REPUBLIC OF UZBEKISTAN

MINISTRY OF HIGHER EDUCATION, SCIENCE AND INNOVATIONS

NAMANGAN ENGINEERING – CONSTRUCTION INSTITUTE

“MECHANICAL ENGINEERING” DEPARTMENT

“CALCULATION AND CONSTRUCTION OF MACHINE TOOLS AND MACHINE TOOL SYSTEMS”

by subject

STUDY IS A METHODOLOGICAL COMPLEX

Field of knowledge:	700000 – Engineering, machining and construction industries
Field of study:	710000 – Engineering work
Educational specialty:	70712301 – Machine – building technology

Namangan – 2024

This educational-methodical complex is created in accordance with the working curriculum for the science of foundry furnaces for the bachelor of metal technologies 70712301 – "Engineering technology".

Developer:

V.B.Bekchanova NECI, senior teacher of the department of "Mechanical engineering"

K.Kh. Abdullaev NECI, associate professor of the department of "Mechanical engineering"

Reviewer:

N.M. Saidmakhamadov NECI, associate professor of the department of "Mechanical engineering"

The educational-methodological complex of the subject was discussed at the "№1" – number meeting of the "Mechanical Engineering" department in "28" 08 and was recommended for discussion in the educational – methodical council of the faculty.

Head of the department M.M.Ubaydullaev

The educational-methodological complex of the subject was discussed and recommended for use №1 at the meeting of the Faculty Council of Engineering Communications "28" in 08.

Chairman of the faculty council R.Soliev

Head of the educational-methodological department: T. Juraev

It was reviewed and recommended by the educational and methodological council of the Namangan Engineering – Construction Institute "__" ____ 2024y. Minutes of the meeting numbered ___. (__ - listed with a number).

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O'quv-uslubiy boshqarma
№ 123
«28» 08 2024 y.

Contents

The purpose and tasks of teaching science

The goal of learning science – The role and importance of science in the training of specialists in mechanical engineering. General information on technical and economic indicators of machine tools and machine tool systems, evaluation of indicators, stages of technological equipment design.

Tasks of science – master's students will be able to know the types of machine tools used in today's advanced technologies, their application, create modern devices, perform the necessary economic and technical calculations, as well as select a technological device for controlling the mechanical processing and processing of details, perform calculations is to teach them to get.

1.3. The connection of this subject with other subjects in the curriculum

The subject of "CALCULATION AND CONSTRUCTION OF MACHINE TOOLS AND MACHINE TOOL SYSTEMS"is a subject of the integrated course of general specialization of specialty subjects for masters and is taught in the 5th semester. The implementation of the program requires the student to have sufficient knowledge and skills in the subjects of materials science, construction materials technology, and the basics of new materials technologies, which are taught in the undergraduate curriculum.

1.4. Application of new pedagogical technologies in teaching science

The project (work) of a course in science is one of the important components of the educational process. While working on the project, graduate students get acquainted with modern development trends of machine tools and machine tool complexes, acquire practical skills in calculation, design and construction of machine tools, independent solution of the set problems. The scope of the course plays an important role in determining the creative and analytical abilities of students. During the completion of the course project, graduate students learn to apply the acquired theoretical knowledge to practical design work.

1. CONTENTS OF STUDY MATERIALS

1.1 The name of the subjects of the lecture classes of science and the number of hours allocated to them

№	Subject Name	Auditorium hour			Independent work
		lecture	Laboratory training.	Practice training.	
1.	Technical and economic indicators of machine tools and machine tool systems (MTMTS). MTMTS design steps.	2			
2.	Selection of the main technical characteristics of MTMTS	2			
3.	Development of a kinematic scheme of machine tools, calculation of kinematic chain parameters	2			
4.	Criteria for choosing the denominator of the rotation frequency series and the number of rotation frequencies	2		2	6
5.	Features of the kinematic calculation of chains of movements of thrusts	2	4	2	6
6.	Development and kinematic calculation of the kinematic scheme of boxes of speeds and thrusts on machine tools	2	2	2	
7.	Graphoanalytic method in kinematic calculation of boxes of velocities and thrusts.	2			
8.	Factors for choosing the optimal option of machine tool kinematics	2	2		6
9.	Speeds and thrusts to determine the number of teeth of gear wheels in boxes	2		2	6
10.	Speed boxes of special structure. Gearboxes with interchangeable gears. Gearboxes with perebors	2	2	2	6
	JAMI:	**20**	**10**	**10**	**30**

REPUBLIC OF UZBEKISTAN
MINISTRY OF HIGHER EDUCATION, SCIENCE AND INNOVATIONS

NAMANGAN ENGINEERING – CONSTRUCTION INSTITUTE

“CONFIRM”
Rector of namangan engineering
and construction institute
___________ Sh. Ergashev
“___” “____” 2024 year

“CALCULATION AND CONSTRUCTION OF MACHINE TOOLS AND MACHINE TOOL SYSTEMS”

SCIENCE CURRICULUM

Field of knowledge:	700000–Engineering, machining and construction industries

Field of study: 710000 – Engineering work

Educational specialty: 70712301 – Machine – building technology

Namangan 2024

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I. The content of science

The purpose and tasks of teaching science

The goal of learning science – The role and importance of science in the training of specialists in mechanical engineering. General information on technical and economic indicators of machine tools and machine tool systems, evaluation of indicators, stages of technological equipment design.

Tasks of science – master's students will be able to know the types of machine tools used in today's advanced technologies, their application, create modern devices, perform the necessary economic and technical calculations, as well as select a technological device for controlling the mechanical processing and processing of details, perform calculations is to teach them to get.

II. The main theoretical part (lectures)

2.1. Science content topics:

Topic 1. Technical and economic indicators of machine tools and machine tool systems (MTMTS). MTMTS design steps
Topic 2. Selection of the main technical characteristics of MTMTS
Topic 3. Development of a kinematic scheme of machine tools, calculation of kinematic chain parameters
Topic 4. Criteria for choosing the denominator of the rotation frequency series and the number of rotation frequencies
Topic 5. Features of the kinematic calculation of chains of movements of thrusts
Topic 6. Development and kinematic calculation of the kinematic scheme of boxes of speeds and thrusts on machine tools
Topic 7. Graphoanalytic method in kinematic calculation of boxes of velocities and thrusts
Topic 8. Factors for choosing the optimal option of machine tool kinematics
Topic 9. Speeds and thrusts to determine the number of teeth of gear wheels in boxes
Topic 10. Speed boxes of special structure. Gearboxes with interchangeable gears. Gearboxes with perebors
Topic 11. Multi – speed and DC electric motor gearboxes
Topic 12. Gear boxes with added structure. Gearboxes of a different structure
Topic 13. Selection of the material and structural forms of the machine tool holding system
Topic 14. Calculation of the integrity and stability of the support system against

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vibration

Topic 15. Calculation of temperature deformations of the support system

Topic 16. Classification of router types of machines

Topic 17. Methodology for calculation of friction guides

Topic 18. Methodology for calculation of rolling guides

Topic 19. Router protection devices

Topic 20. Spindle parts of machine tools and their requirements. Construction of spindle parts

Topic 21. Methods of calculation of the main types of supports of spindle parts

Topic 22. Classification of traction devices. "Screw – friction nut" gear calculation

Topic 23. Calculation of the "screw – rolling nut" gear

Topic 24. Calculation of hydrostatic transmissions

Topic 25. Devices for micro thrusts. Calculation of microthrusts

Topic 26. Classification of MTMTS auxiliary devices (manipulators, accumulators, transport devices, etc.)

Topic 27. Methodology for calculating MTMTS auxiliary devices

Topic 28. Classification of automatic control systems in MTMTS. Methods of controlling the operating conditions of MTMTS. Calculation method of automatic control elements

Topic 29. Criteria for selection and application of management systems of MTMTS

Topic 30. Construction of performance cyclograms of automatic machines. Classification and description of DDT control systems.

III. Instructions and recommendations for practical training

The following topics are recommended for practical training:

1. Determining the main technical characteristics of lathes
2. Determining the basic technical characteristics of milling machines
3. Determining the basic technical characteristics of milling machines
4. Analysis and development of the machine tool kinematic scheme
5. Graph analytic method of kinematic analysis for different kinematic structure of machine tools
6. Construction of structural grids for rotation frequencies and thrusts for various kinematic structures of machine tools
7. Construction of graphs of rotation frequencies and thrusts for various kinematic structures of machine tools
8. Methodology of construction of kinematic schemes of the main movement and push chains of the machine tool
9. Determining the number of teeth of group gears for various kinematic structures of machine tools by analytical methods
10. Determining the number of teeth of group gears for various kinematic structures of machine tools by tabular method
11. Performing the integration of typical mechanisms in the workshop procedures:

• For tape transmissions
• Transmission of gear wheels
• Discussion of clutches
• Separation of shafts (axles)
12. Control of sliding and rolling guides
13. Setting the power parameters of the shafts of speeds and thrusts
14. Determining the bases of velocities and impulses
15. Correction of the construction of the mechanisms of push – pull mechanisms. Adjusting the walking screws to perfection
16. Methodology for developing the construction of speed and thrust boxes
17. Calculating the power required for workbench operations and choosing the type of electrical operation
18. Methodology for choosing the form of structure for different types of workshops

Practical training should be conducted by one professor-teacher for one academic group in an auditorium equipped with multimedia devices. It is desirable that the classes should be conducted using active and interactive methods, appropriate pedagogical and information technologies should be used.

IV. Instructions and recommendations for laboratory work

Laboratory work is not included in the curriculum.

V. Instructions and recommendations for course work

The project (work) of a course in science is one of the important components of the educational process. While working on the project, graduate students get acquainted with modern development trends of machine tools and machine tool complexes, acquire practical skills in calculation, design and construction of machine tools, independent solution of the set problems. The scope of the course plays an important role in determining the creative and analytical abilities of students. During the completion of the course project, graduate students learn to apply the acquired theoretical knowledge to practical design work.

