f (t) e t ...

Distribution function F (t) 1 e t
...

Dimension s-1 is the number of failures per unit of time.
It can be shown that the mean time to failure T0 1/ and variance D 1/ 2
.

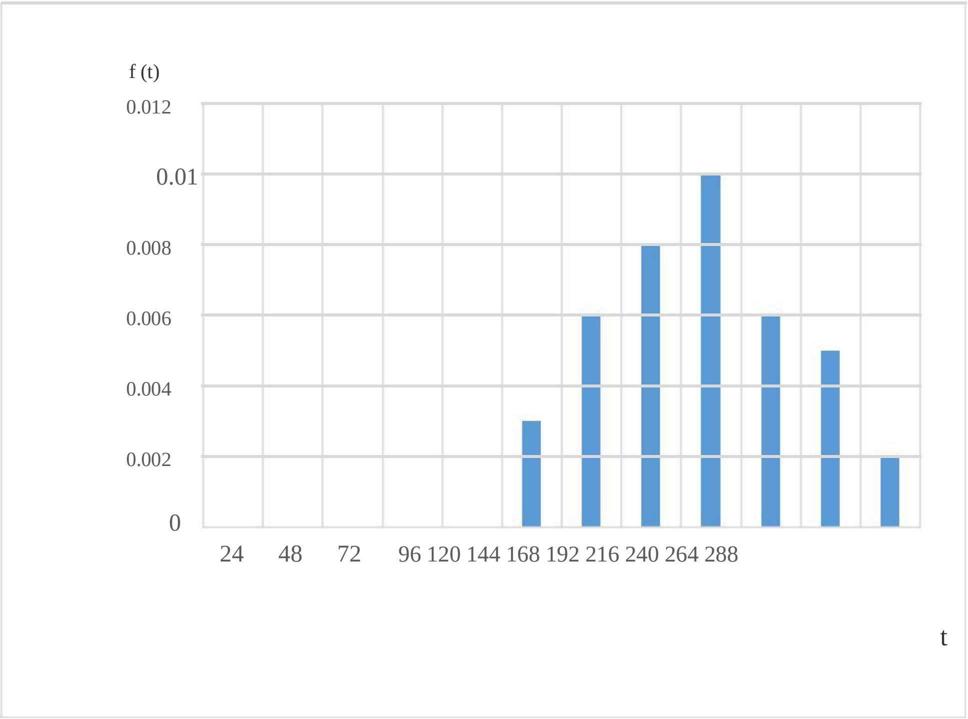


Figure 5.1 Histogram of the density of distribution of failures of elements

Task. During the tests according to the plan [n,B, t0] failed d devices, and the failed devices worked until failure, respectively t1-tn hour.

Assessment required and a two-sided confidence interval for ... Initial data for
solutions to the problem are shown in Table 5.

Table 5. Input data for task 5

Option No.	N	t_0	d	t_1-t_n	2
1	100	1000	7	100, 200, 300, 500, 700	0.7
2	90	110		nine150, 200, 250, 300, 400	0.8
3	110	950	eleven	200, 400,600, 800	0.7
4	125	650	21	100, 150, 200, 250	0.6
5	210	700	13	150, 300, 450, 600	0.9
6	130	800		fourteen 200, 250, 400, 700	0.8
7	95	850		nine200, 400, 600, 800	0.7
eight	70	500	5	150, 200, 300, 350, 450	0.8

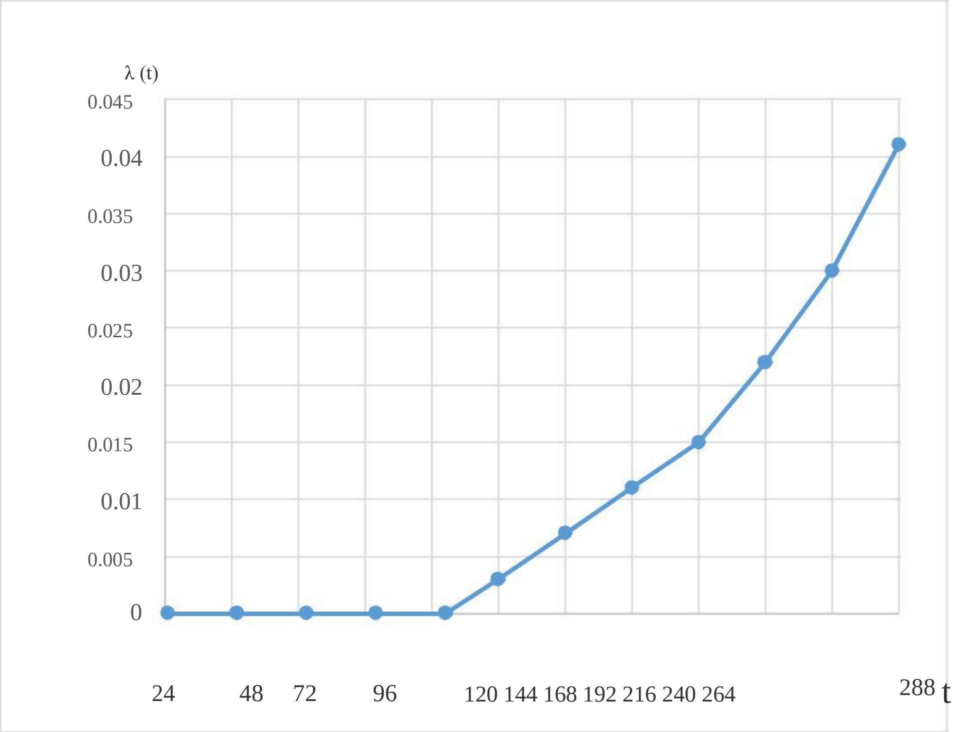


Figure 5.2 Component Failure Rate Curve

Solution

Total operating time t:

d

t ti (n d) 0

*t = 33950;

i 1

_

Failure Rate Assessment :

_ d

—= 0.000147275;

Upper bound V :

2 ( )2

(2d) 0.000268

041;

2t

Bottom

line H :

2 (1 2) =

(2d) 0.00013947.

2t

Two-sided confidence interval: [0.00013947; 0.000268041].

Practical work No. 6

Calculations of reliability indicators for parallel connection of elements

Calculation of the reliability of a product consisting of a number of elements is possible after the formation of its structural diagram. At the same time, it is considered that the elements of the product interact sequentially if the failure of any of them leads to the failure of the entire system. In this case, the system is operable if both element A and element B are operable, etc. The conjunction "and" predetermines the application of the probability multiplication theorem. The system is in a state of failure if either element A or element B fails, etc. In this case, the probability of failure is determined by the addition theorem for the probabilities of failure of elements.

The elements of the product interact in parallel if its operability is ensured while maintaining the operability of at least one element, i.e. workable or A, or B, etc. The probability of failure-free operation of such a product is determined by the theorem of addition of probabilities for joint events. With a large number of parallel connected elements, the use of the probability addition theorem leads to a very cumbersome calculated dependence. Therefore, it is more convenient to determine the probability of product failure by the theorem of multiplying the probability of failure and only then the probability of failure-free operation:

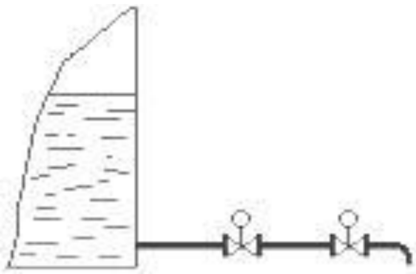
m m

P = 1 - Q = 1 - i 1qi = 1 - i 1(1 - pi).

It should be noted that the concepts of parallel and sequential interaction from the point of view of the theory of reliability do not correspond to the connection of elements in the physical sense. For example, on the drain lines from the sump of the factory, two valves are installed, physically connected in series (Figure 6.1). From the point of view of the theory of reliability, these valves interact sequentially when the drain is opened (the normal position of the valves is closed) and in parallel when the drain is closed (the normal position is open).

Figure 6.1. Types of connection of elements

Thus, when forming a structural diagram of the interaction of elements



any system requires a preliminary analysis of its normal operation. It is recommended to use functional analysis tools for this.

First, the main function of the product is formulated, and then the main ones, which ensure the performance of the main function and allow you to highlight the main structural elements of the product. After that, the sequence of the passage of the most important flow (material or field) through the structural elements is established. It is this sequence establishes the nature of the interaction of elements - parallel, sequential or mixed.

For NS parallel interacting elements probability of failure ith element qi = 1 - pi , and the probability of failure T elements

n n

Q = i 1qi = i 1(1 - pi).

Probability of failure-free operation of the entire product

n

P = 1 - Q = 1 - i 1 (1 - pi).

With the same elements

P = 1 - (1 - R)NS...

If the product consists of T elements that interact sequentially and form NS in parallel interacting chains, then the probability of failure-free operation of the entire product

n m

P = 1 - j 1 (1 - i 1 pi).

With the same elements

P = eleven - RT)NS...

Task. The machine node consists of two parallel-connected blocks with a failure rate equal to:

1   0.32 * 10 5 (1 / h);
2 0.18 *ten 5 (1 / h).

If one of the blocks fails, the node continues to function, but the load factor of the second element will increase, as a result of which the failure rate increases to the value

(2) (1) ten 5 1 2
(1 / h).

It is required to calculate the probability of failure-free operation of the link under these conditions for the time t= 44,000 h.

Option	λ1	λ2	t	
1	0.37 * 10-5	0.16 * 10-5	50,000	
2	0.4 * 10-5	0.17 * 10-5	55,000	
3	0.35 * 10-5	0.18 * 10-5	37,000	
4	0.5 * 10-5	0.11 * 10-5	44,000	
5	0.45 * 10-5	0.15 * 10-5	48,000	
6	0.39 * 10-5	0.13 * 10-5	36,000	
7	0.37 * 10-5	0.2 * 10-5	50,000	

Solution:

From the total number of node states, we select the following three favorable hypotheses:

1 both elements are in good working order (H0),

2 the first element (H1) failed,

3 the second element (H2) failed.

The rest of the states, when both elements failed in a different sequence, correspond to unfavorable hypotheses (node failure).

1 Probability of the first state

R(H   e (1 2   5
)   )t   (0.32 * 10 5 0.18) * 44000 e
0   e   0.22 0.7125

2 Probability of the second state

R(H
1) e
(1)
2t
0.32 * 10 5 e 0.44 e
1 0.22 /
= -1.45 * 0.6440 0.7125 =
0.0996

3 Probability of the third state

e
R(H (1) e (1 2 2 0.18 * 10 5e 0.44 e
) t)t / (1 (2) 1) 0.22/ 0.22 * 10 5
1 2
=- 0.82 * 0.6440 0.7125 = 0.056,

Probability of node uptime

3
P1 (t) = R(Hi) = 0.7125 + 0.0996 + 0.056 = 0.868,
1

Answer:

The probability of failure-free operation under these conditions is 0.868

Practical work No. 7

Calculation of a node from redundant elements

Reservation - a method of increasing the reliability of an object by introducing redundancy.

Redundancy - additional funds and opportunities beyond the minimum

necessary for the object to perform the specified functions.

Redundancy:

1) the presence of redundant elements object structure;

2) use of additional time over the minimum;

3) the use of additional information;

4) the ability of elements to perform additional functions, except

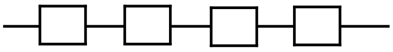
directly installed;

5) the ability of the elements to carry out additional loads.

