TASHKENT INSTITUTE OF TEXTILE AND LIGHT INDUSTRY

5320900- Design and technology of products light industry (textile industry)

towards baccalaureate

DIPLOMA PROJECT

Theme **Project technological process of canvas fabrics on base of "SHAMS" weaving mill**

The Student : **Ilyosov O.R.**

Faculty **TSTF** group **7-12**

Advisers:

1. ***Technological part*** ***Ass.prof. Baymyratov B.H.***
   (composition DP, full name consultant, date and signature)

2. ***Scientific part*** ***Ass.prof. Baymyratov B.H.***
   (composition DP, full name consultant, date and signature)

3. ***Methodical part*** ***Ass.prof. Baymyratov B.H.***
   (composition DP, full name consultant, date and signature)

4. ______
   (composition DP, full name consultant, date and signature)

5. ______
   (composition DP, full name consultant, date and signature)

The supervisor of studies ***Ass.prof. Baymyratov B.H.*** ______ ______

full name *date* *signature*

Head of department ***Ass.prof. Kadirova D.N*** ______ ______

full name *date* *signature*

Tashkent -2016

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«Confirm»
The Dean of faculty

______ __________________

«______»__________201 y.

TASKS OF THE DIPLOMA PROJECT

Departament: **“TECHNOLOGY OF TEXTILE CLOTHS”**______________

Head of department____ ***Ass.prof.   Kadirova D.N***________________________
(full name and signature)

Adviser: ***Ass.prof.Baymyratov B.H.`***__________ __________________________

It is accepted to task performance:_____________________________________
(date)

The signature of the student ____

_______**TASHKENT INSTITUTE TEXTILE AND LIGHT INDUSTRY**___
(name of institute)

Tasks on preparation of the degree project

To The student _______________________ **Ilyosov O.R** ___________________

1. Name of project __**Project technological process of canvas fabrics on base of "SHAMS" weaving mill**

It is confirmed by the order №_453-T_the rector of the Institute from 12.12. 2015 year.

2. Term of protection of the complete degree project____

3. Primary date on the project__**Technical datas of canvas fabric, technological techniques of "Shams" weaving mill**____ ___________________________

4. The name of parts carried out in the degree :
   A)____ ***Technological part***_____________________________________
   B)____ ***Scientific part*** ____
   C ____ ***Methodical part*** _______________________________________
   D) ____

5. The list of obligatory descriptive - geometric materials :

_____**Prezentation materials regarding to the project.**__________________

6. Advisers of parts of the project:___***Ass.prof. Baymyratov B.H.***____________

7. Date of the set task:____

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INRODUCTION

Entering the path of independent development of diverse activities as the President of the Republic of Uzbekistan Islam Karimov with his speeches in 2015, articles and it should be noted that the publication of the works of importance. In this game, every citizen can find the answer to any self-interest. The supervisor has never been the most complex and difficult problems, avoid unnecessary attention. Among them are questions about its role and functions of the previous. They are reflected in many of the writings and speeches of the president. This is seen as the most pressing problems. Before his remarks on the subject of discussions, conclusions based on scientific evidence of ownership, noting that the methodological and stylistic direction [1].

President of Uzbekistan Islam Karimov, one of his first works, independence and development in his description of the work: Uzbekistan - a country with a great future. It is an independent, democratic and legal state. This is based on the principles of humanism, national origin, religion, social status, regardless of their political beliefs human rights and freedoms granted by the State 13.

In the same paper, he said: "People's source of state power He wants to determine the policy of the state. Such policies and social welfare, should be aimed at ensuring a decent life for all citizens of 14, he said.