Sample topics of the course work:

• Development of projects of head and push movements of machines with various technological tasks, including machines working on the basis of digital software;

• Development of projects of flexible production modules and their elements and devices;

• Development of projects of auxiliary mechanisms and devices of workshops

	(tools, mechanisms for changing zagotovka, transport and other devices); • Development of projects of inspection – measuring devices of workbench and bench systems; • Calculation and design of the parameters of the conductor of the milling machine. **VI. Independent education and independent work** • The independent work of master's students in science includes work on the abstracts of lectures and recommended literature in accordance with educational standards, working with periodicals and Internet resources, preparing for practical and laboratory exercises, writing abstracts, scientific articles. In the process of independent work, extensive use of computer technology is mandatory. ***Recommended topics for independent study:*** 1. Modern systems for automation of machine shop accounts and construction work 2. Methods of calculating auxiliary devices and equipment of machine tools and machine tools 3. Systems for developing models for calculating machine tools and details 4. Calculation of the speed box of the machine tool 5. To study the principle of operation of machine tools 6. Analysis of the processing mode of the milling machine for semi – finished products 7. Determination and analysis of machine vibration process 8. Selection of the material and structural forms of the machine tool holding system 9. Calculation of the integrity and stability of the vibration generation system during machine operation 10. The method of calculating the coefficient of friction.

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“CALCULATION AND CONSTRUCTION OF MACHINE TOOLS AND MACHINE TOOL SYSTEMS”

Independent assignment (IA)

Independent assignment (IA)

IA1 Modern systems for automation of machine shop accounts and construction work

IA2 Methods of calculating auxiliary devices and equipment of machine tools and machine tools

IA3 Systems for developing models for calculating machine tools and details

IA4 Calculation of the speed box of the machine tool

IA5 To study the principle of operation of machine tools

IA6 Analysis of the processing mode of the milling machine for semi – finished products

IA7 Determination and analysis of machine vibration process

IA8 Selection of the material and structural forms of the machine tool holding system

IA9 Calculation of the integrity and stability of the vibration generation system during machine operation

IA10 The method of calculating the coefficient of friction

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NAMANGAN ENGINEERING – CONSTRUCTION INSTITUTE

“MECHANICAL ENGINEERING” DEPARTMENT

“CALCULATION AND CONSTRUCTION OF MACHINE TOOLS AND MACHINE TOOL SYSTEMS” LECTURES ON SCIENCE

Namangan-2024

1 – Lecture: Technical and economic indicators of machine tools and machine tool systems (MTMTS). MTMTS design steps

Study module units:

1. Productivity and technical – economic efficiency of machines

2. Processing cost and economic efficiency

Machine tool productivity is measured by the number of parts produced per unit of time. The total productivity of the machine is found as follows:

$$Q = \frac{1}{t_d} \tag{1}$$

But not only the productivity of the machine, but also the labor productivity is important for the product cost. At the same machine tool productivity, labor productivity depends on the number of machines serviced by one worker, and in some cases by the number of workers serving one machine.

Productivity and product cost are determined based on the time norm. The time frame for granular production includes the following elements:

$$t_d = t_b + t_{aux} + t_m + t_{mm} + t_{ph}, \tag{2}$$

here: t_b – basic (technological) time; t_{aux} – auxiliary time; t_m – machine maintenance time; t_{mm} – machine tool maintenance time; t_j – time of physical needs of workers.

The time norm for semi – automatic machines is defined as follows:

$$t_d = t_s + t_{yor} + t_{tex.x} + t_{tash.x} + t_j, \tag{3}$$

The time standard for automatic machines is found as follows:

$$t_d = t_a + t_{tex.x} + t_{tash.x} + t_j, \tag{4}$$

here t_s – automatic cycle time.

The main (technological) time t_a – is cutting time; it is defined as:

$$t_a = \sum t_{ol} \tag{5}$$

For turning, drilling, zenkerlasch, reaming, boring operations

$$t_{ol} = \frac{l_i}{n_i + S_i}, \tag{6}$$

here: l_i – path of the cutting tool, mm; this path length is the slow approach of the tool to the part (0,5.. .2,0 mm), the detailing path and processing are the paths in the process; n_i – the number of revolutions of the spindle during this transition, rev/min; S_i – amount of pushing during this transition, mm/month.

In the knurling operation, the number of revolutions is replaced by the number of double strokes per minute.

Milling time is calculated as follows: $t_{ol}=\frac{l_i}{S_{mi}}$, here S_{mi} – thrust value, mm/min.

Base time is determined for other processing types in similar ways.

The composition of *auxiliary time* depends on the structure of the processing technological process. However, regardless of the structure of the technological process, the auxiliary time includes the time of installing the semi – finished product on the machine, clamping and loosening, turning on and off the head and push movement.

In the case of semi – automatic machines, the auxiliary time structure consists only of the times of installation, clamping and removal of the semi – finished product. There is no auxiliary processing time in automatons.

Maintenance time – ($t_{tex.x}$) is spent on machine setup, tool alignment and replacement of stuck tool, chip removal. Maintenance time cost is calculated as a percentage of base time based on available data.

Organizational service time ($t_{tash.x}$) is spent on machine tool lubrication and cleaning and is calculated as a percentage of the sum of main and auxiliary times based on available data.

When determining the cost of processing, it is necessary to know the calculation time.

$$t_k = t_d + \frac{t_t - y}{i}, \quad (7)$$

here: t_t – y preparation and completion time; i – the number of details in the batch being processed at the same time.

The preparation and completion time is divided into tasks such as receiving the production order, familiarizing with the product drawing, receiving the necessary tools and equipment, and setting up the machine.

Processing cost and economic efficiency

The cost of processing performed on a given machine is the monetary representation of the social labor spent to perform the work. The composition of costs consists of the following:

a) previous labor costs materialized in the used means of production, that is, depreciation of devices and equipment, electricity and other costs;

b) live labor costs equivalent to the wages of employees involved in the production process. In the spread view, the cost of the product can be expressed as follows:

$$S_m = S_z + S_{sta} + S_t + S_e + S_{yor} + S_{ma} + S_{aa} + S_{o\text{‘}a} + S_b + S_s, \qquad (8)$$

here: S_z – with wage increases for production workers; S_{sta} – machine tool depreciation costs; S_t – machine repair costs; S_e – electricity costs; S_{yor} – costs of auxiliary materials; S_{ma} – allowances for depreciation and repair of equipment; S_{aa} – allowances for depreciation, repair and sharpening of cutting tools; $S_{o\text{‘}a}$ – allowances for amortization and repair of measuring instruments; S_b – expenses related to the use of buildings; S_s – other shop expenses.

The salary of production workers, in turn, consists of the sum of the following elements:

$$S_{\mathrm{z}} = S_{\mathrm{zst}} + S_{\mathrm{zsoz}} + S_{\mathrm{ztr}} \qquad (9)$$

here: S_{zst} – wages of workers working on the machine; S_{zsoz} – wages of adjusting workers attached to the machine; S_{ztr} – wages of transport and auxiliary workers attached to the machine.

Other additional costs include the wages of engineering and technical staff, administrative staff, assistants and transport staff who are not attached to the machines, labor protection costs, household equipment, sanitary equipment, etc. The cost of other additional expenses is determined based on the available information, based on the amount of the basic salary.

When comparing several options of the machine being designed, it is necessary to take into account the payback period of additional capital costs. This period is found from the following expression:

$$T_{ok} = \frac{K_2 - K_1}{S_1 - S_2} * t_k, \quad (10)$$

here: K_1, K_2 – the amount of capital expenditure incurred on the options being compared; S_1, S_2 – the transaction cost of the options being compared.

2 – Lecture: Selection of the main technical characteristics of MTMTS

Study module units:

1. Indicators of technical and economic level of machine tools

2. Evaluation of technical level of machines

The system of technical and economic indicators is used to evaluate the quality of the machines. Technical – economic indicators can be absolute and relative. Relative indicators are usually dimensionless and are used to compare the design version of machine tools with the baseline or to compare their different versions.

The technical – economic level of machines is determined by a set of properties that include functional devices, socially useful results, the level of all types of costs, and consumption and economic characteristics.

The names of the main indicators determining the technical and economic level of machine tools are determined by the special state standard ((GOST 4.93 – 86 “SPKP. Metalworking machines. Nomenclature of indicators”).). According to this standard, eight groups of indicators are used. Usually, each group consists of several indicators that form the technical-economic level and allow quantitative description of one or another property of the product. Indicator groups are composed of:

1. Task indicators. They are the technological capabilities of the machine tool, adaptability to processing the workpieces of a certain size and mass, the possibility of using a tool of a certain size on the machine tool, the efficiency and accuracy of processing, the level of power consumption, the suitability for transportation and portability, and the consumption of materials in production. describes the economics of The following task indicators are used:

• description of the semi – finished product used on the machine (checks for mass and dimensions of the semi – finished product);

• specifications of the tool installed on the machine tool (the largest size of the tool, the largest mass of the workpiece in the magazine, the presence of tool collectors);

• descriptions of working and installation thrusts (maximum thrusts of working bodies, discreteness of setting thrusts, accuracy of movement to position, etc.);

• descriptions of the main and auxiliary thrusts of the machine (rotational frequencies, working thrusts, limits of movement of moving bodies);

• indicators of the power description of the machine (maximum torque on the spindle, power of the main drive, total power of the electric motors installed on the machine);

• dimensions and mass of the machine tool;

• accuracy and roughness of the surface of the product;

• performance indicator (performance growth factor compared to the compared model);

• technical excellence, including an indicator of the level of automation (list of automation tools); the level of equipment and devices that expand technological capabilities; machine tool accuracy class; automatic tool change time.

2. Accuracy indicators. They are the unbroken performance and durability of the machine. Describes the level of repairability and maintainability. Effective use of the machine by the consumer in many cases depends on these indicators.

3. Indicators of efficient use of materials and electricity describe the economy of metal consumption in the production of machine tools, as well as the economy of electricity consumption in their operation.