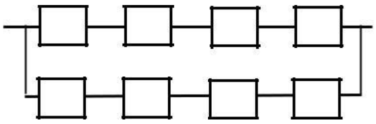
Reservation - one of the ways to maintain the level of equipment reliability.

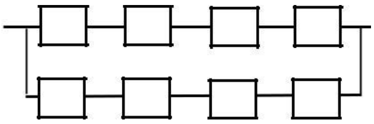
Reliability indicators depend on the scheme and methods of redundancy. There is a concept of "state" of the system, which is characterized by the performance of one of the elements and the entire system as a whole. The system states are described using graphs of transitions from one state to another. On the basis of the transition graphs, systems of differential equations are compiled, the solution of which makes it possible to determine the probability of failure-free operation of the machine with various options for the layout and redundancy of the object's elements.

a



b v





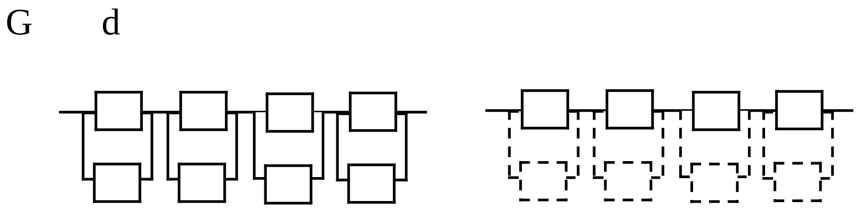


Figure 7.1. Structural diagrams of various types of redundancy:a - no redundancy; b - general permanent redundancy; v - general reservation by replacement; G - separate permanent reservation of each element; d - separate reservation by replacing each element

There is a non-redundant system of five blocks. The probability of block failure and their weights will be as follows: q1 = 0.51; q2 = 0.33; q3 = 0.20; q4 = 0.37; q5 = 0.24.

G1 = 4; G2 = 1; G3 = 1; G4 = 5; G5 = 1.

It is required to reserve the system so that its weight does not exceed Gperm. = 60 kg, and the probability

uptime would be maximized.

Var.	q1 ■	q2	q3	q4	q5	G1 ■	G2	G3	G4	G5
1	0.67	0.5	0.3	0.35	0.25	3	4	1	3	1
2	0.7	0.6	0.37	0.45	0.34	5	3	2	3	2
3	0.61	0.4	0.43	0.55	0.23	3	5	2	3	4
4	0.54	0.57	0.23	0.5	0.32	2	5	3	1	1
5	0.46	0.47	0.34	0.53	0.4	3	2	5	3	1
6	0.45	0.43	0.35	0.47	0.3	1	2	3	3	1
7	0.38	0.34	0.28	0.39	0.35	3	1	1	3	1
eight	0.5	0.44	0.35	0.54	0.42	2	3	5	3	3
nine	0.6	0.54	0.26	0.45	0.25	3	3	1	3	5

Solution
The problem will be solved in this way
1 By the formula:

Gg____
ln 1 __

aj =   qg ,

define for each block:

4   _____
ln 1 ___

a1 = 0.51 = 5.94;

1   _____
ln 1 ___

a2 = 0.33 = 0.902;

1   ____
ln 1   __

a3 = 0.2 = 0.621;

5   _____
ln 1 ___

a4 = 0.37 = 5.029;

1   _____
ln 1 ___

a5 = 0.24 = 0.701.

2 we find y0 - the root of the equation

a j ln a
a j ln (a j y0) Gadd j
y 1 1 ;
5.94 ln (y0 5.94) 0.902) 0.621 ln (y0 0.621) 5.029ln (
0.902 ln (y0 y0 5.029)
60 5.94ln 5.94 60 0.902ln 0.902 60 0.621ln
0.701 ln (y0 0.7012) 0.621

60 5.029ln 5.029 60 0.701ln 0.701

This is a tedious task, so you can use the following trick:

y(1) exp   B
0   ——

J 1 a j ,

a j lg a j

where B = Gdop + j 1   ,

Calculation gives the value B =

60 + 18.69 = 78.69

78.69

y0 exp 13.19 =389.29,

This approximation can be refined using, for example, Newton's method:

a j ln (y(1)0 a
j)   B
y(2) (1)
y0   1   j
0   0)
a j / (a j
y(1)
j 1   = 389.29 - 1 =
388.29
y (2)   y(1)   y (2)
We get   0 = 388.29 linear interpolation of values 0 and   0
Gives   y (3)
root   0 = 387.29

We calculatesj0,

s0j (ln 1 / q j) 1 y0 a j
* ln
a j

	s0 j	a	b	v
s1	6.23	6	6	7
s2	5.47	6	5	5
s3	4,00	4	4	4
s4	4.38	4	4	5
s5	4.43	4	5	4
Gtotal, kg	60.71	58	58	66
	G (s0 s*j j j j 1)	16.71	2.71	- 5.29

s*
which can have any meaning. But you need valuesj which give the maximum

functions Pp (s) and satisfy the condition

GJ s*JGP
j 1 ;
We calculate the generalized weight according to this formula, see the table. We accept integer values, see table

We find j G j(s0j s *j)
1 0;
Gj (s0j s *j)

and j 1= min

The best approximation is obtained in option "b". According to the formula
PP (1 q s j j)
,
j 1

we determine the probability of failure-free operation of the redundant system Pp = 0.957
For comparison, for fractional sj, we calculate

Pmax = 0.967

Answer:

Probability of failure-free operation of the redundant system Pp = 0.957
In the chosen conditions, we got the maximum probability of failure-free operation.

Practical work No. 8

Exercise

According to the structural diagram of the reliability of the technical system in accordance with the option of the task, the required value of the probability of failure-free operation of the system and values

the failure rates of its elements i required:

Construct a graph of the change in the probability of failure-free operation of the system from the operating time in the range of decreasing the probability to the level of 0.1 - 0.2.

2. Determine - percentage of the operating time of the technical system.

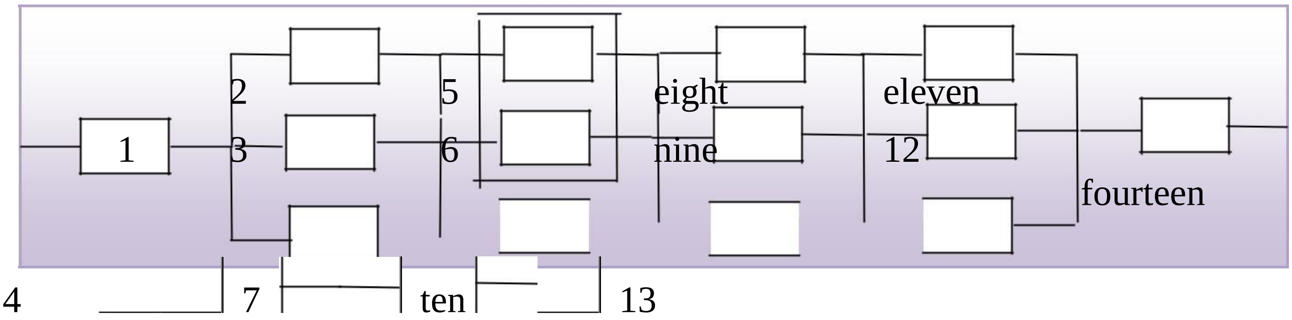
3. Provide an increase - percentage operating time not less than in 1.5 times due to:

increasing the reliability of elements;

structural redundancy of system elements.

All elements of the system operate in normal operation mode (the simplest flow of failures). Redundancy of individual elements or groups of elements is carried out by redundant elements or groups of elements identical in reliability. Redundant switches are considered ideal.

In the diagrams, elements circled by a dotted line are functionally necessary from n parallel branches.



No. var ...	, % 1	The failure rate of the elements, ten 6 h 1													
		2 3 4 5	6 7 8							nine	ten	el ev en	12	13	fou rtee n
3	60	0.03	0.5 0.2 1.0									0.03 .	.		0.1

Calculated part

We begin the calculation by simplifying the original scheme.

Elements 2-4 are connected in parallel. Replace items 2-4 with item A.

By condition, the failure rates of elements 2-4 are equal. Therefore, the probability of failure-free operation of element A is determined by the formula:

$p_A \quad (p_2 \quad 1)^3 \quad 1$

Items 5-7 form a 2 of 3 connection. The failure rate of these elements is. Therefore, to determine the probability of no-failure operation, you can use the combinatorial method:

2
3 3 5 k 3! 5 3! 3 2 5 5 3
pB C k pk 3 3p5 (1 p5 p2
pk 5 (1 p) 3 2! p52 (1 p) 3! p5) p5 3p ...
k 2 k 2 1! 0!

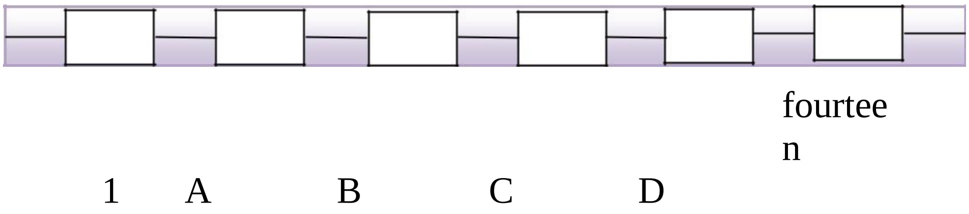
Elements 8-10 are connected in parallel. We replace elements 8-10 with element C. The failure rates of elements 8-10 are equal, therefore, the probability of failure-free operation of element C is determined by the formula:

pC (peight 1)3 1

Elements 11-13 are also connected in parallel. We replace elements 11-13 with element D. The failure rates of elements 11-13 are also equal, therefore, the probability of failure-free operation of element D is determined by the formula:

pD (peleven 1)3 1

After replacing the elements, the structural diagram of the system will take the form:



Elements 1, A, B, C, D and 14 are connected in series, therefore, the probability of failure-free operation of the entire system is determined by the formula:

P p1 pA pB pC pD pfourteen

According to calculations in Microsoft Excel and raw data, the least reliable elements are 8-10.

The operating time must be increased with r = 0.9298 * 106 h. up to 1.3947 * 10 6 h. Improving the reliability of the system can be done in two ways:
Replacement of unreliable elements with more reliable ones.