The history of the Light Industry of Uzbekistan traces back to the times when the Great Silk Road crossed Uzbekistan’s territory, and the goods made by Uzbek handicraftsmen, especially yarn and fabrics were widely known. The Light Industry of Uzbekistan, being today one of the most promising branches of the national economy, has a special importance for the Republic, providing a significant share of employment and a considerable volume of production of industrial and consumer goods. As part of the administrative reforms that have been implemented in all the industries of the Republic, the branches of silk and footwear production were separated and the State Joint Stock Company O’zbekyengilsanoat inherited a major portion of the Light Industry. Today, the

Company unites more than 120 textile, clothing and apparel enterprises, as well as porcelain manufacturers. SJSC O'zbekyengilsanoat has shares in the charter capital of 40 joint-stock companies, owning from 2.8 up to 25 percent. It is also co-founder of a number of joint ventures. Other enterprises are associate members of the Company. Priorities for the Company include the determination of a long term strategy for the industry's steady development, provision of all possible support in attracting foreign investments, establishment of new enterprises, implementation of modernisation and re-equipment of the existing capacities, advanced training of personnel and promotion of domestic products to the international markets. Enterprises united by SJSC O'zbekyengilsanoat have capacities to produce a wide range of cotton and semi-wool yarn and fabrics, non-woven fabrics, carpets and rugs, medical cotton, sewing threads, clothing and apparel, hosiery and porcelain products.

Despite some difficulties during the transition period, a sharp recession of production was prevented. From 1994 until 2004, the value of output of consumer goods increased from US$27 million to almost US$175 million, and that of industrial goods from US$29 million to almost US$445 million. During the same period, more than 100 enterprises have been privatised. In 2004, the state disposed of shareholdings ranging from 20 percent to 67 percent in 11 enterprises. The processing of cotton fibre has changed greatly. Previously the share of this most valuable raw material used in domestic processing was relatively small. The proportion has risen gradually, from 13 percent in 1994 to 28 percent in 2004. However, the most important indicator that demonstrates a dynamic development of the industry is the stable inflow of direct foreign investment. Before 1991 there were only 4 large textile complexes operating in the Republic, but since 1995 the value of foreign investment attracted into the industry is already more than US$800 million. More than 44 projects have been implemented and 36 joint ventures have been established with partners from Germany, Switzerland, Japan, Turkey, the USA, South Korea and elsewhere.

In 2004 alone, O'zbekyengilsanoat implemented 17 new projects, valued at US$180 million. Of this sum, direct foreign investment and credits (not under government guarantee) accounted for US$99.4 million, which is 2-1/2 times more than in 2003. The annual processing capacity represented by these investments is 51,000 tonnes of raw cotton and export potential is valued at US$147 million.

As a result of these initiatives, the share of exports in the turnover of O'zbekyengilsanoat has increased from 17 percent to 70 percent. Export earnings have grown from US$7.76 million in 1994 to the present day's level of US$279.8 million. The year-on-year growth in 2004 alone was more than 31 percent.

This growth has occurred hand-in-hand with a change in the export product mix, from mainly semi-finished textile products, such as yarn and grey cloth, to incorporating an increasing volume of clothing, which in 2004 accounted for 7.8 percent of the total.

More changes lie ahead for the Uzbek industry, as it strives to meet the requirements of the domestic market while at the same time exploiting the export potential, by widening the range of goods made available and improving quality.

The attractiveness of investment opportunities is assisted by availability of stable supplies of raw materials, qualified and relatively inexpensive labour resources, but primarily, by the favourable conditions created by the government. These conditions include a stable legal framework in which companies can operate, elimination of excessive external intervention in economic activity, simplification of licensing, registration and certification procedures, together with privileges, preferences and guarantees for foreign investors.

For example, the state guarantees and protects by law all the rights of foreign investors, and the legislation effective at the time the investment was made will remain in force for a period of ten years if subsequent legislation should in any way worsen investment conditions.