4. Ergonomic indicators describe the suitability of the machine to the physical capabilities of a person, to the conditions of operation in accordance with sanitary norms. These indicators include the sound level and sound power level in the workplace.

5. Indicators of compatibility with technology indicate the labor cost in the preparation of the machine tool. The standard specifies only one indicator for this purpose, that is, the relative labor cost in the preparation of the machine tool.

6. The indicators of standardization and unification describe the repairability of the machine tool and the cost-effectiveness of its preparation, achieved due to the use of unified details and parts.

7. Patent and legal indicators include patent purity index and patent protection index.

8. Safety indicators describe the provision of human protection in the area of danger.

Depending on the problem to be solved, machines of the same technological task can be compared and used on the basis of each of the indicators specified in the standard. But in order to obtain a large-scale comparative evaluation of machine tools, it is often limited to the use of basic indicators. These include performance indicators, accuracy indicators, material and energy efficiency indicators.

Most of the indicators are used during the development stage of the prototype of the product and in order to inform the customer as fully as possible about the consumer properties of the machine tool, as well as in the prepared technical conditions about the machine tool.

In practical work, it may be necessary to use a lot more indicators that describe the specific properties and characteristics of the machine tool that is of interest to a specific buyer. The more the machine tool manufacturer knows about the needs of different groups of consumers, as well as the product that is or may be competing in the market, the more the advertising objective that needs to attract consumers. and the range of indicators used in the creation of the machine will be even wider. Therefore, the search for such indicators, the determination of their normative quantities, the development of methods for confirming (or demonstrating) the conformity of the machine to the advertised specifications are among the most important issues to be solved in the creation of new products.

Determining the technical level of machine tools is carried out on the basis of a special state standard ((GOST 2.116 - 84 “Technical level map and product quality” (Technical level card and product quality)). The level card is used to evaluate the technical level and quality of machine tools for decommissioning or decommissioning determined on the basis of a comparative analysis of comparison with indicators or forecast values reflecting world achievements and development trends.

To evaluate the technical level, it is determined whether the product belongs to one of the following three categories:

P – the product is world class;

S – the product corresponds to the world level;

U – the product is below world level.

The world technical level of the machine is characterized by the basic samples that include the advanced scientific and technical achievements in the development of this type of equipment. The base sample group consists of the best samples (analogs) sold on the world market and promising samples whose indicators are predicted for the future.

The results of the evaluation of the technical level of the machine are used in the solution of the following issues:

• in substantiating the requirements included in the technical assignment of the machine tool development;

• when creating and putting into production a new or modernized machine tool;

• proving the expediency of replacing or discontinuing the production of the machine tool;

• when examining the technical level of the machine tool outside the office;

• in the design of production development and technical re – equipment;

• in the formation of proposals for export and import, etc.

The technical level of the machine tool is determined depending on which area of the parameters of the evaluation parameters correspond to the relevant indicators of the evaluated machine tool. Then the following limits of technical level fields are established:

• limit of minimum permissible values of assessment indicators;

• world achievement limit;

• lower and upper limits of the world achievement area.

If the parameters of the machine are in the area within the acceptable limits, then the machine is considered to be in accordance with the world level.

If the evaluation parameters of the machine are outside the range of permissible values, or the performance of the machine does not meet the modern requirements set by consumers. or if the machine tool technology is outdated. then it is concluded that the machine is below the world level.

3 – Lecture: Development of a kinematic scheme of machine tools, calculation of kinematic chain parameters

Study module units:

1. Classification of movements in machine tools

2. Kinematic connections in metal cutting machines

3. Fundamentals of kinematic adjustment of machine tools

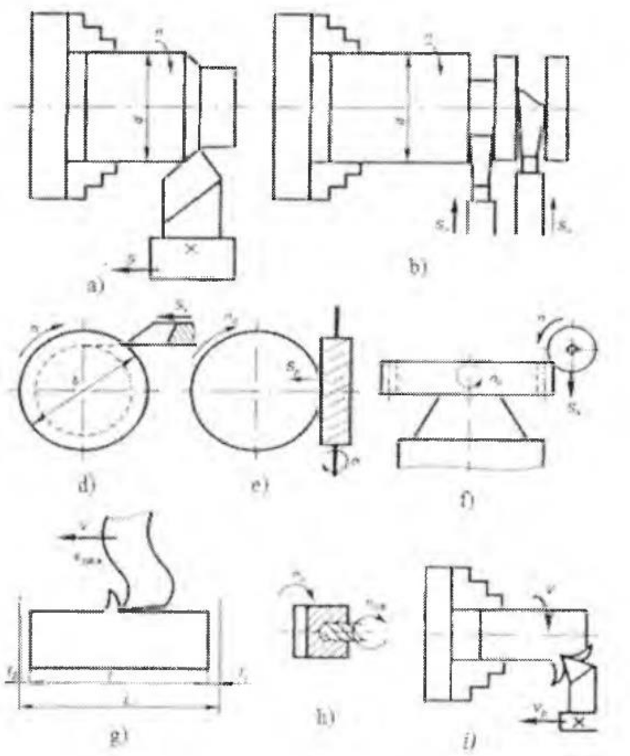
In metal cutting machines, the joints that hold the tool and the tool are called working or performing joints. The actions of these joints in the process of processing are also called working or performing actions. According to the mechanism of action, there can be actions of forming, settling, and dividing.

Shape – making movements refer to coordinated movements of the semi – finished product and the tool relative to each other. As a result of such actions, the semi – finished product will have the form given in the task.

It is agreed to separate the shape – forming movements of the tool and the tool in the cutting process into the main movement and the pushing movement.

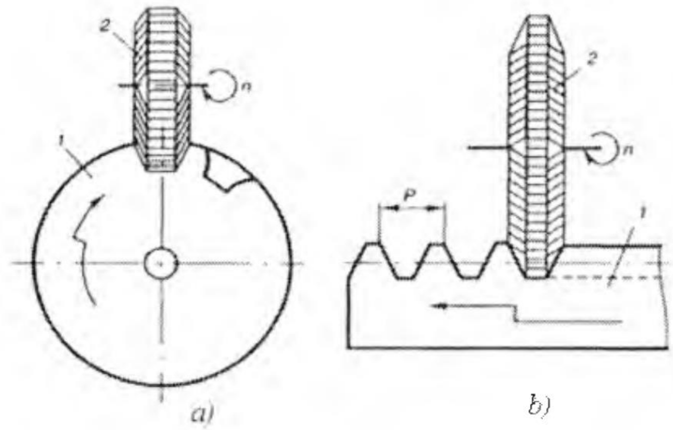
The head or cutting movement is the movement that ensures that the slag is separated from the semi – finished product at a certain speed. The pushing action serves to bring new layers of material under the cutting edge of the tool and to ensure the continuity of the cutting process. Head and push movements can be circular and linear; they can be performed by both a semi – finished product and a tool. For example, on lathes, the head (rotational) movement is performed by the spindle, and the pushing (straight line) movement is performed by the tool (cutter) (fig. 1 a, b). In milling machines, on the other hand, the rotary head movement is taken by the cutting tool (milling machine), and the rectilinear pushing movement is transferred to the table fixed to the semi – finished product.

Depending on the direction of movement of the tool in relation to the semi – finished product, thrusts can be longitudinal (1, a – picture), transverse (1, b – picture), radial (1, d – picture), circular (1, e – picture) . In addition, thrusts on drilling machines are axial (1, h – horizontal) and vertical (1, f – picture) on tooth milling machines.



1 – picture. Types of head and push movements in metal cutting machines

The splitting movement serves to turn the tool or the tool to the required angle (2, a – picture), or to ensure the linear movement of the tool to a certain value relative to the tool (2, b – picture). The act of being can be continuous or continuous. In the first case, it is done periodically. In the second case, the cutting action is performed continuously and lasts for the time it takes to move the tool along the semi – finished product.



2 – picture. Examples of the movement of division: a – burcliuldi (circular); b – linear

The installation action creates conditions for cutting the slag from the semi – finished product and getting the required size. If the settling movement causes the sediment to be removed, then a sinking movement occurs. Otherwise, such an action is called an adjustment. In addition to the actions considered above, auxiliary, differential, control actions are also required in the machines. Auxiliary movements are not directly involved in the cutting process, but they are necessary to carry out milling and processing. Actions related to mounting and removing the workpiece, tightening and loosening the workpiece, moving the tool in and out, mounting and removing the tool, checking dimensions, etc. are included in the auxiliary operations. Auxiliary actions can be performed both automatically and manually.

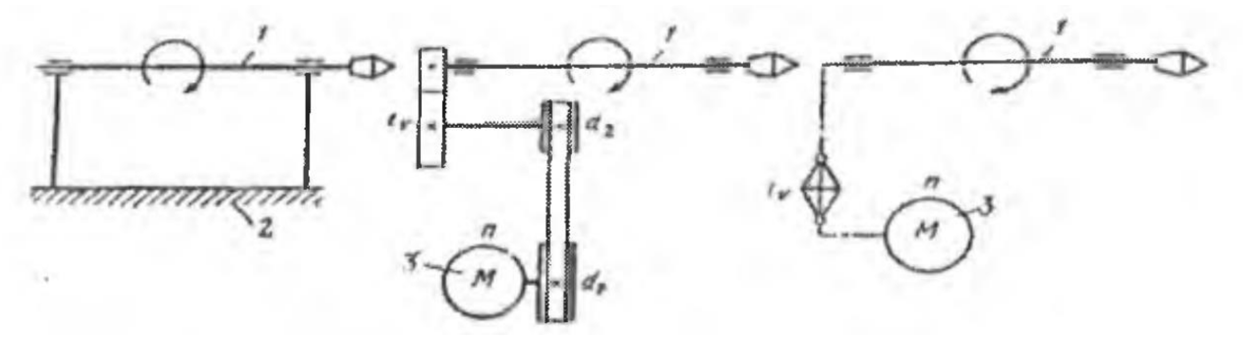
Actions related to management, adjustment and coordination of the working actions of the executive bodies on the machine are included in the control actions. Examples of such actions are starting and stopping the movement of the machine tool, selecting and starting the frequency of rotation of the spindle and feed speed, changing the direction of rotation of the spindle (reversing), etc. The differential motion is added algebraically to any motion of the semi – finished product or tool. The concept of differential action is similar to the mathematical concept of “differential”, that is, it corresponds to the concept of “addition”. Addition can only be applied to movements of the same type, i.e. rotation with rotation and advance with advance. Differential movements are often used in tooth processing machines.