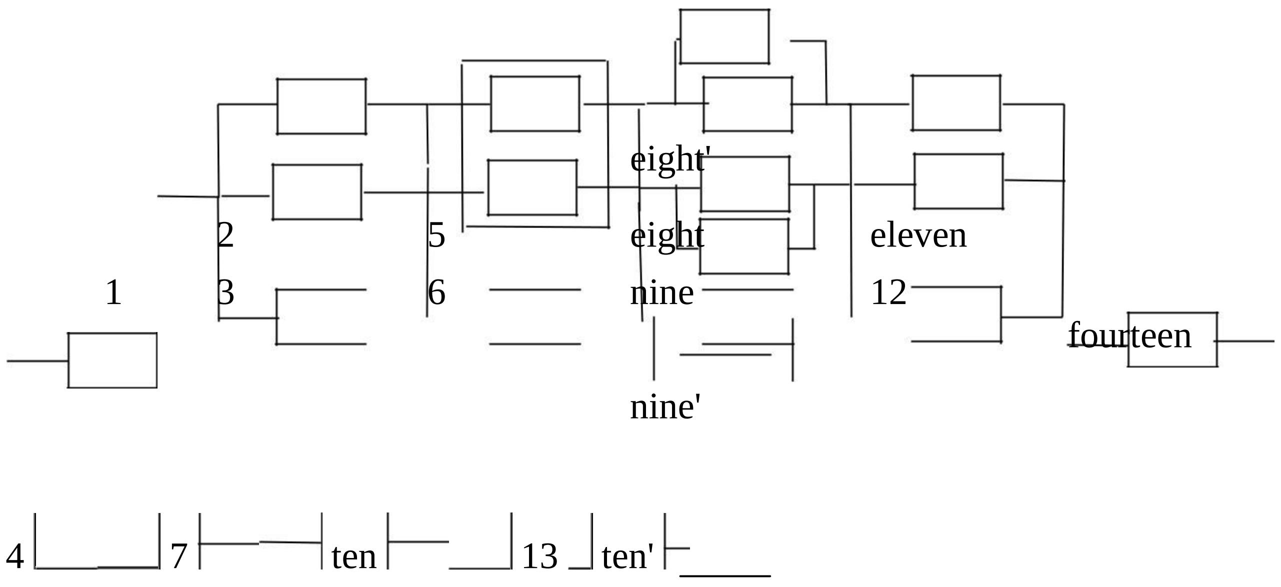
Structural redundancy of elements.

The first way

Replace elements 8-10 that have i =1 * 10-6 1 / h, for elements with i =0.5 * 10-6 1 / h The new values are calculated in Excel.

In this case, the probability of system uptime will increase from 0.356271899 to 0.541566249. Second way

We use the always-on reserve. We connect additional elements in parallel:



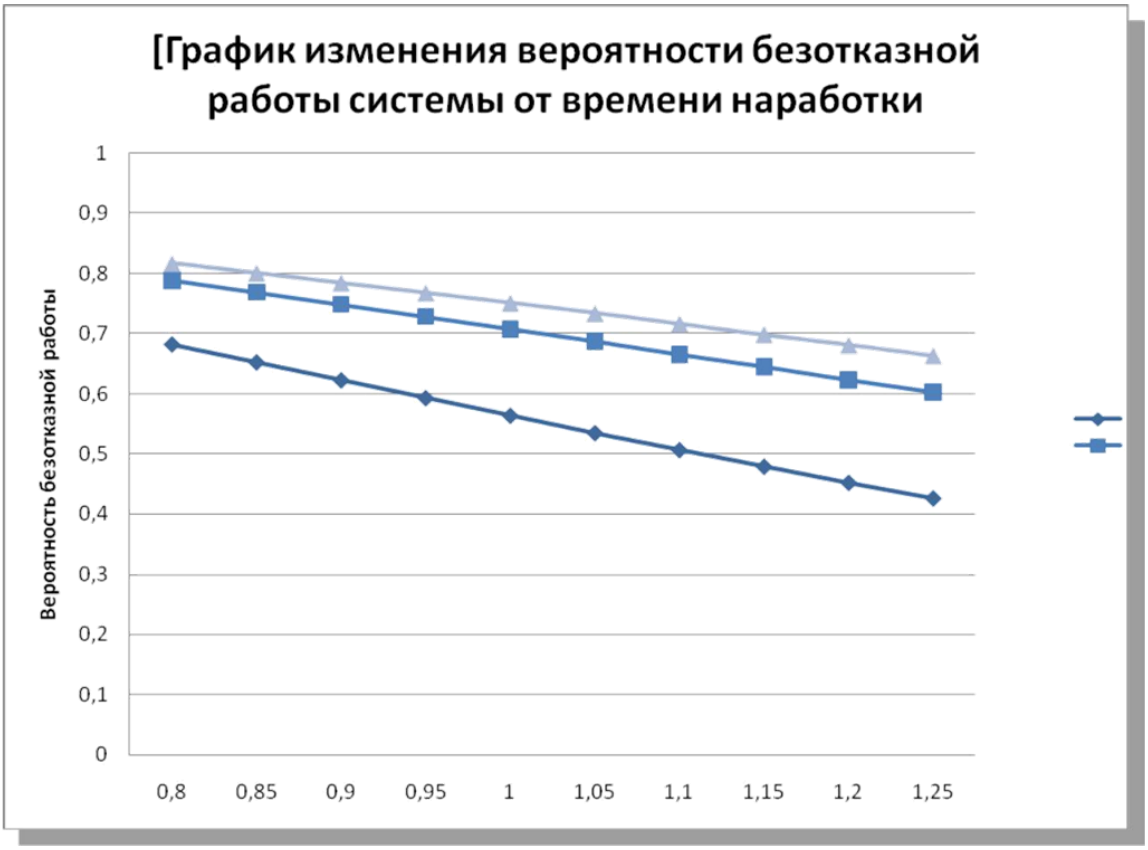
This increases the likelihood of failure-free operation of the quasi-element C. The new values are calculated in Excel.

In this case, the probability of system uptime will increase from 0.356271899 to 0.610117356.

Calculation of the probability of system uptime

		Running time											
Element	**ten $_{6}$ *h* $_{1}$**	**0.8**	**0.85**	**0.9**	**0.95**	**1**	**1.05**	**1.1**	**1.15**	**1,2**	**1.25**	**0.9298**	**1.3947**
1	**0.03**	**0.97628571**	**0.974822379**	**0.973361242**	**0.971902294**	**0.970445534**	**0.96899096**	**0.96753856**	**0.96608834**	**0.964640293**	**0.96319442**	**0.972491445**	**0.959022253**
2-4	**0.5**	**0.670320046**	**0.653769785**	**0.637628152**	**0.621885056**	**0.60653066**	**0.59155536**	**0.57694981**	**0.562704869**	**0.548811636**	**0.53526143**	**0.628197922**	**0.497903**
4-7	**0.2**	**0.852143789**	**0.843664817**	**0.835270211**	**0.826959134**	**0.818730753**	**0.81058425**	**0.8025188**	**0.794533603**	**0.786627861**	**0.77880078**	**0.830306807**	**0.756585297**
8-10	**1**	**0.449328964**	**0.427414932**	**0.40656966**	**0.386741023**	**0.367879441**	**0.34993775**	**0.33287108**	**0.316636769**	**0.301194212**	**0.2865048**	**0.394632629**	**0.247907397**
11-13	**0.03**	**0.97628571**	**0.974822379**	**0.973361242**	**0.971902294**	**0.970445534**	**0.96899096**	**0.96753856**	**0.96608834**	**0.964640293**	**0.96319442**	**0.972491445**	**0.959022253**
fourteen	**0.1**	**0.923116346**	**0.918512284**	**0.913931185**	**0.909372934**	**0.904837418**	**0.90032452**	**0.89583414**	**0.891366144**	**0.886920437**	**0.8824969**	**0.911211724**	**0.869819117**
A	**-**	**0.964167458**	**0.958495528**	**0.952415736**	**0.945940562**	**0.939083816**	**0.9318604**	**0.92428609**	**0.91637735**	**0.908151161**	**0.89962486**	**0.948603276**	**0.873420645**
B	**-**	**0.940880328**	**0.934319811**	**0.927532473**	**0.92053335**	**0.913336866**	**0.90595686**	**0.89840659**	**0.890698798**	**0.882845663**	**0.87485887**	**0.923385556**	**0.851092839**
C	**-**	**0.833015292**	**0.81227589**	**0.791017827**	**0.769361534**	**0.747419542**	**0.72529609**	**0.70308694**	**0.680879413**	**0.658752498**	**0.63677714**	**0.778151229**	**0.574583871**
D	**-**	**0.99998666**	**0.99998404**	**0.999981097**	**0.999977817**	**0.999974185**	**0.99997018**	**0.99996579**	**0.999961002**	**0.999955789**	**0.99995014**	**0.999979184**	**0.999931191**
P	**-**	**0.681031834**	**0.651317488**	**0.621614724**	**0.592091521**	**0.562898769**	**0.53417008**	**0.50602202**	**0.478554554**	**0.451851851**	**0.42598314**	**0.60**	**0.356271899**
Improving reliability by replacing the most unreliable components													
		0.8	**0.85**	**0.9**	**0.95**	**1**	**1.05**	**1.1**	**1.15**	**1,2**	**1.25**	**0.9298**	**1.3947**
1	**0.03**	**0.97628571**	**0.974822379**	**0.973361242**	**0.971902294**	**0.970445534**	**0.96899096**	**0.96753856**	**0.96608834**	**0.964640293**	**0.96319442**	**0.972491445**	**0.959022253**
2-4	**0.5**	**0.670320046**	**0.653769785**	**0.637628152**	**0.621885056**	**0.60653066**	**0.59155536**	**0.57694981**	**0.562704869**	**0.548811636**	**0.53526143**	**0.628197922**	**0.497903**
4-7	**0.2**	**0.852143789**	**0.843664817**	**0.835270211**	**0.826959134**	**0.818730753**	**0.81058425**	**0.8025188**	**0.794533603**	**0.786627861**	**0.77880078**	**0.830306807**	**0.756585297**
8-10	**0.5**	**0.670320046**	**0.653769785**	**0.637628152**	**0.621885056**	**0.60653066**	**0.59155536**	**0.57694981**	**0.562704869**	**0.548811636**	**0.53526143**	**0.628197922**	**0.497903**
11-13	**0.03**	**0.97628571**	**0.974822379**	**0.973361242**	**0.971902294**	**0.970445534**	**0.96899096**	**0.96753856**	**0.96608834**	**0.964640293**	**0.96319442**	**0.972491445**	**0.959022253**
fourteen	**0.1**	**0.923116346**	**0.918512284**	**0.913931185**	**0.909372934**	**0.904837418**	**0.90032452**	**0.89583414**	**0.891366144**	**0.886920437**	**0.8824969**	**0.911211724**	**0.869819117**
A '		**0.964167458**	**0.958495528**	**0.952415736**	**0.945940562**	**0.939083816**	**0.9318604**	**0.92428609**	**0.91637735**	**0.908151161**	**0.89962486**	**0.948603276**	**0.873420645**
B '		**0.940880328**	**0.934319811**	**0.927532473**	**0.92053335**	**0.913336866**	**0.90595686**	**0.89840659**	**0.890698798**	**0.882845663**	**0.87485887**	**0.923385556**	**0.851092839**
C '		**0.964167458**	**0.958495528**	**0.952415736**	**0.945940562**	**0.939083816**	**0.9318604**	**0.92428609**	**0.91637735**	**0.908151161**	**0.89962486**	**0.948603276**	**0.873420645**