CHAPTER I.   LITERATURE REVIVE

1.1. Types of textile fabrics

In the first part of this paper, a review was given on the fibres used in the production of technical textile. Although it is difficult to define the term "technical" and the scope of the term "textiles", Fig. 1 summarizes the principle mate-

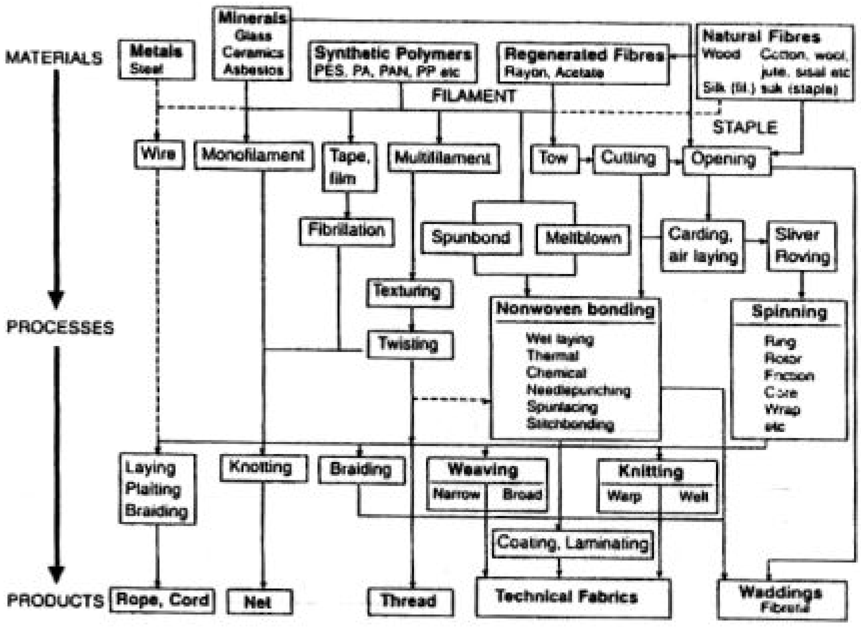


Fig. 1. Materials, processes and techniques employed in production of technical textile

rials, wide range of processes employed in the manufacture of technical textiles and final products which are commonly regarded as falling within "technical textile structures manufacturing" [2].

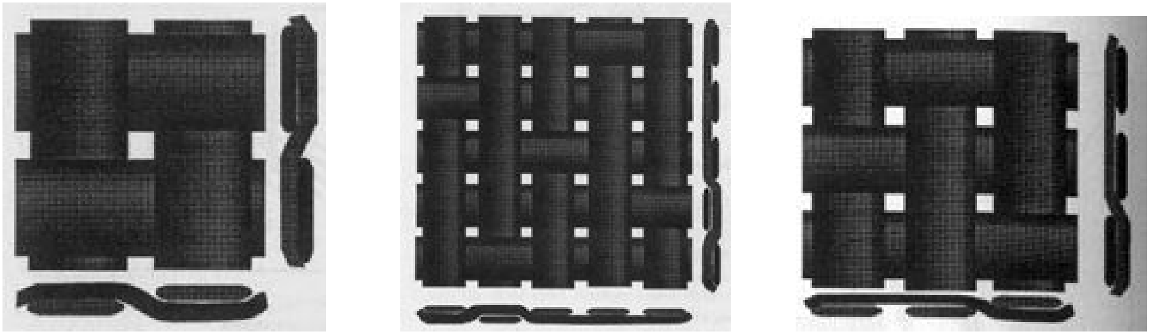
In this second part of the paper the basic technologies and the textile structures used as technical textiles will be briefly described. It is worth mentioning that for instance, within the composite industry (which is a great consumer of technical textile structures) braided, woven, knitted, stitched and nonwoven textiles made of carbon glass, PA, PET, PAN, PE, aramid and other fibers are widely used [3].