In metal cutting machines, the connection between gears and moving elements of mechanisms is more complicated, so the question of kinematic connections is important.

The term “kinematic linkage” refers to the interconnection of the moving elements of the machine tool. Due to the fact that the moving elements are part of the mechanism of any working body, the kinematic connection means the structure of the mechanism.

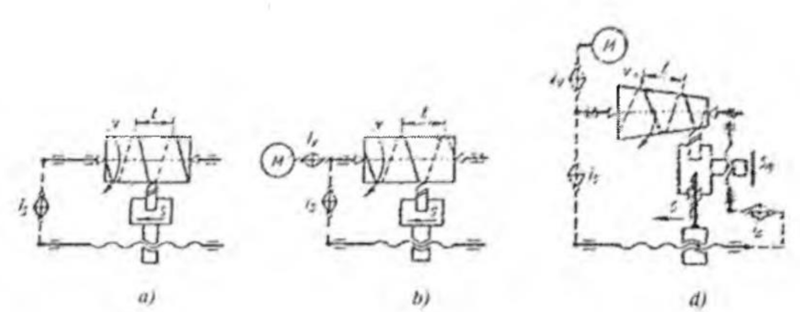
Each kinematic connection consists of one or more mechanical, electrical, hydraulic and other kinematic chains to perform the necessary executive actions. In order to ensure some kind of executive movement in the machine tool, it is necessary to have a kinematic connection between the executive bodies of the machine tool and to connect these bodies with the source of movement. Mutual kinematic connections of executive bodies are called internal kinematic beginnings. If the executive movement is simple (Fig. 3, a), for example, rotation, then the internal kinematic connection is the executive body participating in the movement (spindle 1 in this example) and the executive body that is not participating in the relative movement in question is performed by a single rotating kinematic pair between the organ (2 in the example). Internal kinematic connection refers to the nature of executive action. The speed of the executive movement is not determined by the internal kinematic connection.

The main kinematic connection is the connection between the moving executive body (spindle 1) and the source of movement (electric motor 3) (Fig. 3, b). The external kinematic link serves to transfer power from the source of motion to the internal kinematic link and provides the speed, direction, and starting point of the movement. The external kinematic connection is between several joints, and with the help of the adjustment body (iv), the executive movement is adjusted to the required speed without changing the speed of the electric motor.



3 – fig. Kinematic links for simple executive movements

Some examples of kinematic connections that perform complex executive actions are presented in Figure 4.



4 – fig. Examples of kinematic linkages for complex executive movements:
a – internal connection work for opening a groove on a lathe; b – structural diagram of a lathe with a thread opening chain; d – structural diagram of a lathe for opening a conical groove

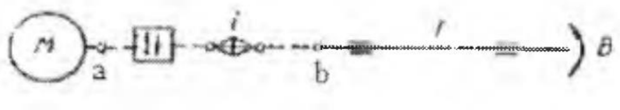
Kinematic adjustment of machine tools mainly means determining the parameters of the adjustment bodies and is considered a component of the work of adjusting the machine tool. Kinematic adjustment consists of making the kinematic chains of the performing organs move at the required speed, as well as coordinating the movement or speed of these organs.

In most metal cutting machines equipped with mechanical linkages, gear shifters, belt drive pulleys, variators, gearboxes, and gearboxes act as adjusting bodies. Kinematic adjustment is performed in the following order:

1. Defining the coordinating chain of actions. The chain should be taken from the kinematic scheme of the machine tool, and it should show the speed and displacement of the executive bodies and the last links of the chain. For example, in

the kinematic chain of the head movement of a lathe (Fig. 5), the last links consist of an electric motor *M* and a spindle, that is, the first stage can be written as follows:

$$elektr\ dvigatel \rightarrow shpindel.$$



5 – fig. Scheme of kinematic adjustment

2. Determination of conditions for coordination of movements or speeds of the last links for the selected kinematic chain. In this case, the calculated movements of the joints are determined. For example, in the kinematic chain of the lathe head movement (Fig. 5), the calculated movements of the last links are as follows:

$$n_{el}, \frac{ayl}{min} \rightarrow n_{shp}, \quad \text{ayl/min}$$

here n_{el} – rotation frequency of the electric motor rotor; n_{sh} – the required rotation frequency of the spindle, it is determined from the following formula:

$$n_{ig} = \frac{1000 \cdot V_p}{\pi \cdot d},$$

here V_p – cutting speed. m/min or m/s; d – diameter of the machined surface, mm.

3. Writing the kinematic balance equation of the coordinating chain, taking into account the calculated displacements. In this equation, the gear ratio of the tuning body is unknown. In the given example, this equation for the kinematic chain of the head movement is as follows:

$$n_{el} \cdot i_{y1} \cdot i_v \cdot i_{y2} = n_{shp},$$

here i_{y1} *va* i_{y2} – general transmission ratios of constant mechanical (gear, belt, chain) transmissions located before and after the adjustment body in the kinematic chain; - unknown transmission ratio of the adjustment body.

4. Determining the adjustment formula (gear ratio of the adjustment body) by solving the equation of the kinematic balance of the adjustment chain. The adjustment formula for the example under consideration is as follows:

$$i_v = \frac{n_{shp}}{n_{el} \cdot i_{y1} \cdot i_{y2}}$$

4 – Lecture: Criteria for choosing the denominator of the rotation frequency series and the number of rotation frequencies

Study module units:

1. Rotational frequencies are stepped

2. Velocities are kinematic calculations of boxes

In universal non – automated machine tools, the main drive consisting of an asynchronous electric motor and a gear box, which allows adjusting the spindle rotation frequency from the minimum frequency (n_{min}) to the maximum frequency (n_{max}), is the most common.

The following mathematical relations exist between the values of rotation frequencies n, their range R_n and number z, and the denominator φ of the geometric series:

$$n_2 = n_1 \cdot \varphi;\ n_3 = n_2 \cdot \varphi = n_1 \cdot \varphi^2; \ldots.. n_z = n_1 \cdot \varphi^{z-1};$$

$$z = 1 + \frac{\log_{10} R_n}{\log_{10} \varphi};\ \varphi = \sqrt[z-1]{\frac{n_{max}}{n_{min}}};\ R_n = \varphi^{z-1};$$

Graphoanalytic method is used for kinematic calculations of velocities. The method allows to graphically represent the elements of the kinematic chain in the form of a graph of structural meshes and frequencies of rotations.

Structural grids give an idea of the structure of the drive and are built in order to consider different options for the structure of kinematic chains and choose the most suitable one among them. From the structural grid, information can be obtained about the number of sliding blocks, their location and connection to the kinematic chain, the number of gear wheels in the blocks, the adjustment ranges of each block and the entire drive, and the number of steps of the rotation frequency of each shaft in the drive.

Graphs of rotation frequencies are built to determine the exact values of shaft rotation frequencies, the number of teeth and transmission ratios of all gears, as well as single gears (gear, belt, etc.).

Structural grids are built in the following order:

1) Horizontal (or vertical) lines whose number is one more than the number of extension groups are drawn at an equal distance; the area between two horizontal (vertical) lines is allocated for one extension group;

2) Vertical (or horizontal) lines, the number of which is equal to the number of driving speeds, are drawn at an equal distance; the distance between the lines is equal to lgφ, because for a geometric series $n_Z = n_{Z-1}\,\varphi$ and after logarithmization it becomes $lg\, n_z = lg\, n_{z-1} + lg\, \varphi$.

3) Next to the field, the number of transmissions in the group R_i and the characteristic X_i of the group are shown in the order of the constructive arrangement of the groups;

4) Point “O” is marked in the middle of the upper horizontal (or left vertical) line; from this point (or center) rays with the number R_i are passed symmetrically, the distance between the ends of the rays in the next horizontal (or vertical) is equal to $X_i\, lg\, \varphi$;

5) From the points on the second and subsequent horizontal (or vertical) lines, similarly, the second, third, etc. beams are passed for extension groups.

The actual number of revolutions and gear ratios of the gears in the gear groups cannot be determined from the structured mesh. To determine these values, a graph of rotation numbers should be constructed. To construct a graph, the following should be known: a) the denominator of the number of rotations series φ b) actual values of the number of revolutions; c) the number of rotations of the selected electric motor ne; g) complete kinematic scheme of the procedure.

5 – Lecture: Features of the kinematic calculation of chains of movements of thrusts

Study module units:

1. A chain of thrusts

2. Push chain of lathe screw cutting machines

Depending on the requirements of the drive mechanism, the machine tools can be adjusted in a wide range of stepless and stepless values.