D '		0.999986664	0.99998404	0.999981097	0.999977817	0.999974185	0.99997018	0.99996579	0.999961002	0.999955789	0.99995014	0.999979184	0.999931191
P '		0.788255317	0.768562636	0.748447917	0.72798465	0.707245521	0.68630171	0.6652223	0.644073746	0.622919509	0.60181969	0.73628909	0.541566249
Improving reliability through structural redundancy													
		0.8	**0.85**	**0.9**	**0.95**	**1**	**1.05**	**1.1**	**1.15**	**1,2**	**1.25**	0.9298	**1.3947**
1	**0.03**	0.97628571	0.974822379	0.973361242	0.971902294	0.970445534	0.96899096	0.96753856	0.96608834	0.964640293	0.96319442	0.972491445	0.959022253
2-4	**0.5**	0.670320046	0.653769785	0.637628152	0.621885056	0.60653066	0.59155536	0.57694981	0.562704869	0.548811636	0.53526143	0.628197922	0.497903
4-7	**0.2**	0.852143789	0.843664817	0.835270211	0.826959134	0.818730753	0.81058425	0.8025188	0.794533603	0.786627861	0.77880078	0.830306807	0.756585297
8-10	**0.5**	0.670320046	0.653769785	0.637628152	0.621885056	0.60653066	0.59155536	0.57694981	0.562704869	0.548811636	0.53526143	0.628197922	0.497903
11-13	**0.03**	0.97628571	0.974822379	0.973361242	0.971902294	0.970445534	0.96899096	0.96753856	0.96608834	0.964640293	0.96319442	0.972491445	0.959022253
fourteen	**0.1**	0.923116346	0.918512284	0.913931185	0.909372934	0.904837418	0.90032452	0.89583414	0.891366144	0.886920437	0.8824969	0.911211724	0.869819117
A "		0.964167458	0.958495528	0.952415736	0.945940562	0.939083816	0.9318604	0.92428609	0.91637735	0.908151161	0.89962486	0.948603276	0.873420645
B "		0.940880328	0.934319811	0.927532473	0.92053335	0.913336866	0.90595686	0.89840659	0.890698798	0.882845663	0.87485887	0.923385556	0.851092839
C "		0.998716029	0.998277379	0.997735738	0.997077577	0.996289218	0.99535699	0.9942674	0.993007252	0.991563791	0.98992483	0.997358377	0.983977667
D "		0.999986664	0.99998404	0.999981097	0.999977817	0.999974185	0.99997018	0.99996579	0.999961002	0.999955789	0.99995014	0.999979184	0.999931191
P "		0.816500509	0.800461423	0.78406226	0.767339091	0.750328219	0.73306604	0.71558888	0.6979329	0.680133943	0.66222742	0.774131937	0.610117356



Output: After plotting the graphs, it can be seen that replacing elements is more efficient for improving reliability. Especially if the system needs to be used for a long period of time.

Practical work No. 9

Determination of reliability indicators of a complex system

Exercise... For the connection diagram of the system elements shown in Figure 9.1,

using the analytical method and the method of statistical modeling, determine the probability of failure-free operation as a function of time on the interval [0, 3To]. Mean time between failure-free operation of the system To be calculated by the method of statistical modeling. Reliability law
elements - exponential. Analyze the results obtained by comparing the corresponding values of the probabilities calculated by the analytical method and by the method of

statistical modeling. Explain the reasons for possible differences in results.

Failure rates of elements:

1 = 10-6 1 / h,

2 = 10-7 1 / h,

3 = 5 10-6 1 / h,

4 = 3 10-6 1 / h,

5 = 3 10-7 1 / h,

6 = 2 10-eight 1 / h,

7 = 10-7 1 / h

Initial data: ((1 2) (3 4)) (5 6 7)

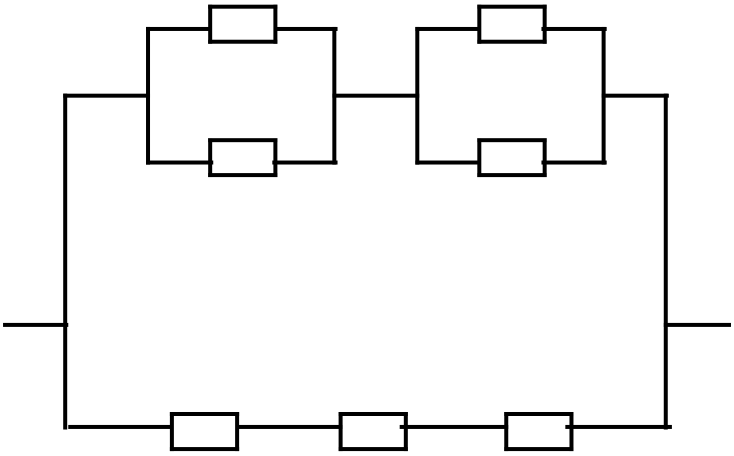


Figure 9.1 is an initial connection diagram of the elements.

To determine the reliability indicators of systems using the analytical and statistical method, we will use the MathCAD 14 package.
Let's make a calculation using the analytical method:

Enter the failure rate: lia1: = 1

* 10-6 1 / h

lia2: = 1 * 10-7 1 / h

lia3: = 5 * 10-6 1 / h

lia4: = 3 * 10-6 1 / h

lia5: = 3 * 10-7 1 / h

lia6: = 2 * 10-eight 1 / h

lia7: = 1 * 10-7 1 / h

Time:

t: = 0.50..20000000

Probabilities of no-failure operation of elements:

P1
(t) e lia1 t
P2 lia2 t
(t) e
P3 lia3 t
(t) e
P4 lia4 t
(t) e
P5 lia5 t
(t) e
P6 lia6 t
(t) e
P7 lia7 t
(t) e

Let us calculate the probability of failure-free operation of the system, which, with series connected elements, is calculated by the formula:

n

Pc(t)   Pi (t)

1

And when connected in parallel:

Pc(t) 1   [1n Pi (t)]

1

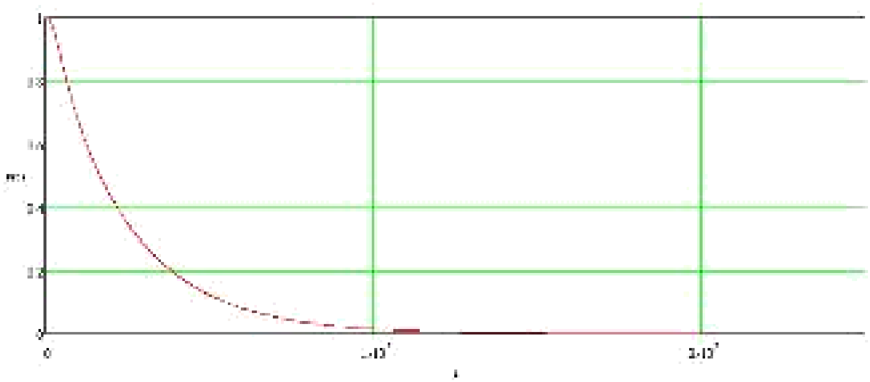
As a result, we obtain the probability of a failure-free system for a given system; probability statistical failure-free modeling P12 (t): = P1 (t) + P2 (t) -P1 (t) · P2 (t) P34 (t): = P3 (t) + P4 (t) -P3 (t) · P4 (t)

P1234 (t): = P12 (t) · P34 (t)

P567 (t): = P5 (t) · P6 (t) · P7 (t) P (t): = P1234 (t) +

P567 (t) -P1234 (t) · P567 (t)

Let's build a graph P (t):



Let's make a calculation using the statistical method:

Since the distribution law is exponential, the random uptime for each of the elements is calculated by the formula:

j ,i   ln (x) / j

The X value is a random variable evenly distributed in the range from 0 to 1.

1 ln rnd 1
tau1i lia1

1 ln rnd 1

tau2i lia2

1 ln rnd 1

tau3i lia3

1 ln rnd 1

tau4i lia4

1 ln rnd 1
tau5i lia5

1 ln rnd 1

tau6i lia6

1 ln rnd 1

tau7i lia7

Let's calculate the operating time of the object:

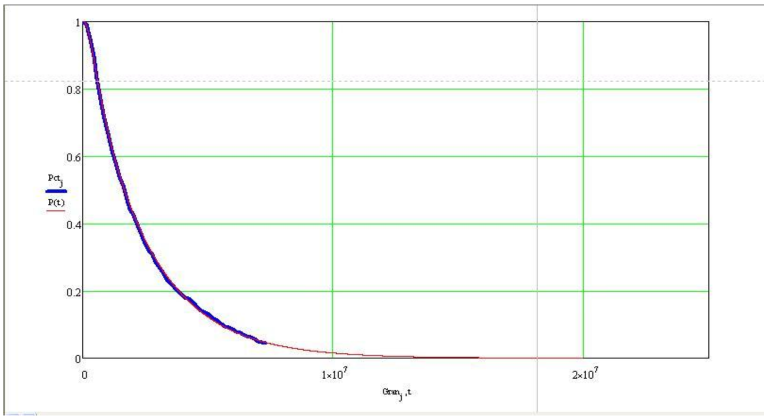
when connecting elements in series: tpos min (1, 2 , 3, ... n)
with parallel:

tsteam max (1, 2 , 3, ... n)

As a result, we get: tautci: = max [min (max (tau1i, tau2i), max (tau3i, tau4i))), min (tau5i, tau6i, tau7i)]

Let's calculate the average system uptime: mean (tautc) = 2.431x106
Tcc: = mean (tautc) · 3

Tcc= 7.293x106



kor: = 50

j: = 0..kor

Tcc

shag: = kor

Granj: = 0 + j · shag

Gran50: = 7.293x106

H0ti, j: = if (tautci Granj, 1.0)

N

0ti , j

0 _______

Pctj: = N 1

Let's build a graph of dependences of the probabilities of no-failure operation, calculated by analytical and statistical methods:
The differences in the probabilities calculated by the analytical and statistical methods are explained by the following: analytical methods give the best results (more accurate), since they allow analyzing the reliability characteristics in a wide range of parameters and in any time intervals. They make it possible to trace the tendencies of changes in the main characteristics of reliability when changing the characteristics of systems. Statistical modeling methods allow the analysis of complex reliability models, although they are not very general. It can be seen from this graph that the probabilities obtained with the analytical method are the most accurate in comparison with the probabilities obtained with the statistical method.

Practical work No. 10

Determination of reliability indicators of non-recoverable elements

Test set N0 = 1600 samples of non-repairable equipment number of failures

n(t) was recorded every 100 hours of operation. It is required to calculate the quantitative characteristics of the reliability of non-recoverable reliability and to plot the dependence of the characteristics on time.

Solution

1. Let's calculate the probability of failure-free operation R*(t), which is evaluated by the expression:

n(t
R*(tN 0)
) ______
N 0 ,

where N 0 - the number of products at the beginning of the test;

n(t) is the number of failed products during t ...

R 1600 55
*(100) 0.966
1600
R 1600 55 50
*(200) 0.934
1600

2. Calculate the failure rate f *(t):

n(t
f *(t))i
N0 t ,
where n(t) is the number of failed products in the time t t t t
interval from 2 to 2.
3
* 55 1
f (50) ______ 0, 344 _

1600 ten
100 h
* 50 1

f 1600 0, 313
(150) 100 ten 3 h

3. Let's calculate the failure rate *(t):
n(t)
*(t) i
Nci t
,
where Nci - the average number of serviceable working products in the interval ti ...