WOVEN FABRICS

Woven structures have the greatest history of application in textile manufacturing. Conventional woven fabrics consist of two sets of yarns mutually interlaced into a textile fabric structure. The threads that run along the length of the fabric are called warp or ends, while the threads that run along the width of the fabric from selvedge to selvedge are referred as weft or picks. Warp and weft yarns are mutually positioned under the angle of 90°. The number of warp and weft yarns per unit length is called warp and weft density. The warp and weft yarns in a woven fabric could be interlaced in various ways that is called a weave structure. A crimp is the ratio of the yarn actual length to the length of the fabric it traverses. The crimp influences the fiber volume fraction, fabric thickness and fabric mechanical properties [4]. A cover factor is the fraction of the total fabric area that is covered by the component yarn. Fabric area density and cover factor influence strength, thickness, stiffness, stability, porosity, filtering quality and abrasion resistance of fabrics [5].

The structure where warp yarns alternatively lift and go over across one weft yarn and vice versa is the simplest woven structure called plain weave (Fig. 1.2a). Other most common structures are twill and satin weave. Twill is a weave that produces diagonal lines on the face of a fabric (Fig 1.2b). The direction of the diagonal lines viewed along the warp direction can be from upwards to the right or to the left making Z or S twill. Compared to plain weave of the same cloth parameters, twills have longer floats, fewer intersections and a more open construction.

There are many variations of twill construction (the smallest repeat is three in warp and weft direction) but the technical application of twills is restricted to simple twills. A weave where binding places arranged to produce a smooth fabric surface free from twill lines is called satin (Fig 1.2c). The distribution of interlacing points must be as random as possible to avoid twill lines. The smallest repeat of satin weave is 5, while the most popular are satins of 5 and 8 repeats. The 5 ends satin is most frequently used for technical applications for providing firm fabric although having moderate cover factor [6].



a) b) c)

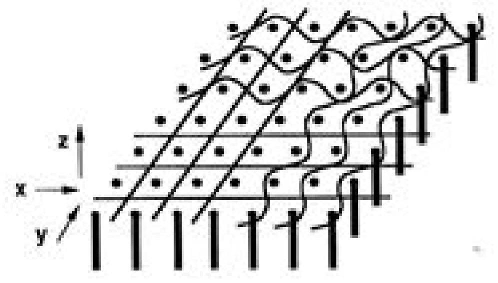
Fig.1.2. Schematic illustration of plain (a), twill (b) and satin (c) weave structures

Mechanical properties of woven fabrics, which are especially important for technical textile, depend on: type of raw materials, type and count of warp and weft yarns, yarn density and the type of weave structure. The strength of the woven fabric is the highest in warp and weft direction, while in bias, the fabrics show lower mechanical properties, higher elasticity and lower shear resistance. In order to increase the mechanical properties, a triaxial woven structure that consists of three systems of threads: one system for weft and two systems for warp, is constructed [7]. Warp threads in a basic triaxial fabric are interlaced at 60° and the structure is fairly open with a diamond shaped centre (Fig. 1.3a). A modification of basic triaxial fabric is basket weave that forms a closer structure with different characteristics (Fig. 1.3b).

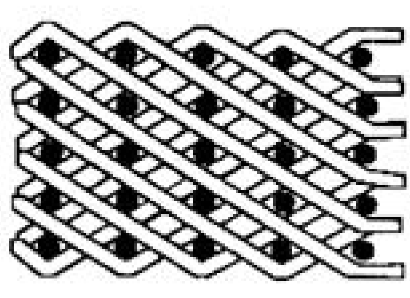
a) b)

Fig. 1.3. Schematic diagram of traxial woven structure: basic weave (a) and basket weave (b)