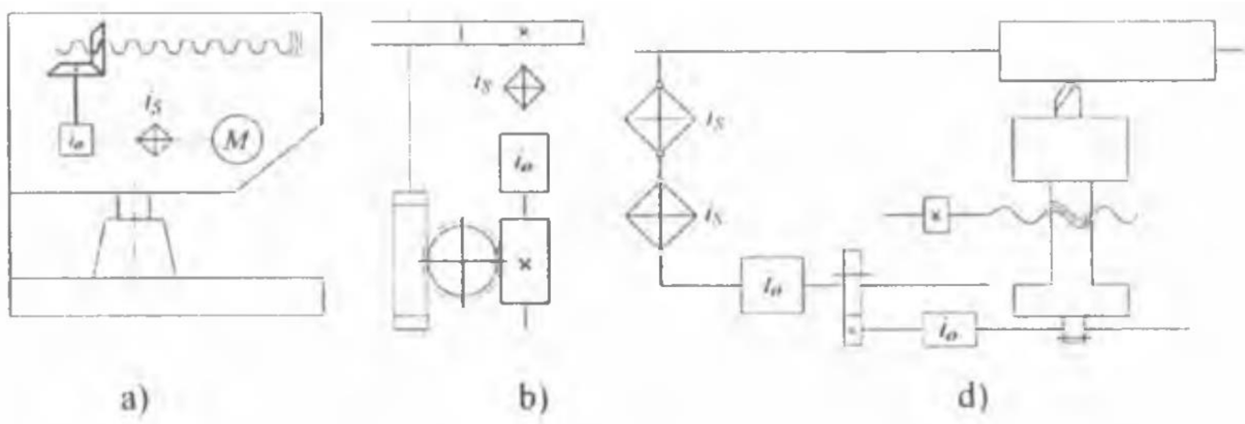
Stroke variation range

$$R_S = \frac{S_{max}}{S_{min}} \; ; \; [\,S\,] - \frac{\mathrm{mm}}{\mathrm{ayl}} ; \mathrm{mm/min}$$

The question of the range of change of the thrust value is related to the structure of the thrust behavior when specifying the thrust in units of revolutions per minute. If the thrust movement is the same as the main movement movement (Fig. 1, b and d), the thrust value corresponding to one revolution of the spindle

$$S = 1\ shp.\ aylanishi \cdot i_o \cdot i_s \cdot S_n \text{ ga}$$

will be equal, here is the transmission ratio of the constant gears in the thrust drive; is is a variable transmission ratio adjusted by the push box (i_{kn}).; S_n – displacement value corresponding to one rotation of the last output shaft of the push box of the working body of the machine tool (support, spindle, etc.) (if the push mechanism is a screw-nut transmission, in it S_n the pitch of the screw is equal to t_v, and in the case of gear – rack transmission $S_n = \pi\, m$ z. here m and z wheel module and number of teeth respectively).



1 – fig. Schemes of the structure of push – ups:

a) separated, separately driven by an electric motor; b, d) general, spindle – driven movement

Minimal S_{min} surishga i_{Smin} uzatish nisbati to‘g‘ri keladi, maksimal Smax surishga esa - i_{Smax} uzatish nisbati to‘g‘ri keladi. Shpindelning bir aylanishida maksimal va minimal surish qiymatlariga mos keladigan surish qutisi so‘nggi valining aylanishlar soni quyidagicha topiladi:

The minimum thrust S_{min} corresponds to the transmission ratio i_{Smin}, and the maximum thrust S_{max} corresponds to the transmission ratio – i_{Smax}. The number of revolutions of the thrust box end shaft corresponding to the maximum and minimum thrust values per revolution of the spindle is found as follows:

$$n_{max} = 1\ shp.\ ayl \cdot i_o \cdot i_{Smax}: \quad n_{min} = 1\ shp.\ ayl \cdot i_o\ \ i_{Smin}$$

In the case of independent (separate from the electric motor) thrust operation (Fig. 1, a) thrust speed coefficient is measured in mm min and S_{min} $n \cdot S_o$ will be equal, here – M the frequency of the procedure. It is recommended to place the thrusts on the basis of geomelric series. Therefore, like a dizzying movement:

$$R_S = \frac{S_{max}}{S_{min}} : \varphi_S = \sqrt[Z_S - 1]{R_S}\ ;\ Z_S = 1 + \frac{\lg R_s}{\lg \varphi_S}$$

The selection of the row denominator φ_s and the number of thrusts Z_s is mainly based on the rules used for main motion chains. Deviation of the actual values of thrusts from the known values is allowed within the limits of $\pm\ 10(\varphi_s - \lambda)\%$.

In machines with periodic thrusts, in which the thrust movement is carried out by a ratchet mechanism, the magnitudes of thrusts are placed on the basis of arithmetic progression. The following follows from the properties of arithmetic series:

$$S_2 = S_1 + C;\quad S_3 = S_2 + C = S_1 + 2C; \ldots..; S_z = S_{z-1} + C = S_1 + (Z-1) \cdot C.$$

here C – arithmetic series difference: $C = \frac{S_{max} - S_{min}}{Z_s - 1}$

An additional requirement is placed on the push chains of the lathe screw cutting machines to ensure the possibility of obtaining the required exact ratio between the movement of the spindle and the speed of the advance of the tool. This ratio should be proportional to the step of opening grooves.

6 – Lecture: Development and kinematic calculation of the kinematic scheme of boxes of speeds and thrusts on machine tools

Study module units:

1. Development and kinematic calculation of the kinematic scheme of the boxes of speeds and thrusts

2. Procedure for connecting extensions

The chain of transmission kinematics of the spindle rotation process must ensure the sequence of the spindle rotation frequencies (n), the denominator φ of the selected series and the outermost number of revolutions $n_{min} = n_1$ and $n_{max} = n_z$ of the given spindle along the geometric series. The kinematic calculation of the method provides a solution to these problems.

A set of gears connecting two adjacent shaft drives constitutes a gear group. A group is characterized by two indicators: 1) the number of transmissions in the group P and 2) the transmission ratio of the transmission i. The arrangement of groups along the kinematic chain indicates a constructive variant of the speed box.

The existence of some regularity among the rotation numbers n means that there is a similar regularity in the series of gear ratios i. When adjusting spindle rotation frequencies using only one set of gears, that is, with only one set of gears between two shafts, any range of spindle rotation numbers can be established. All you have to do is select the appropriate range of gear ratios for the group transmissions.

When adjusting the drive with the help of continuous transmission groups (Fig. 1), it is possible to implement only the geometric series of rotation numbers from the regular series.

In order to develop a kinematic scheme of the head movement chain of a machine tool with a rotary head movement, the following should be known: 1) the number of steps of the spindle speed Z_n 2) the denominator of the geometric series phn; and 3) the number of revolutions of the spindle from n1 to n_Z (or n_1 and n_z).

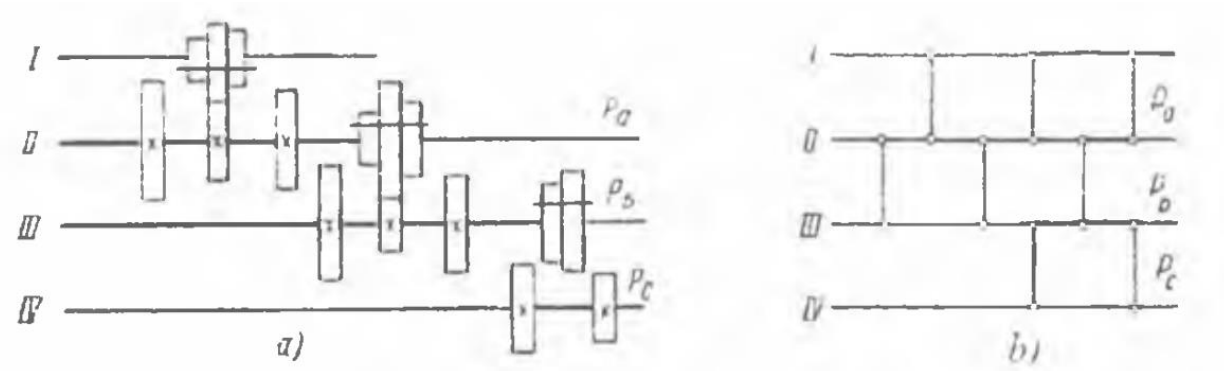
When adjusting the head movement with serially connected group gears, the number of spindle speed steps Z_n is equal to the product of the number of gears in each group. That is, if the drive has a sequentially connected group of gears consisting of gears equal to p_a, p_b, p_c..., p_k, respectively, in each gear group, then the number of steps of the spindle rotation speed is found as follows:

$$Z_n = p_a \cdot p_b \cdot p_c \cdot p_k$$

For example, for the kinematic scheme of the movement presented in Fig. 1, the number of rotation steps is equal to $Z_n = p_a \cdot p_b \cdot p_c = 3 \cdot 3 \cdot 2 = 18$.

For a given (or selected) number of steps, the number of gears in each group and the choice of the order of placement of the groups may vary. It is not advisable to use 6 or more gears in one group, because in this case the reading dimensions of the box will increase.

If the number of spindle revolutions changes according to a geometric series, the transmission ratios of the transmission in the group form a geometric series with denominator φ^X (where X is an integer named group description (characteristic).



1 – picture. The method of sequentially connecting extension groups: a – kinematic scheme: b – structural scheme

The group characteristic is equal to the number of speed steps of the set of group gears kinematically preceding the given group. To get the spindle rotation frequencies in sequence, first one group of gears is connected, then another group of gears, and so on.

Depending on the order in which the extensions are connected, a group of extensions can be one of the following:

a) ***main group,*** this group is the first in the kinematic order of gearing, and its gearing gives a series of rotational frequencies. The characteristic of the main group is Xo = 1, because according to the kinematic arrangement, this group is preceded by a set of gears with one step speed;

b) ***l is a gear group***, the characteristic of which is that the number of gears in the main group X_1 is equal to P_1 ($X_1 = P_1$), because before this group there is a set of gears equal to the speed steps of P_1; l – the transmission ratios of gears in the gear group form a geometric series whose denominator is equal to φ^{P1};

v) **2 – pereboric and next pereboric groups.** their characteristic is equal to the number of transmissions of the groups before the X_1 group, i.e. $X_2 = P_1 P_2; X_3 = P_1 \cdot P_2 \cdot$

P_3, where P_2, P_3 – 1 – and 2 – number of transmissions of perebor groups; In the 2 – perebor group, the denominator of transmission ratios of gears is a geometric series $\varphi^{P_1 P_z}$, and in the 3 – perebor group, the denominator is equal to $\varphi^{P_1 P_2 P_3}$, and so on.

Any gear group of the system can be a main or a numbered gear group. The number of kinematic variants Bkin for a given structural variant of the method is equal to the number of displacements from the number of “K” gear groups, i.e. Bkin = K!. For example, the number of kinematic options for the driving scheme shown in the figure $B_{kin} = 3! = 1 \cdot 2 \cdot 3 = 6$.