55 1
*(50) 0.350 ten 3
1600 1545 h
100
2

50 1
*(150) 0.329 ten 3
1545 1495 h
100
2

Calculate the probability of failures q * (t): q *

(t) = 1-p * (t)

q * (100) = 1- p * (100) = 1-0.966 = 0.034

q * (200) = 1- p * (200) = 1-0.934 = 0.066

5. Let's calculate the average uptime using the expression below, since

tests were terminated before failure of all elements:

0 tcp i n(ti) tr N0 n(tr)

T * i 1
Wed
N0
,

where t r - time of the end of tests;

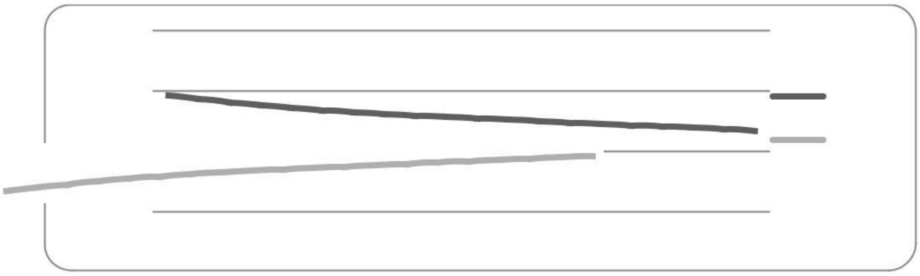
n(tr) is the number of elements that failed during tr ...

$$T\ We d^* \frac{50\ 55\ 150\ 50\ \ \dots\ 2000\ (1600\ 525)}{1600} 1598,\ 469h$$

Calculation results

*
(t), f *(t) , R*(t) ,q (t) is entered into the table

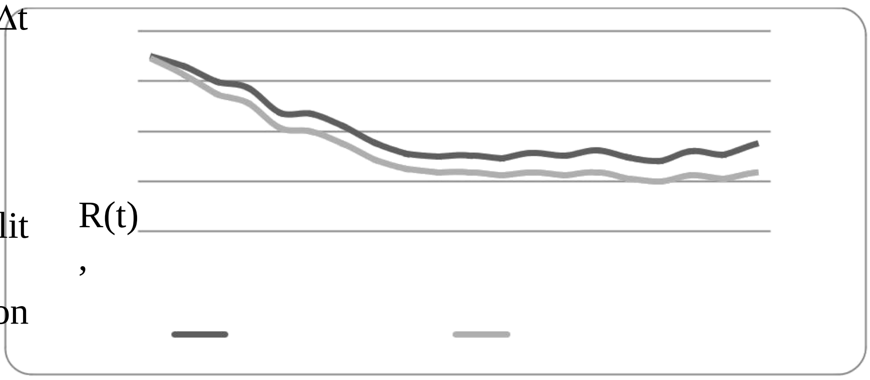
Δti	n (Δti)	P * (t)	q * (t)	N (cpi)	l * (ti) * 10 (-3), 1 / h	f * (ti) * 10 ^ (-3), 1 / h
0-100	55	0.966	0.034	1572.5	0.350	0.344
100-200	50	0.934	0.066	1520.0	0.329	0.313
200-300	44	0.907	0.093	1473.0	0.299	0.275
300-400	41	0.881	0.119	1430.5	0.287	0.256
400-500	33	0.861	0.139	1393.5	0.237	0.206
500-600	32	0.841	0.159	1361.0	0.235	0.200
600-700	28	0.823	0.177	1331.0	0.210	0.175
700-800	23	0.809	0.191	1305.5	0.176	0.144
800-900	twenty	0.796	0.204	1284.0	0.156	0.125
900-1000	19	0.784	0.216	1264.5	0.150	0.119
1000-1100	19	0.773	0.228	1245.5	0.153	0.119
1100-1200	eighteen	0.761	0.239	1227.0	0.147	0.113
1200-1300	19	0.749	0.251	1208.5	0.157	0.119
1300-1400	eighteen	0.738	0.262	1190.0	0.151	0.113
1400-1500	19	0.726	0.274	1171.5	0.162	0.119
1500-1600	17	0.716	0.284	1153.5	0.147	0.106
1600-1700	16	0.706	0.294	1137.0	0.141	0.100
1700-1800	eighteen	0.694	0.306	1120.0	0.161	0.113
1800-1900	17	0.684	0.316	1102.5	0.154	0.106
1900-2000	19	0.672	0.328	1084.5	0.175	0.119



p *, q *

P * (t)

q * (t)



λ *, f *

Δt

λ * (ti) * 10 (-3), 1 / h   f * (ti) * 10̃(-3), 1 / h

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Practical work No. 11

Determination of quantitative characteristics of the reliability of a complex system

As a result of the analysis of data on system failures, the failure rate was determined
P(t) 2 e t e 2 t , 1,2 ten 6 ,1/ h... It is required to determine all quantitative
characteristics
(t), T , f (t), fWed(t). Build graphsR(t) (t), f (t), fWed(t).

Wed

Let's calculate the mean time to first failure:

TWe 2e t e 2 1, 25
d P ()t dt tdt 2 1 3 3 ten6h
0 0 2 2 2 12 ten 6

Determine the failure rate:

f t P ' t

ft 2 e t 2 e 2 t
2, 4 ten 6 e 2, 4 ten 6 e
ft 1,2 ten 6 t 2.4 ten 6 t
f 2, 4 ten
ten 2, 4 ten e 2, 4 ten e (0.887 0.787) 0, 241 ten
1.2
10 6
5 6 ten5 6 .4 10 6 5 6 6 1
h
6 1
2 ten5 2, 4 1,2 ten 6 2 ten5 2, 4 ten 6 e 2.4 ten0, 619) 0, 403 ▮
ften 6 e 6 2 ten5 2, 4 ten 6 (0, 787 ten
h

Let's define the dependence of the failure rate on time:

ft
t
Pt
2 e
2 e t t 2 e 2 t
2e e 2
t t t 2e t e 2 t
12 ten 12 ten 6 e
t 6 2.4 ten 6 t

e 2.4
2e 1,2 ten 6
ten 6 t t
12 ten 2.4 ten 12 ten
5 6 6 e 6 ten5 6 6 0.787
ten 12 2e 1,2 ten e 2.4 ten12 2 0, 244
ten 6 ten5 6 ten5 ten 0.887 0.787 ten 6 1h
6 e 2.4
ten 6 2 12 ten 60,
5 —— 12 ten ten5 619 2 6 1
2 ten 12 ten 5 12 0, 422 _
6 ———— 6 ~~5 6~~ ten6 ten
e 2.4
~~2e 1,2 1~~0 2 0.787
ten 2 ten 10 0.619 h

~~Let us define th~~e depend~~ence of the p~~arameter fñð t from

4. of the flow of failures time:

f (t)e ~~2 e t 2 e 2 t e stdt~~ 2 e (s)t ~~e (2 s)t~~
f s stdt dt
0 0 0

2 —— 2 —— 2 2 ————
s 2 s s 2 s

f s —— 2 2 ——
fs
We
d

1 f s s s 3

To find the original

Wed t f find the inverse Laplace transform of the function

fWe fWe
d t L 1 d s

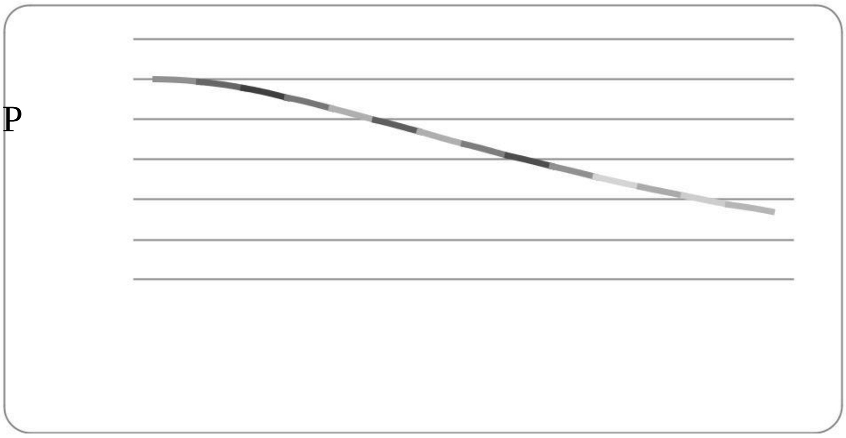
f t 2 2 e 3 t
—
Wed
3 3
2 12 10 3 6 2 12 e 3 1,2 ten 6 t 0.8
ten 6 0.8e 3.6 ten 6 t
fWedt
3

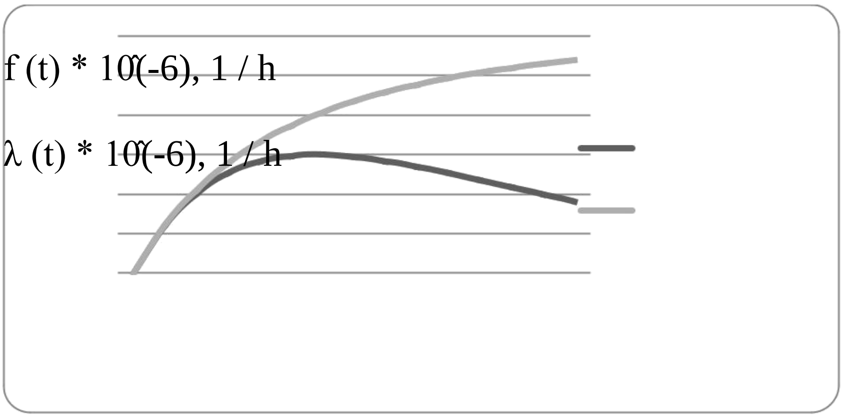
1
fWedte 0.8e 3.6 ten 6 ten5 0.8 0.8 0, 698█
n5 0.8 0, 242
h
fWed2 0.8 0.8e 3.6 ten 60.8 0.8 0, 489 1

ten5 2 ten5 0.411 [redacted]

h

t	P (t)	f (t) * 10 ^ (- 6),1 / h	l (t) * 10 ^ (- 6),1 / h	fcp (t) * 10 ^ (- 6), 1 / h
0	1,000	0	0	0
100,000	0.987	0.241	0.244	0.242
200,000	0.954	0.403	0.422	0.411
300,000	0.909	0.506	0.557	0.528
400,000	0.855	0.566	0.662	0.610
500,000	0.796	0.594	0.746	0.668
600,000	0.737	0.600	0.814	0.708
700,000	0.677	0.589	0.870	0.736
800000	0.619	0.567	0.916	0.755
900000	0.564	0.538	0.955	0.769
1,000,000	0.512	0.505	0.987	0.778
1,100,000	0.463	0.470	1.015	0.785
1,200,000	0.418	0.434	1.039	0.789
1,300,000	0.376	0.398	1.059	0.793
1,400,000	0.338	0.364	1.077	0.795





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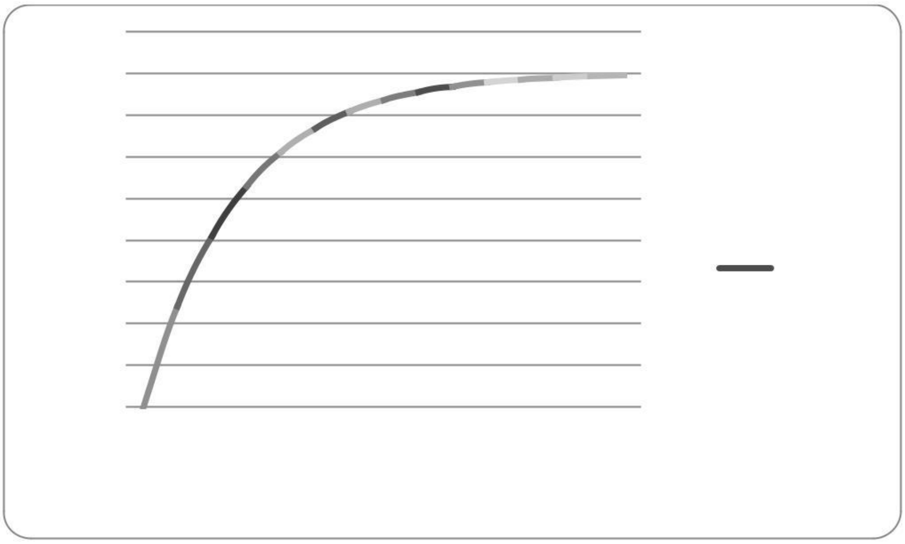

Practical work number 12

Calculation of the probability of no-failure operation of elements

As a result of the operation of N = 1600 recoverable products, the following statistics on failures were obtained, presented in the table. Number of refusalsn(ti) recorded through t i hours. It is necessary to determine:

is the mean time to the first failure of the product TWed;

- the probability of failure-free operation P (t);

is the average failure rate (parameter of the failure flow) fWed(t);

failure rate f (t);

failure rate l (t).