Due to specific arrangement triaxial fabrics can not reach higher thread densities and they obtain values from 3.5 to mostly 7.4 cm –1 . In further demanding for new structures of high mechanical properties for technical application, the new tetra axial fabrics where four sets of yarns are interlaced at 45° at each other are introduced. So far to our knowledge, there is no commercial loom for production of tetra-axial fabrics on the market. Since the interlacing points are fixed into the fabric structure, these fabrics exhibit high shear resistance. Woven fabrics have broad application in all segments of technical textile production. Conventional and triaxial fabrics fall into the group of 2-D fabrics (the term is used in composite industry) [8]. However the application of woven fabrics in production of technical textile (as reinforcement in composite production in particular), has inflicted the need of production of 3-D fabrics, which have high mechanical properties in x, y and z directions. The textile technology has been involved with the construction of 3-D shells, but these are rather flexible structures for clothing and similar purposes. For production of strong 3-D composite construction, cutting, sewing and joints should be avoided as much as possible. True 3-D weaving can be accomplished on special machines as already developed [9, 10, 11]. The simplest case of such a structure where the warp is crossed by two sets of wefts is shown in Fig. 4a. A woven structure where multilayer warp moves between top and bottom of material thus providing x and y directions at an angle of 45°, and weft yarns crossing between the warp, providing z direction, is shown in Fig. 1.4b.



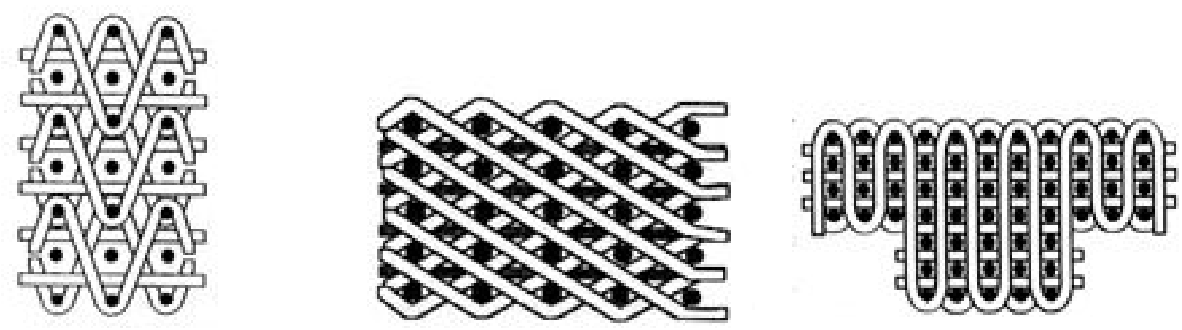
a)



b)

Fig. 1.4 3-D weaving with warp in *z* direction and wefts inserted in *x* and *y* directions (a), multilayer 3-D weave with warps in *x* and *y* directions and weft in *z* direction (b)

In general, a variety of 3-D structures can be accomplished. For example the warp yarns can go only part way across the whole material (Fig. 1.5a), or one set of warp yarn can be introduced in the axial direction and one set angled, thus providing yarns in four different directions (Fig. 1.5b). The later structure possesses higher control of the directional properties of the material. Shaping of 3-D weaves can be accomplished by varying the warp layers in width thus creating the required cross section for example in a form of T-beam (Fig. 3c) [1



a) b) c)

Fig. 1.5. Variants of 3-D multilayer weaving: partial interlocking of layers (a), two sets of warp yarns (b), shaping of 3-D weaving by varying warp layers (c)

KNITTED FABRICS

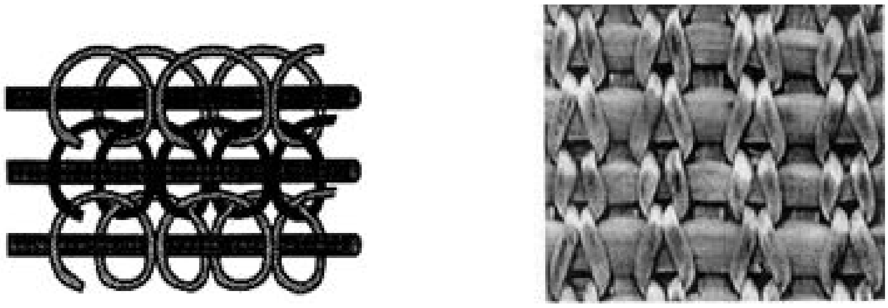
Knitted fabrics are textile structures assembled from basic construction units called loops. There exist two basic technologies for manufacturing knitted structures: weft and warp knitted technology. 2.1. Weft knitted fabrics The repeating unit of the knitted fabric is called loop. The feature of the weft knitted fabric is that the loops of one row of fabric are formed from the same yarn. A horizontal row of loops in a knitted fabric is called a course and vertical row of loops is called a wale (Fig. 1.6a). The stitch density is the number of stitches per unit area in the knitted fabric.