The number of structural options for the transmission consisting of “K” gear groups $B_{kon} = \frac{K1}{m1}$, here К – number of transmission groups, m – the number of groups with the same number of transmissions. For examle, if K = 3. m = 2, number of constructive options $B_{kon} = 3!/2! = 6/2 = 3$.

The total number of options is determined as follows:

$B = B_{kin} \cdot B_{kon} = 3 \cdot 6 = 18$

7 – Lecture: Graphoanalytic method in kinematic calculation of boxes of velocities and thrusts

Study module units:

1. Graphoanalytic method in kinematic calculation of boxes of velocities and thrusts

2. Rotational frequencies

The graph – analytical method consists in making a series of structural (structural) grids and graphs of rotation frequencies and thrusts. The purpose of structural grid analysis is to visually determine all possible options of kinematic variation and choose the most convenient option from them.

Contains the following information about structured networking:

• number of transmission groups;

• the number of passes in each group;

• mutual constructive arrangement of groups along the transmission chain;

• the order of kinematic connection of groups, that is, connections between connection characteristics and transmission ratios;

• adjustment range of the entire drive and group transmission;

• the number of steps of the frequency of rotation of the leading and driven shafts of the group transmission.

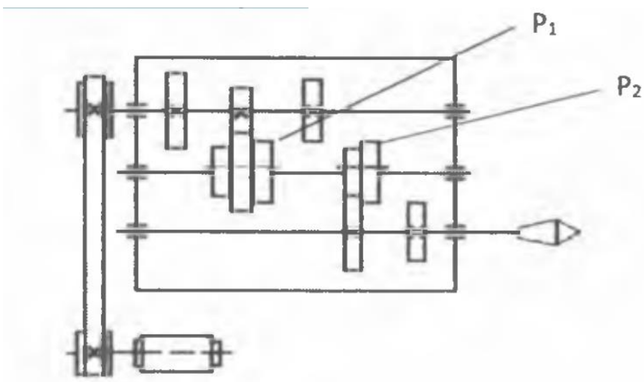
The graph of rotation frequencies is built to determine the exact values of the transmission ratios of all gears in the drive and the number of revolutions of all shafts. Based on the graph, it is possible to choose the most convenient values of these data. The graph of rotation frequencies includes all the information in the structural grid, and allows you to get the following additional information about the process:;

• the structural structure of the drive and the number of single (permanent) transmissions required to obtain the required frequency of oscillation of the final link;

• A single gear is located between group gears;

• gear ratios of all gears in the drive;

• rotation frequencies of all shafts and final joints when gears are connected to each other differently. Let's look at the procedure for creating a graph of structural networks and rotations on the example of the procedure presented in Fig. 1.



1 – fig. The kinematic scheme of the drive designed for six rotation speed

The structural formula of such a drive is $Z = 6 = 3 * 2$, the formula shows that the drive consists of two groups of gears (P_1 3 and P_2 2), so that group P_1 is located closer to the source of motion (electric motor). But the formula does not answer the question of which of the groups is the main one and which one is the pereborli, because the characteristics of the groups are unknown. If in the structural formula we indicate the characteristics of the group with numbers in square brackets, i.e. $Z = 6 = 3\ [1] \cdot 2\ [3]$, the result is a variant of the structural formula. Writing the formula in this way also explains that the first transmission group is structurally fundamental, and its geometric series denominator is equal to φ, and the second transmission group is the first pereboric group, whose series denominator is equal to φ^3.

For the structural variant of the procedure in Fig. 1, two structural formula variants are possible: $Z = 6 = 3\ [1] \cdot 2\ [3]$ and $Z = 6 = 3\ [2] \cdot 2\ [1]$. If the driving structure is changed, that is, the two – gear group is made the first structurally, and the three – gear group is the second in the constructive order, then the structural formulas are as follows: $Z = 6 = 2\ [1] \cdot 3\ [3]$, and $Z = 6 = 2\ [3]\ 3\ [1]$.

8 – Lecture: Factors for choosing the optimal option of machine tool kinematics

Study module units:

1. Choosing the optimal option of machine tool kinematics

2. The largest adjustment range of the group transmission

We will consider the choice of the optimal option of the kinematic structure of the machine tool in the following example: a) the number of spindle rotation frequencies $Z = 12$; b) the denominator of a geometric progression series φ = 1,26; d) number of spindle revolutions, rev/min: $n_1 = 50$, $n_2 = 63$, $n_3 = 80$, $n_4 = 100$, $n_5 = 125$, $n_6 = 160$, $n_7 = 200$, $n_8 = 250$, $n_9 = 315$, $n_{10} = 400$, $n_{11} = 500$, n_{12}: = 630.

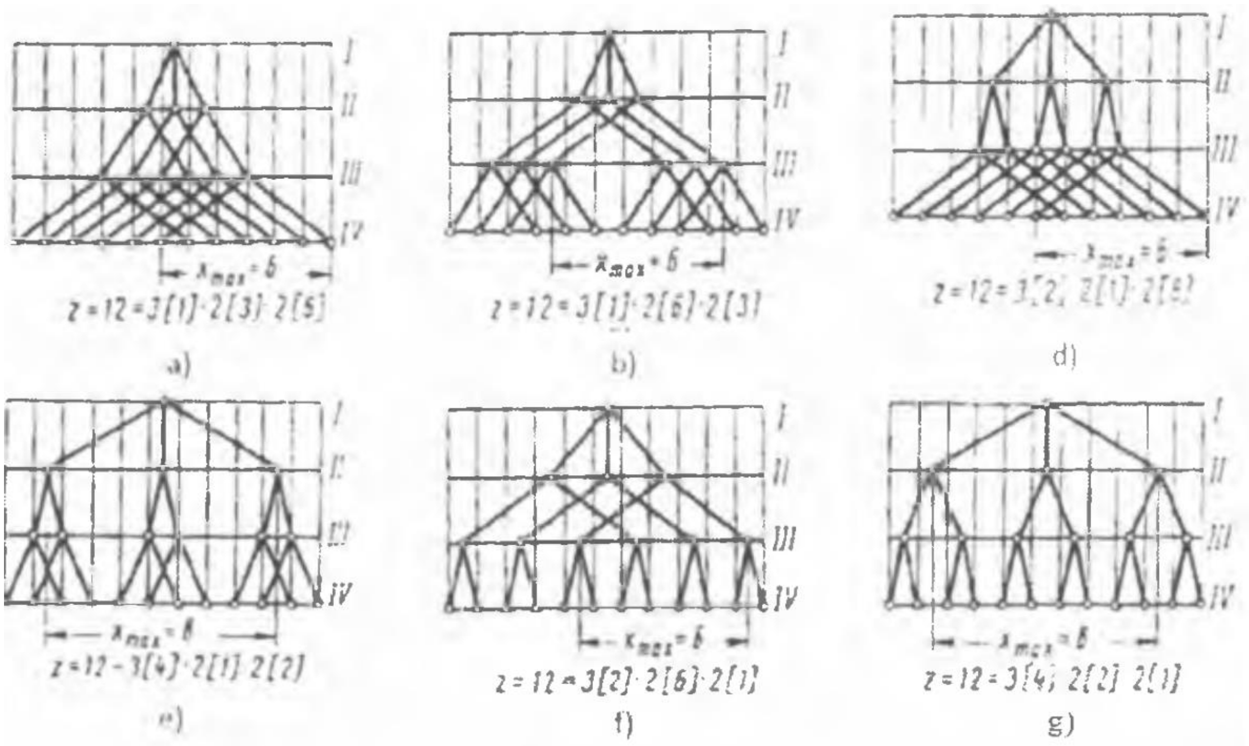
For the number of revolutions Z = 12, five different structural (structural) formulas of kinematics can be made (3 · 2 · 2; 2 · 3 · 2; 2 · 2 · 3; 3 · 4 and 4 · 3), and each of them has its own kinematic options are available. The total number of variants is 22.

When choosing the optimal option for the structural mesh of the gearbox, it is necessary to take into account the following:

Regardless of the order of connection of the extension group, the range of adjustment of the last perebor group is the largest, therefore, determining the adjustment range of the last perebor group for each variant of the structural mesh and $\frac{i_{max}}{i_{min}} \leq 8$ Any variant that does not meet the condition should be excluded from further calculations.

The magnitude of the torque on the shafts is $M_k - 975 - \frac{N}{n}\eta$, therefore, as the rotation frequency n decreases (when the power $N = const$), the torque increases and, accordingly, the dimensions of the driving details also increase. Structural webs with denser beams in early transmissions have smaller spans of intermediate shafts. For this reason, the calculated minimum rotations for the same maximum number of rotations of the shaft will be large (from this point of view, a hinge – shaped structure will be convenient). For our example, first options “a” and then “d” will be most convenient.

It is best to select the group with the smallest number of gears as the last gear group so that the largest adjustment range of the group gear is the smallest. This can be clearly seen in Figure 1.