Solution

1. Let's calculate the probability of failure-free operation R(t), which is evaluated by the expression:

$$R(t)\ \frac{N\ 0\ n(t)}{N\ 0},$$

where N 0 - the number of products at the beginning of the test;

n(t) is the number of failed products during t

$$R(200)\ \frac{1600\ 59}{1600}\ 0.963$$

$$R(400)\ \frac{1600\ 59\ 53}{1600}\ 0.930$$

2. Calculate the average failure rate fcp (t) :

$$fcp\ (t)\ \frac{n(\ t\ )i}{N0\ \ t},$$

where n(t) is the number of failed products in the time interval from t $\frac{t}{2}$ to t $\frac{t}{2}$

f 59 0.184 ten 1
(100) 3
cp
1600 200 h
f 53 0.166 ten 1
(300) 3
cp
~~1600 200~~ h

3. Let's calculate the failure rate (t):

n(t
)i
(t) Nc
i t
,

where Nci - the average number of serviceable working products in the interval ti ... reliability element

trigger system

*(100 59 1
) 0.188 ten 3
1600 1541 h
200
2
*(300 53 1
) 0.175 ten 3
1541 1488 h
200
2

Let's calculate the mean time of failure-free operation according to the expression below, since the tests were stopped before the failure of all elements:

0

tcp i n(ti) tr N0 n(tr)

TWe i 1

d

N0

,

where t r - time of the end of tests;

n(tr) is the number of elements that failed during tr ...

4000 (1600

100 59   300 53 ... 668)

TWe

d   3038, 625h

1600

(t) fcp (t) R(t) we enter into the

Calculation results   table

Δti, h	n (Δti)	P (t)	fcp (t) * 10 ^ (̂-3), 1 / h	l (t) * 10 ^ (̂-3), 1 / h	N (cpi)
0-200	59	0.963	0.184	0.188	1570.5
200-400	53	0.930	0.166	0.175	1514.5
400-600	48	0.900	0.150	0.164	1464
600-800	44	0.873	0.138	0.155	1418
800-1000	40	0.848	0.125	0.145	1376
1000-1200	37	0.824	0.116	0.138	1337.5
1200-1400	34	0.803	0.106	0.131	1302
1400-1600	32	0.783	0.100	0.126	1269
1600-1800	thirty	0.764	0.094	0.121	1238
1800-2000	28	0.747	0.088	0.116	1209
2000-2200	28	0.729	0.088	0.119	1181
2200-2400	27	0.713	0.084	0.117	1153.5
2400-2600	27	0.696	0.084	0.120	1126.5
2800-3000	26	0.663	0.081	0.121	1073
3000-3200	26	0.646	0.081	0.124	1047
3200-3400	26	0.630	0.081	0.127	1021
3400-3600	26	0.614	0.081	0.131	995
3600-3800	25	0.598	0.078	0.129	969.5
3800-4000	25	0.583	0.078	0.132	944.5

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EDUCATION
National University of Science and Technology
"MISIS" in Almalyk

GLOSSARY

by discipline:
"RELIABILITY OF MINING MACHINES"

Glossary

Reliability - the property of an object to perform specified functions, keeping in time the values of the established performance indicators within the specified limits, corresponding to the specified modes and conditions of use of the facility, repair, storage and transportation.

Reliability includes:

reliability;

durability;

maintainability;

preservation...

Reliability - property of the object to continuously maintain operability for some time or some work.

Durability - the property of the object to remain operational until the onset limiting state with the installed system of maintenance (MOT) and repair.

Maintainability - property of an object, which consists in adaptability to prevention and detection of the causes of its failures, damage and elimination of their consequences by carrying out repairs and maintenance.

Persistence - property of the object to continuously maintain serviceable and efficient condition during and after storage and (or) transportation.

To assess the reliability of an object, indicators are used.

Reliability index is a quantitative characteristic of one or more properties that make up the reliability of the object.

An object - the subject of appointment and practical human activity. In theory reliability, the considered objects of a certain purpose are the result of human production activity: a product, a system, an element.

The product consumes its resource, the product is consumed by itself. The product is considered during the periods of design, manufacture, operation, research, reliability tests.

Technical system is a set of elements interconnected functionally and interacting with each other in the process of performing a certain range of tasks.

Element - the simplest component of the system within the framework of a specific consideration.

The concept of a system and an element are relative and are transformed depending on the task at hand.

Running time - the duration or amount of work of the object.

Limit state - the state of the object, in which its further operation must be terminated due to unrecoverable violations of safety requirements, or unrecoverable departure of the set parameters beyond the established limits, or unrecoverable decrease in operating efficiency below permissible, or the need for medium or major repairs. The signs (criteria) of the limiting state are established by the normative and technical documentation for this object.

Serviceable condition (serviceability) - the state of the object in which it corresponds all the requirements established by the normative and technical documentation (NTD).

Serviceable state (operability) - the state of the object in which it is able to perform the specified functions, keeping the value of the specified parameters within the limits established by the NTD.

Fault condition (malfunction) - the state of the object in which it is not meets at least one of the requirements established by the NTD.

Inoperative state (inoperability) - the state of the object in which the value of at least one of the specified parameters characterizing the ability to perform the specified functions does not meet the requirements established by the NTD.

Damage - an event consisting in a violation of the serviceability of an object or its components due to the influence of external influences exceeding the level established in the NTD on the object.

Damage can be minor or major. The first means a violation of serviceability while maintaining serviceability, the second means a failure of the object.

Refusal - an event involving a malfunction of the object. Signs (criteria) refusals are established by the technical documentation for this object.

Recoverable object - an object, the performance of which in the event the occurrence of a failure is subject to recovery in the situation under consideration.

Unrecoverable object - an object, the performance of which in the event failure cannot be recovered in the situation under consideration.

Sudden failure - a failure characterized by an abrupt change in one or several specified parameters of the object.

Gradual failure - failure characterized by a gradual change in one or several specified parameters of the object.

Independent element failure - failure of an element of an object, not due to damage or failure of other items.

Dependent element failure - element failure due to damage or failure another element of the object.

Crash - self-correcting failure, leading to short-term violations performance.

Intermittent failure - multiple failures of the same nature. Structural failure - failure resulting from violations of the established rules and (or) design standards and (or) imperfections in design methods.

Manufacturing failure - failure resulting from violation of the established the process of manufacturing or repairing an object.

Operational failure - failure resulting from violation of the established rules and (or) operating conditions or the influence of unforeseen external influences.

Complete refusal - failure, after the occurrence of which the use of the object according to the appointment is impossible until its working capacity is restored.

Partial refusal - failure, after which the product may be used for its intended purpose, but with less efficiency.

Rejection reason - phenomena, processes, events and conditions that caused the occurrence object failure. The occurrence of a failure can be caused by errors or a low level of design of the facility, non-compliance with the technology during production, violations of operating rules, various types of damage, natural processes in the facility itself (material fatigue, wear, corrosion, etc.).

Reliability is the property of the object to perform the specified functions, keeping in time the values of the established performance indicators within the specified limits, corresponding to the specified modes and conditions for using the facility, repairing, storing and transporting.

Reliability includes:

failure-free operation;

durability;

maintainability;

maintainability...

Reliability - the property of the object to continuously maintain its performance for some time or some time.

Longevity - the property of the object to remain operative until the onset of the limit state with the installed maintenance and repair system.

Repairability - the property of the object, consisting in fitness to prevent and detect the causes of its failures, damages and elimination of their consequences through repair and maintenance.

Retentivity - the property of an object to continuously maintain a healthy and efficient state during and after storage and (or) transportation.

To assess the reliability of the object, indicators are used.

Object - the subject of the appointment and practical activities of man. In reliability theory, the objects under consideration for a specific purpose are the result of a person's productive activity: the product, system, element.

The product spends its resources, the product is consumed by itself. The product is considered in the periods of design, manufacture, operation, research, reliability tests.

The technical system is a set of elements interconnected functionally and interacting with each other in the process of performing a certain range of tasks.

The element is the simplest part of the system, within the framework of a particular examination.

The concept of the system and the element are relative and are transformed depending on the task.

The operating time is the duration or volume of the work of the facility.

Limit state - the state of the facility in which its further operation should be terminated due to unavoidable violations of safety requirements, or the unavoidable departure of the specified parameters beyond specified limits, or the ineradicable decrease in operating efficiency below the permissible level, or the need for medium or major repairs.

Failure is an event involving a violation of the operability of an object. The characteristics (criteria) of failures are established by the NTD on this object.

A recoverable object is an object whose operability in the event of a failure is subject to recovery in the situation in question.

An unrecoverable object is an object whose operability in the event of a failure is not recoverable in the situation in question.

A sudden failure is a failure, characterized by an abrupt change in one or more specified parameters of the object.

Partial failure is a failure, after which the product can be used for its intended purpose, but with less efficiency.

The reason for the refusal is the phenomena, processes, events and states that caused the object to fail. The appearance of a failure can be caused by errors or low level of the design of the facility, non-compliance with the technology in production, violations of operating rules, various types of damage, natural processes in the facility itself (fatigue, wear, corrosion).

Ishonchlilik - mulkni doimiy ish quvvati bir necha vaqt davomida yoki bir necha ish tutish uchun ob'ekt.

Foydalanish qulayligi - uning buzilish sabablari oldini olish va aniqlash uchun moslashish iborat bo'lgan ob'ekt, mulkka zarar

Ishonchlilik - belgilangan vazifalari, belgilangan limitlar, belgilangan operatsion ko'rsatkichlar qiymati vaqt tutib amalga oshirish uchun ob'ekt mol-mulk.

Qaysarlik - mulkni doimiy ish va serviceable va (yoki) saqlash, tashish davomida so'ng holatini saqlab qolish uchun ob'ekt.

Element - oddiy sayt-maxsus tizimining bir qismi ko'rib chiqish. Tizimi va element nisbiy tushunchasi

Serviceability - qaysi da texnik hujjatlar barcha talablarini u javob ob'ekt holati yaxshi holatda Noto'g'ri holati - NTD talablari kamida bitta qondirish emas, qaysi maqomi ob'ekt.

Zarar - tadbir tashqi ta'sirlar natijasida ob'ekt yoki uning tarkibiy qismi qismlari serviceability buzganlik yilda tashkil topgan

Rad - tadbir ob'ekt ishchi salohiyatini buzilishi yilda tashkil topgan. Belgilari (mezonlar) NTD ob'ektida o'rnatilgan pog'ona.

Kollapsining - samoustraniajutsia etishmovchiligi, qisqa muddatli buzilish natijasida.

Ishlab chiqarish qobiliyatsiz - qobiliyatsiz ishlab chiqarish tashkil jarayoni buzilishi natijasida yoki ob'ekt ta'mirlash.

Chidamlilik - o'rnatilgan tizimiga texnik xizmat ko'rsatish qachon chegarasi, davlat boshlanganidan oldin, ish salohiyatini saqlab qolish uchun ob'ekt mol-mulk

Chegara davlat - qaysi-da, uning yanada operatsiya halokatli buzilishi tufayli bekor bo'lishi kerak, qolaversa, davlat

Mahsulot bir resurslarini is'temol, iste'mol o'zi mahsulot. Mahsulotni loyihalash, ishlab chiqarish, ishlatish, ilmiy-tadqiqot, IP davrlar davomida qabul qilinadi

Tezkor qobiliyatsiz - etishmovchiligi va (yoki) qoidalari, shartlari buzilishi natijasida.

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National Research Technological University
"MISIS" in Almalyk
(NUST MISIS branch in Almalyk)

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At the rate: "RELIABILITY OF MINING MACHINES"

For undergraduates

Knowledge area 300,000		Production and technical sphere
Field of education 2140070		Engineering
Direction of education 21.05.04.		Mining
Speciality	SGD-16-9	Mining machinery and equipment

Semester	1	Common
Total	120	120
Lectures	36	36
Practical lessons	36	36
Laboratory work	-	-
Selfeducation	48	48

Almalyk-2021

The program was (s):

Ph.D., Assoc. Kakharov Sergey Karimovich

Working programm

Reliability of mining machines

Designed in accordance with OS VO:
Independently established educational standard of higher education Federal State Autonomous Educational Institution of Higher Education "National Research Technological University" MISiS "in the specialty 21.05.04 MINING (order dated 02.12.2015 No. 602 o.v.)

Compiled on the basis of the curriculum:

21.05.04 MINING, 21.05.04-SGD-16-9.PLX Mining machines and equipment approved by the Academic Council of the Federal State Autonomous Educational Institution of Higher Education NUST "MISIS" 21.05.2020, protocol No. 10 / zg

The work program was approved at a meeting of the department

Department of Mining Equipment, Transport and Mechanical Engineering

Minutes dated 09.06.2021, No. 10

Head of the Department Rakhutin Maxim Grigorievich

INTRODUCTION

The program for studying the discipline "Reliability of mining machines" is intended for undergraduates in the direction 5A310705 "Mining machines and equipment".

The purpose of the discipline "Reliability of mining machines" is to study methods for assessing the reliability indicators of electromechanical equipment and ensuring the necessary reliability in the operation of electromechanical equipment.

The objectives of the discipline are

- to acquaint students with the basic concepts and methods of calculating the reliability of electromechanical systems;
- provide information about the features of different types of electromechanical machines and auxiliary equipment in terms of assessing the reliability of the entire electromechanical system;
- to acquaint students with the methods of experimental assessment of the reliability of units of electromechanical mining equipment;
- to give practical skills to ensure the reliability of electromechanical equipment during operation;
- to show the areas of practical application in electromechanics of theoretical knowledge obtained in special courses of higher mathematics on probability theory and mathematical statistics.

The study of the discipline is carried out by familiarizing with the relevant topics in the recommended literature, completing the tasks of the test work, performing practical tasks and passing the final test work.

The curriculum provides for the implementation of one independent work. The delivery of the final test is the final stage in the study of the discipline.

EXPLANATORY NOTE.

The program of the discipline "Reliability of mining machines" provides for the study of methods for assessing the reliability of electromechanical equipment and ensuring the necessary reliability in the operation of electromechanical mining equipment. The program meets the requirements for educational documents, taking into account the national components of education.

The content of the program meets the requirements of the educational standard of the SSO RUz and corresponds to the basic and advanced level of training of graduates in specialties.

The program provides for the systematic control of students' knowledge by conducting surveys, competitions, tests, independent and control works.

The distribution of study time by hours, topics, sections and types of classes can be changed by the decision of the commission within the total amount of time.

As a result of studying the discipline, the master should know:

- main indicators of the reliability of electromechanical equipment, factors affecting the reliability;

- methods for calculating reliability indicators, as well as methods for their experimental evaluation;
- the main ways to increase the reliability of electromechanical mining equipment during operation through structural, time and information redundancy at the lowest possible cost.

As a result of studying the discipline, the master should be able to:

assess the reliability of electrical or mechanical equipment;

- conduct a systemic comparative analysis of the reliability characteristics of various alternative options to justify the choice of the most effective solution;
- analyze the reliability of complex electromechanical systems;
- receive statistics on refusals;
- conduct determinative and control tests for reliability; diagnose
- and predict reliability.

As a result of studying the discipline, the master must own:

- elements of probability theory and mathematical statistics; methods of
- analyzing the reliability of complex electromechanical systems; skills in
- conducting experimental assessment of reliability and statistical data processing;
- methods for assessing the operational reliability of electromechanical equipment.

ALLOCATED HOURS OF THIS DISCIPLINE BY TYPES OF ACTIVITIES

In total, 120 hours are allotted for mastering the discipline. Of these: 48 hours for independent work. For classroom lessons: 36 hours of lectures, 36 hours of practical training.

CONTENT OF THE LECTURE MATERIAL (36 hours)

Lecture. The subject of the science of reliability. The theoretical basis of the science of reliability (2 hours)

The problem of reliability is at the center of modern technology, the study of the nature of reliability at different levels of its concretization makes it practically necessary and theoretically significant to develop the dialectics and methodology of modern technology. With the growth of the technical level of the means of complex mechanization, reliability becomes more and more important among the factors affecting the level of use of mining equipment.

2. Lecture. Improving the durability of mountain cars (2 hours)

Durability - the property of the object to remain operational until the limit condition with the installed system of maintenance (MOT) and repair. Physical processes in almost any area are random. This is due to the reasons for their occurrence and course. Therefore, research in the theory of reliability is carried out on the basis of methods of probability theory and mathematical statistics. These methods are based on the concepts of an event, a random variable, addition and multiplication theorems for probabilities for reliability assessment.

3. Lecture. Electromechanical equipment failures (2 hours) Operational failures have the greatest specific weight, both in terms of quantity and

duration and complexity of elimination. Up to 50% of their total number are failures caused by mining and technical reasons. These are mainly unexpected overloads of machines. Erroneous refusals are associated with violation of technical instructions, rules and regulations of operation, low professional training of operators, untimely maintenance and repair of equipment.

4. Lecture. Economics and Reliability Random Variables (2 hours)

In the theory of reliability, a number of methods have been developed to improve the reliability of systems. One of them is the creation of reserves of one kind or another, increasing the likelihood of failure-free operation. So, for example, the system includes redundant elements, redundant in relation to the minimum necessary for its operation. This results in a higher probability of uptime than a single element.

5. Lecture. Numerical characteristics of random variables. Distribution laws discrete values (2 hours)

Physical processes in almost any area are random. This is due to the reasons for their occurrence and course. Therefore, research in the theory of reliability is carried out on the basis of methods of probability theory and mathematical statistics. These methods are based on the concepts of an event, a random variable, addition and multiplication theorems for probabilities for reliability assessment.

6. Lecture. Distribution laws of continuous random variables (2 hours)

In the theory of probability, many laws of distribution of a random variable are used.
These include the Laplace, Cauchy, Student, Erlang distributions and many others.
Consider the distributions most commonly used in mining.

7. Lecture. Reliability indicators of recoverable and non-recoverable systems (2 hours)

Indicators of reliability of restored objects:

- the probability of failure-free operation P (t);
- the parameter of the flow of failures R (t) is the probability density of the failure of the restored object, determined for the considered moment in time;
- MTBF T is the ratio of the operating time of the restored object to the mathematical expectation of the number of its failures during this operating time.

The probability of failure-free operation is determined in the same way as for non-recoverable objects. However, it should be borne in mind that the distribution functions of the operating time between the start of operation and the first failure, the first and second failure, and so on, may be different.

eight. Lecture. Methods for ensuring the reliability of mining machines (2 hours)

Ensuring the reliability of a machine cannot be considered in isolation from its operating conditions. Depending on the purpose of the machine, the requirements for reliability may be different. In cases where they are not guided by economic considerations, they usually strive for maximum reliability.

nine. Lecture. Reservation (2 hours)

Redundancy is one of the ways to maintain the level of equipment reliability. Reliability indicators depend on the scheme and methods of redundancy. There is a concept of "state" of the system, which is characterized by the performance of one of the elements and the entire system as a whole. The system states are described using graphs of transitions from one state to another. On the basis of the transition graphs, systems of differential equations are compiled, the solution of which makes it possible to determine the probability of failure-free operation of the machine with various options for arrangement and redundancy of the object's elements.

ten. Lecture. Technical diagnostics of objects (2 hours)

The elements of the product interact in parallel if its operability is ensured while maintaining the operability of at least one element, i.e. workable or A, or B, etc. The probability of failure-free operation of such a product is determined by the theorem of addition of probabilities for joint events. With a large number of parallel connected elements, the use of the probability addition theorem leads to a very cumbersome calculated dependence.

eleven. Lecture. FBG calculations for serial and parallel connection of elements (2 hours)

For m sequentially interacting elements, the probability of failure-free operation

m

is determined by the dependence P = $_{i\ 1}$pi, where pi is the probability of failure-free operation of the i-th element. If all elements have the same probability p, then P = pm. For n parallel interacting elements, the probability of failure of the ith element is qi = 1 - pi, and the probability of failure is

$n \qquad n$

m elements Q = $_{i\ 1}$qi = $_{i\ 1}$(1 - pi).

12. Lecture. Probabilistic methods for determining the frequency of repairs (2 hours)

There are two main methods for organizing maintenance of mining equipment: on the basis of a statistical analysis of the causes and frequency of equipment failures and on the basis of monitoring the technical condition of the elements and units of the machine and predicting its resource.

13. Lecture. Calculation of the number of spare parts (2 hours)

During operation, any part or assembly may fail. To ensure high the efficiency of the object, it is necessary to replace the failed part with a new one as soon as possible. This work is carried out with sufficient stock in the warehouse of the established nomenclature of spare parts. There are single, group and repair kits of spare parts.

fourteen. Lecture. Formation of a strategy for servicing mining machines (2 hours)

To build a strategy for servicing machines and installations, it is necessary to have data on the duration of their operation between repairs, on the types and causes of failures, measures to restore operability, the amount of repair costs and the elimination of the consequences of an emergency failure. The data is processed by methods of mathematical statistics. Knowing the specific form and analytical expression of the distribution function of the investigated random variable, it is possible to calculate the probabilities of no-failure operation and failures of objects for any operating time values.