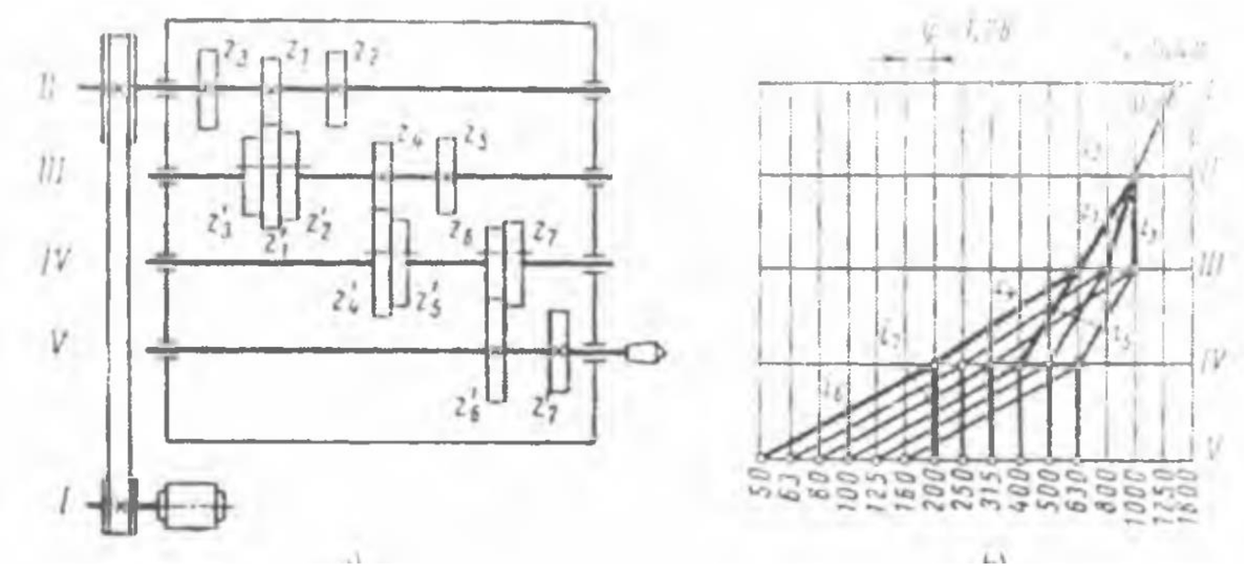
1 – fig. Structural mesh options for Z = 12 = 3 · 2 · 2

Taking into account the above, the optimal option of the structural grid for the considered example is option “a”. A graph of the number of rotations is constructed for the selected optimal variant of the structural grid and the developed kinematic scheme (Fig. 2).

1. When constructing a graph of rotation frequencies, the points on the intermediate shafts should be selected in such a way that the transmission ratios in them should be within the permissible limits of $i_{max} \leq 2$ and $i_{min} \geq ¼$, that is, the number of intervals between the points of the line indicating the transmission at the selected φ value is 1 – in the table should not exceed the specified amount.

Table 1

Extensions	number of intervals for *φ*						
	1,06	1,12	1,26	1,41	1,58	1,78	2,0
Decreasing	24	12	6	4	3	2	2
Increaser	12	6	3	2	1	1	1



2 – fig. The kinematic scheme of the method (a) and the graph of the number of revolutions (b) for the kinematic variant Z = 12 = 3 [l] · 2[3] · 2[6]

2. In order to reduce the torque and, accordingly, the weight of the entire drive and its details, the intermediate shafts should have as high rotations as possible; this is achieved by using large gear ratios between the primary shafts of the drive and small gear ratios on the shafts close to the spindle. To reduce the weight of the transmission, it is desirable to reduce the number of gears in groups in the chain from the electric motor to the spindle. i.e. $P_a > P_b > P_c$ and so on. It is best to place single reduction gears close to the spindle.

3. It is not recommended to install three or more gears on the spindle, because it increases the bending of the spindle, increases vibrations and, as a result, reduces the quality of the machined surface. The wheels should be placed as close as possible to the front support of the spindle.

4. It is desirable to increase the characteristics of the group from the electric motor to the spindle, that is, if $Z = P_a \cdot P_b \cdot P_c \ldots P_k$, then $a < b < s < \ldots < k$.

5. It is desirable to achieve the required speed range Z with a small number of gear groups, because in this case the amount of shafts, bearings and other details is reduced.

6. In order to achieve significant economic efficiency, it is necessary to strive to reduce the number of gears used in boxes. This can be achieved by symmetrical arrangement of beams in the area of one extension group.

9 – Lecture: Speeds and thrusts to determine the number of teeth of gears in boxes

Study module units:

1. Determining the number of teeth of spur gears

2. Determining the number of teeth of spur gears

Distances between axles, number of teeth of pairs of adjacent wheels, modules and numbers of worm wheels are normalized in machine tool construction. Deviations from the distances specified by the norm are allowed in the following cases:

• there is a need to have a clear relationship between the angular or linear displacements of kinematically interconnected elements (in grooving, grooving, etc.);

• the distances between the axles are not constant (guitars of exchangeable wheels, cast – on wheels, etc.);

• the distances between the axes are determined by the coordinates of the machining locations (in multi – spindle boxes, etc.).

The normalized range of modules belongs to all types of gears. For wheels with helical and chevron teeth, it is allowed to use the default value of the modulus in the direction of the torus pitch.

Determining the number of teeth of spur gears

There are several ways to determine the correct number of teeth for a set of gears when the modules are the same.

1. <u>Analytical method</u> (least common divisor method). In this method, based on the constancy of the distances between the axles, the number of teeth is determined from the following formulas:

$$Z_x = 2Z_o \frac{f_x}{f_x + q_x}; \quad Z'_x = 2Z_o \frac{q_x}{f_x + q_x};$$

$$2Z_o = K * E; \; E_{min} = \frac{Z_{доп}(f_x + q_x)}{K f_x}$$

here: Z_x va Z_x^1 the number of teeth of leading and driven wheels: $2Z_0$ – the number of teeth of the adjacent wheel; f_x – picture of transmission ratio; q_x – denominator of transmission ratio; K – ($f_x + q_x$) the smallest divisor of the sum; E – whole number; Z_{dop} 17 – 18 – the minimum value of the number of teeth.

As an example, the calculation for determining the number of teeth for the kinematic scheme and the graph of the number of revolutions presented above (in the figure 8 in the lecture) is given below.

1. The smallest divisor of the sums ($f_x + q_x$) is determined. For this, the transmission ratios are expressed as simple fractions with the image f_x and the denominator q_x, while the quantity ($f_x + q_x$) must be divisible by simple multiples. Transmission ratios of group transmissions between shafts II and III

$$i_1 = \frac{1}{\varphi^2} = \frac{Z_1}{Z'_1} = \frac{1}{1.26^2} = \frac{1}{1.58} \approx \frac{7}{11}; \; i_2 = \frac{1}{\varphi} = \frac{Z_2}{Z'_2} = \frac{1}{1.26} \approx \frac{4}{5}; \; i_3 = \frac{1}{1} = \frac{Z_3}{Z'_3} = \frac{1}{1} \text{ ga teng.}$$

Demak, $f_1 + q_1 = 7+11 = 18 = 3{\cdot}3{\cdot}2$; $f_2 + q_2 = 4+5 = 9 = 3{\cdot}3$; $f_3 + q_3 = 1+1$

The smallest divisor of the sum ($f_x + q_x$) is: $K = 3 \cdot 3 \cdot 2 = 18$.

2. For transmission ratio i_1, E_{min} is equal to:

$$E_{min} = \frac{Z_{доп}(f_x + q_x)}{K f_x} = \frac{17(7+11)}{18 * 7} = 2{,}43$$

The found value is rounded up to an integer: E = 3.

3. Number of teeth of the wheel in the clutch:

$$2\,Z_o = K * E = 18 \cdot 3 = 54.$$

The calculated total is clarified according to the normal N21 – 5 (table 1) taking into account the module of the wheels and the distance between the centers.

4. The number of teeth of the wheels used is determined:

$$Z_1 = 2Z_o \frac{f_x}{f_x + q_x} = 54 * \frac{7}{7+11} = 54 * \frac{7}{18} = 21;$$

$$Z_1' = 2Z_o \frac{q_x}{f_x + q_x} = 54 * \frac{11}{7+11} = 54 * \frac{11}{18} = 33$$

$$Z_2 = 54 * \frac{4}{4+5} = 54 * \frac{4}{9} = 24;\ Z_2' = 54 * \frac{5}{4+5} = 54 * \frac{5}{9} = 30$$

$$Z_3 = 54\frac{1}{1+1} = 54 * \frac{1}{2} = 27;\ Z_3' = 27;$$

$$Z_1 + Z_1' = Z_2 + Z_2' = Z_3 + Z_3' = 21 + 33 = 24 + 30 = 27 + 27 = 54.$$

In the same way, the number of teeth is found for the remaining gear groups of the drive.

Table 1

(Normal N21-5)

O‘qlar orasidagi masofalarA, mm	Modullar											
	1	1,5	2	2,5	3	(3,5)	4	5	6	(7)	8	10
	Tishlar soni yig‘indisi											
30	60	(40)										
(36)	72	48										
45	90	60	(45)									
60	120	80	60	48	(40)							
75		100	75	60	(50)							
90		120	90	72	60	-	45					
105			105	84	70	60	-	(42)				
120			120	96	(80)	-	60	48	(40)			
135				108	90	-	-	54	(45)			
150				120	100	-	75	60	(50)			
180					120	-	90	72	60	-	(45)	
210						120	105	84	70	60	-	(42)
(225)							-	90	75	-	-	(45)
240							120	96	(80)	-	60	48
270								108	90	-	-	54
300								120	100	-	75	60
(315)									105	90	-	(63)
360									120	-	90	72
420										120	105	84
(450)											-	90
480											120	96

lzoh: 1 Dimensions in parentheses should be avoided as much as possible

2. The table shows the number of gear teeth

2. Table method

Determining the number of teeth of group gears by the tabular method simplifies the calculations somewhat and reduces the time spent on this practice.

For this purpose, the sum of the number of teeth of the leading and driven wheels ∑Z and specific tables are used depending on each transmission ratio.

Guruh uzatmalarining tishlar sonini aniqlash jadvallari

φ	Σz															
		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1		25		26		27		28		29		30		31		32
1,06								27		28		29		30		31
1,12			24		25		26		27		28			29		30
1,19		23					25		26		27		28		29	29
1,26		22		23		24		25			26		27		28	
1,33			22			23		24		25			26		27	
1,41			21		22		23			24		25			26	
1,5		20		21			22		23			24				
1,58				20		21			22		23	23		24		
1,68			19			20		21			22			23		24
1,78		18			19			20		21			22			23
1,88				18			19			20		21	21		22	22
2			17			18			19			20			21	
2,11		16			17			18			19			20		
2,24				16			17			18			19	19		
2,37			15			16			17				18			19
2,51					15			16				17			18	
2,66			14				15			16	16			17		
2,82													16			
2,99				13				14				15				16

Jadval davomi

φ	ΣZ															
		65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
1			33		34		35		36		37		38		39	
1,06			32		33		34		35		36		37		38	
1,12			31		32		33		34		35		36	36	37	37
1,19			30		31		32		33		34	34	35	35		36
1,26		29	29		30		31		32		33	33		34		35
1,33		28			29		30		31			32		33		34
1,41		27		28	28		29		30	30		31		32		33
1,5		26		27	28		28		29	29		30		31	32	
1,58		25		26			27		28	28		29		30	30	
1,68				25		26	26		27	27		28		29	29	
1,78				24		25	25		26			27			28	
1,88			23	23		24			25			26			27	
2			22			23			24			25			26	
2,11		21	21		22	22		23	23		24	24			25	
2,24		20			21			22	22		23	23		24	24	
2,37				20	20			21			22			23	23	
2,51			19	19			20	20		21	21			22	22	
2,66			18			19	19			20	20			21		
2,82		17			18	18			19	19			20	20		
2,99				17	17			18	18			19	19			20
3,16			16	16			17	17				18				19
3,35						16	16				17				18	18
3,55										16	16			17	17	
3,76									15	15			16	16		

Jadval davomi

○	Σz															
		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
1		40		41		42		43		44		45		46		47
1,06		39		40	40	41		42	42	43	43	44	44	45	45	46
1,12		38	38	39		40			41		42		43	43	44	44
1,19			37	38		39		39	40	40	41	41		42		43
1,26			36	37	37			38		39		40	40	41	41	
1,33		34	35	35		36		37	37	38	38		39		40	40
1,41		33	34			35	35		36		37	37	38	38		39
1,5		32		33	33		34		35	35		36		37	37	38
1,58		31		32	32		33	33		34		35	35		36	
1,68		30	30		31		32	32		33	33		34		35	35
1,78		29	29		30	30		31			32		33	33		34
1,88		28	28		29	29		30	30	31	31			32	32	
2			27			28		29	29		30	30		31	31	
2,11			26			27			28	28		29	29		30	30
2,24			25			26	26		27	27		28	28		29	29
2,37			24			25	25		26	26			27	27		28
2,51		23	23			24	24		25	25			26	26		27
2,66		22	22			23	23		24	24			25	25		
2,82		21	21			22			23	23			24	24		
2,99		20			21	21			22	22			23	23		
3,16		19			20	20			21	21			22	22		
3,35				19	19			20	20	20			21	21		
3,55			18	18	18			19	19			20	20	20		
3,76		17	17				18	18				19	19			
3,98		16	16			17	17				18	18	18			19

Jadval oxiri

Q	ΣZ														
		95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
1			48	49	49	50	50	51	51	52	52	53	53	54	54	55
1,06		46	47	47		48		49		50		51		52		53
1,12		45	45	46	46	47	47		48		49		50		51	51
1,19			44	44	45	45	46	46		47		48		49	49	50
1,26		42		43		44	44	45	46		46		47	47	48	48
1,33		41	41		42		43	43	44	44		45		46	46	47
1,41			40	40		41		42	43	43			44	44	45	45
1,5		38		39	39	40	40		41	41	42	42		43	43	44
1,58		37	37		38	38	39	39		40	40	41	41	41	42	42
1,68			36	36		37	37	38	38		39	39		40	40	41
1,78		34		35	35		36	36	37	37		38	38		39	39
1,88		33	33		34	34	35	35		36	36		37	37		38
2		32	32		33	33		34	34		35	35		36	36	
2,11			31	31		32	32		33	33		34	34		35	35
2,24				30	30		31	31		32	32		33	33	33	34
2,37		28		29	29			30	30		31	31		32	32	32
2,51		27			28	28		29	29			30	30		31	31
2,66		26	26		27	27			28	28		29	29	29		30
2,82		25	25			26	26		27	27	27		28	28	28	
2,99		24	24			25	25			26	26	26		27	27	
3,16		23	23			24	24	24		25	25	25		26	26	26
3,35		22	22			23	23	23			24	24			25	25
3,55		21	21			22	22	22			23	23	23		24	24
3,76		20	20			21	21	21			22	22	22		23	23
3,98		19	19			20	20	20		21	21	21	21		22	22

After determining the number of primary teeth. it is passed to the determination of the actual rotation frequencies of the spindle. Spindle for that! The kinematic balance equation of the rotation chain is drawn up in a spread. For example, the equation for the considered procedure will look like this:

$$n_{shp} = 1440\ \frac{100}{144}\begin{vmatrix}\frac{21}{33}\\ \frac{24}{30}\\ \frac{27}{27}\end{vmatrix}\begin{vmatrix}\frac{18}{57}\\ \frac{29}{46}\end{vmatrix}\begin{vmatrix}\frac{18}{72}\\ \frac{45}{45}\end{vmatrix}$$

Actual rotation frequencies calculated from the kinematic balance equation are written in a separate table (table 3).

Table 3

	Standart aylanish chastotasi (N11-1 normali bo'yicha), $n_{ст}$	Haqiqiy aylanish chastotasi, n_{shp}	Og'ish Δ, %
n_1			
n_2			
.....			
.....			
n_7			

The relative deviations of the spindle rotation are calculated from the formula:

10 – Lecture: Speed boxes of special structure. Gearboxes with interchangeable gears. Gearboxes with perebors

Study module units:

1. Speed boxes of special structure

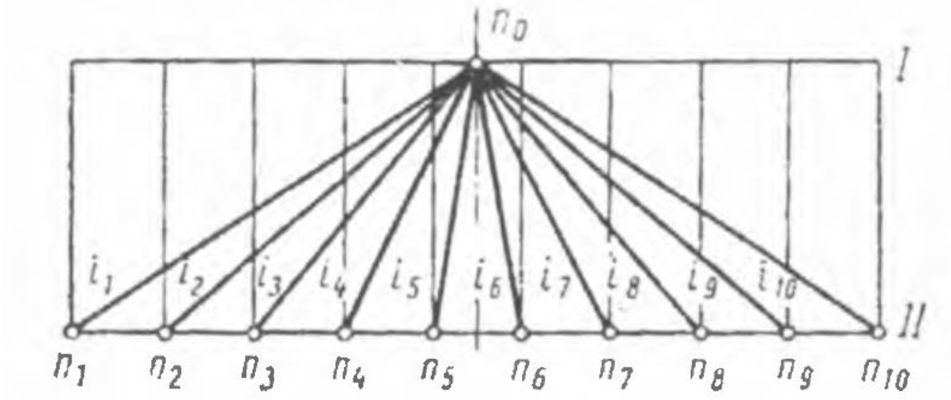
2. Interchangeable gear wheel speeds

3. Gearboxes with perebors

Interchangeable gears are common on special and specialty machines. To reduce the number of interchangeable wheels, they are made reversible, meaning that a pair of wheels can provide two speeds by interchanging the wheel positions. Therefore, in such boxes, the rays are placed symmetrically in the rotation graph (Fig. 1).

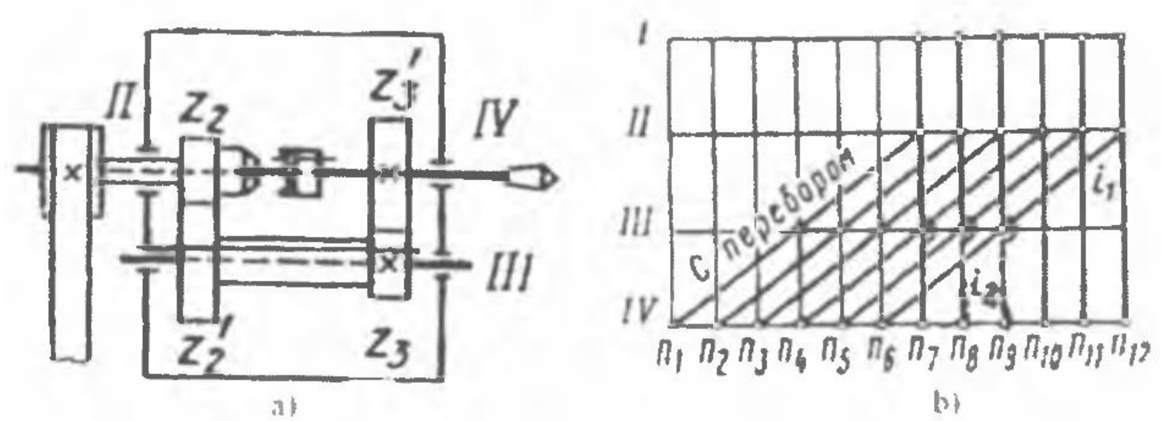
The following inter-axle distances are accepted for single – pair exchangeable wheel mechanisms (in other words, they are called “guitars”) in workshop construction: $A_1 = 36$ m; $A_2 = 45$ m; $A_3 = 60$ m from here; – extension module. So, the sum of the teeth of the exchange wheels can be equal to:

$$\sum Z = Z + Z' = \frac{2A}{m} = 72; 90; 120;$$



1 – fig. Graph of spindle revolutions for a gear box with interchangeable wheels

Perebores in main drive chains serve to obtain low frequencies of spindle rotation. The kinematic diagram of the machine speed box with Perebor and the graph of the number of revolutions are given in Fig. 2.



2 – picture. Kinematic diagram of a gearbox with a bore (a) and a graph of rotation frequencies (b)

Perebor transmission ratio: $i_{per} = i_1$ x $i_2 = \frac{Z_1}{Z_2'}$ x $\frac{Z_3}{Z_3'}$ =

TAYANCH SO'ZLAR

Material, bimetall, struktura, kompozitsion, mikrostrutura, karroziya, nometall, metall, elostomer, noorganik, to'ldiruvchilar, texnologiya, qoplama, polimer, asos, xossa, mexanik, fizik, alyuminiy, nikelg', po'lat, matritsa, titan, magniy, mashinasozlik, ingredientlar, rentgenotexnika, mikroskop, mikroqattiqlik, elektrokontaktli, g'ovak, keramika.