15. Lecture. Methods for testing mining equipment and determining its indicators reliability at the design stage (2 hours)

To conduct the tests, an interdepartmental commission (IAC) is appointed, in which representatives of the customer are included; production association; enterprises where acceptance tests are carried out; developers of technical specifications; basin research institute; developer of design documentation; leading design and engineering institute; manufacturer; head research institute; MakNII or VostNII (if necessary); State Sanitary Inspection; technical inspection of the trade union of the industry in which the product will be used.

16. Lecture. Calculation of reliability indicators of mining machine complexes (2 hours) Before calculating the reliability at the design stage, a calculation scheme is drawn up for

based on the analysis of the process of functioning of the object. Then its possible structural states are formulated and possible failures are described. The calculation of the reliability indicators is carried out using the theorems of addition and multiplication of probabilities. To improve reliability, various redundancy schemes are used. With the help of laboratory and industrial tests, the correspondence of the calculated and actual indicators is established. When organizing trials, a factorial design of experiments is used.

17. Lecture. Calculation and construction of service schedules for mining machines (2 hours)

In the computational work, a probabilistic way of organizing preventive works based on the analysis of statistical information on reliability. The purpose of the calculations is to determine the optimal service life of the elements of mining machines, at which the minimum costs for scheduled and emergency repairs are achieved, the construction of a strategy for the maintenance of mining equipment and the determination of the required number of spare parts.

eighteen. Lecture Factors affecting the reliability of mine electrical equipment (2 hours)

Experience and studies have shown that out of the total number of EO failures on electric motors (ED) account for 25-30%. At the same time, up to 95% of all ED failures are associated with refurbishment, i.e., it requires replacing the failed ED and repairing it in specialized workshops.

Distribution of failures among the nodes of mine ED, which, as practice shows, little depends on the area of their application, which indicates the commonality of the causes of these failures.

CONTENT OF THE TOPICS OF PRACTICAL WORKS (36 hours)

1	Exercise Calculations of indicators of reliability of elements	4 hours
2	Exercise Calculations of FBG and mean time between failures of elements	2 hours
3	Exercise Determination of quantitative indicators of reliability in a certain period of time	4 hours
4	Exercise Plotting graphs of element reliability indicators	4 hours
5	Exercise Determination of the failure rate with two-way confidence interval	2 hours
6	Exercise Calculations of reliability indicators with parallel connecting elements	4 hours
7	Exercise Calculation of a node from redundant elements	2 hours
eight	Exercise Calculations to improve the reliability of system elements	4 hours
nine	Exercise Determination of reliability indicators of a complex system	4 hours
ten	Exercise Determination of reliability indicators non-recoverable elements	2 hours
eleven	Exercise Determination of quantitative characteristics of reliability complex system	2 hours
12	Exercise Determination of indicators of failure-free operation recoverable elements	2 hours

CONTENT OF THEMES FOR SELF-EDUCATION OF STUDENTS:

Independent work 1	Reliability of mining machines	4 hours
Independent work 2	Reliability of drilling equipment	4 hours
Independent work 3	Reliability of tunneling equipment	4 hours
Independent work 4	Dump Trucks Reliability	4 hours

Independent work 5	**Reliability of dumcars and trolleys**	**4 hours**
Independent work 6	**Reliability of mining electrical equipment**	**4 hours**
Independent work 7	**Reliability of pumping units**	**4 hours**
Independent work 8	**Reliability of compressor units**	**4 hours**
Independent work 9	**Reliability of fan units**	**2 hours**
Independent work 10	**Reliability of beneficiation equipment**	**2 hours**
Independent work 11	**Reliability of locomotives**	**2 hours**
Independent work 12	**Reliability of mining excavators**	**4 hours**
Independent work 13	**Reliability of belt conveyors**	**2 hours**
Independent work 14	**Scraper reliability**	**2 hours**
Independent work 15	**The reliability of the cable car**	**2 hours**

CRITERIA FOR EVALUATION
on discipline
"RELIABILITY OF MINING MACHINES"
For the direction of education: 05.21.04 - Mining machines and equipment (specialty: 21.05.04-SGD-16-9.PLX Mining machines and equipment)

Rating development and evaluation criterion on the subject of "The reliability of mountain machines "

The level of progress and knowledge of students in the subject "Reliability of mining machines"Is estimated by quantitative indicators on a 100 point system.

100 points are distributed by type of control: for current and intermediate controls academic performance - 70 points; for the final control -30 points.

Rating development of the assessment and their criterion

No.	Control types	Quantity	Score and number	Overall score
	1. Current total 35 points			
1.1.	Practical exercises 18		1.5x18	27
1.2	Independent work - preparation abstract *	1	8	8
	2.Mid-term total 35 points			
2.1.	1 - intermediate control, mining work (3 questions)	1	4x3	12
2.2.	2 - intermediate control, pysmennaya work (3 questions) Independent work	1	4x3	12
2.3.	- preparation of a presentation *	1	11	11
	∑current+ Mid-term			70
	3. Final			
3.1.	Final control, test work (3 questions)	1	10x3 = 30	30
	TOTAL			100

Note: Mid-term is conducted by a teacher leading a lecture, Current is conducted by a teacher leading practical and laboratory classes, Final is conducted by members of the commission under chaired by the head of the department.

The level of taking notes of practical work, preparation for them, for example, a task, testing, active participation in the classroom. By learning all this, students are graded in the following way:

A student who has completed practical work is fully combed 1.3 - 1.5 points, if the work is done qualitatively, but according to the level of answers to questions, 1.06 - 1.29 points, if not completed, then according to the degree of completion 8.25 - 1.05 balls.

The interim test is carried out in the form of a written work, in the form of answers to 3 questions. Each answer is evaluated on a 4-point system:

if the essence of the question is fully disclosed, the answers are accurate and complete, then - 3.4 - 4 points;

if the answer to the question is generalized, the essence is not fully disclosed and is missing some facts - 2.8 - 3.4 points

if there is an attempt to answer the question, but there is confusion - 2.2 - 2.8 points.

For a student who has completed independent work in full in the form of an essay (with a detailed description of kinematic diagrams, figures and tables, on a given topic) and who fully disclosed the essence of the question, the answers are accurate and extensive, then the student receives 6.88-8 points.

If the volume of the abstract is not complete enough, but at the same time there is the necessary data on the topic, in the form of diagrams of the main units and parts, and the student was able to answer most of the questions, the score will be 5.08-6.8 points.

If the volume of the abstract is not complete enough, but at the same time the student tries to answer the questions posed with inaccuracies in the answers of 4.4-5 points.

For a student who has completed independent work in full in the form of a presentation (with a detailed description of kinematic diagrams, figures and tables, on slides, or in a video on a given topic) and who has fully revealed the essence of the question, the answers are accurate and extensive, then the student receives 9.5- 11 points.

If the volume of the presentation is not complete enough, but at the same time there is the necessary data on the topic, in the form of diagrams of the main units and details (on slides or videos), and the student was able to answer most of the questions, reveal the essence of the topic, the score will be 7.81-9 , 4 points.

If the volume of the presentation is not complete enough, but at the same time the student is trying to reveal the essence of the topic, having inaccuracies in the answers of 6.05-7.8 points.

Questions for control
on subject
"Reliability of mining machines"

1. Operating conditions for electrical equipment of mining enterprises.
2. Requirements for electrical equipment and mechanisms of mining enterprises.
3. Classification and marking of mine electrical equipment
4. Characteristics of mining electrical equipment
5. GM reliability category
6. Equipment durability
7. Wear parts
8. Preservation of parts and assemblies of machines
9. MTBF of equipment
10. Calculation of spare parts.
11. Reliability graphs.
12. Basic quantities in the calculation of electrical loads.
13. Indicators of load schedules.
14. Rated power.
15. Causes and types of mining equipment failures.
16. Equipment redundancy.
17.Reliability indicators.
18. Parallel connection of elements.
19. Serial connection.
20. General information on protection against damage and abnormal operating conditions.
21Overcurrent protection.
22Differential current protection.
23Single-phase earth fault protection.
24Automation in the power supply systems of quarries.
25Types of automatic inclusion.
26Automatic switching on of a reserve (ATS).
27Automatic reclosing (AR).
28Automatic frequency unloading (AFC).
29. Organization of electrical equipment operation.
30. Study of devices and the inclusion of light sources in the network.
31. LN incandescent lamps and quartz halagenic lamps KG.
32. Arc high pressure mercury DRL.
33. Metal halide DRI, arc xenon tubular DKst, sodium lamps.
34. Electrical safety.
35. The effect of electric current on the human body.
36. Types of electrical injuries.
37. Classification of the degree of exposure to electric current on a person.
38 The main causes of electrical injury
Perceptible, releasing, non-releasing and deadly currents.
The main causes of electrical injuries.
The main energy indicators of mining enterprises.
Electricity consumption in quarries.
Tariffication of electricity.
Electricity of labor.
Modes of neutralization of electric networks of open pits.
Insulated neutral.
Deaf-grounded neutral.
Power factor of open-pit electrical installations
Static capacitors

Study of the circuit and the principle of operation of circuit breakers
Study of the design of circuit breakers
Electrical equipment and power supply for single-bucket excavators
Operating modes of excavator electric drives
Electrical equipment of AC excavators
Electric drive and electrical equipment of drainage, compressor, fan, lifting units and auxiliary mechanisms.
Catenary wire lightning rod
Rod lightning rod
Valve arrester
Causes of accidents of machines of mining enterprises
Reasons for downtime of mining equipment
Statistical analysis of equipment failure
Equipment uptime
Methods to improve the reliability of mining equipment
Machine hour

INFORMATION AND METHODOLOGICAL SUPPORT

Main literature

1. Razgildeev G.I. Reliability of electromechanical systems and electrical equipment: textbook. allowance. - 3rd ed., Rev. / G. I. Razgildeev; GU KuzGTU. - Kemerovo, 2005 .-- 157 p.
2. Volkov P.N.and others. - Research of repair - manufacturability of excavators - Reliability and quality control 2005. №11. 41 p.
3. Polovko AM, Gurov CB Fundamentals of the theory of reliability: St. Petersburg. 2008
4. Ostreykovsky V.A. Reliability theory. -M .: Higher school, 2003.677 s
5. Kuznetsov H.JI. The reliability of electrical machines: textbook. manual for universities. - M .: Publishing house MEI, 2006. - 432p.
6. Collection of tasks on the reliability of electrical machines: textbook / N.L. Kuznetsov. - M .: Publishing house MEI, 2008. - 408p.
7. GOST 27.002-89. Reliability in technology. Basic concepts. Terms and Definitions. - M .: Publishing house of standards, 1989 .-- 37 p.
8. Collection of problems on the theory of reliability / ed. A. M. Polovko, I. M. Malikova. - M .: Publishing house "Soviet radio", 2013.-408 p.

Additional literature

1. Internet sites:
http://www.msmu.ru/... http://msmu.ru/index.. mailto: abitur@msmu.ru... http://www.biblus.ru/...
http://www.rosugol.ru/... http://www.conveer.ru/... http://librarv.stroit.ru/...
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2. Polovko AM, Gurov CB Fundamentals of the theory of reliability: St. Petersburg.
3. 2008 Ostreykovsky V.A. Reliability theory. -M .: Higher school, 2003.677 s