The stitch length is the length of a yarn in a knitted loop and is an important factor that determines the properties of the weft knitted fabric. The cover factor is a number that indicates the extent to which the area of a knitted fabric is covered by the yarn. The fabric area density is a measure of the mass per unit area of the fabric [13]. In weft knitted fabrics the loops are formed successfully along the fabric width. The yarn is introduced more or less under the right angle regarding the direction of the fabric formation. The simplest weft knit structure produced by the needles of one needle bed machine is called plain knit or jersey knit (Fig. 6a). The plain knit has different appearance of both sides of the fabric. A structure produced by the needles of both needle beds is called rib structure or double jersey (Fig. 1.6b) having the same appearance on both sides of the fabric [14]

a) b)

Fig. 1.6. Schematic illustration of plain (a) and rib (b) weft knitted structure

The weft knitted fabrics are manufactured in a circular or flat form on the circular and flat knitting machines. Every form can have various configurations depending on the machine performance. It is interesting that the process of yarn conversion into a weft knitted fabric can be performed from only one yarn package, which is a substantial advantage regarding the process preparation. Due to the curved structure of the loop, the weft knitted structures are mostly elastic, stretchable and easily deformed. Regarding application for composite reinforcement this structure has a disadvantage since the stress is transmitted for only short lengths along fibers before being interrupted by the weaker matrix. So compared to woven fabric basic weft knitted structures have more inferior mechanical properties especially regarding technical applications [15]. However, there is a possibility of introducing oriented yarns into the structure of weft knitted fabric thus creating a structure of high mechanical properties for composite application. The Fig. 1.7a shows rib weft knitted fabric with inserted yarns in a course direction (uniaxial) and the Fig. 1.7b shows a biaxial plain weft knitted structure with inserted yarns in a wale and course direction created on a specially developed and modified flat knitting machine [16].



a) b)

Fig. 1.7. Rib knit structure with inserted yarns in a course direction (a), photograph of plain knitted structure with inserted yarns in a wale and course direction (b)

The newest generation of flat knitting machines with computer controlled functions makes possible the individual selection of knitting needles, thus enabling creation of integral 3-D knits directly on the machine (Fig. 8) and various shaping methods of the fabric. So, regarding the application for the technical textile flat knitting technology shows very high potential [17, 18].

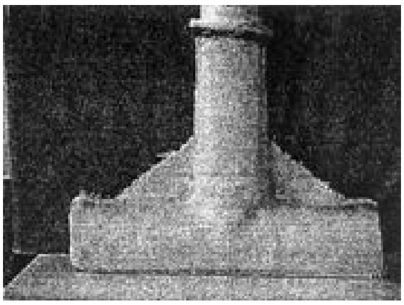


Fig.1. 8. Integral 3-D weft knitted fabric

The shaping methods include a structural variation and a variation of the number of apertures in course and wale directions. The structural variation means the variation of pattern and stitch length [19] Shaping modification effect can also be achieved by varying the number of stitches in course and wale directions. The variation of the number of stitches in the course direction takes place with throw off or increasing and decreasing. For the manufacturing of the fully-fashioned biaxial reinforced fabric the variation of number of stitches in the wale direction could be necessary. This is achieved by selecting the needles in certain courses not to participate in stitch formation but to hold the formed loops and keep them in the needle head until they are employed again. The Fig. 9 depicts various possibilities of shaping by the biaxial weft knitting technology

Variation of the number of stitches in — Variation of the

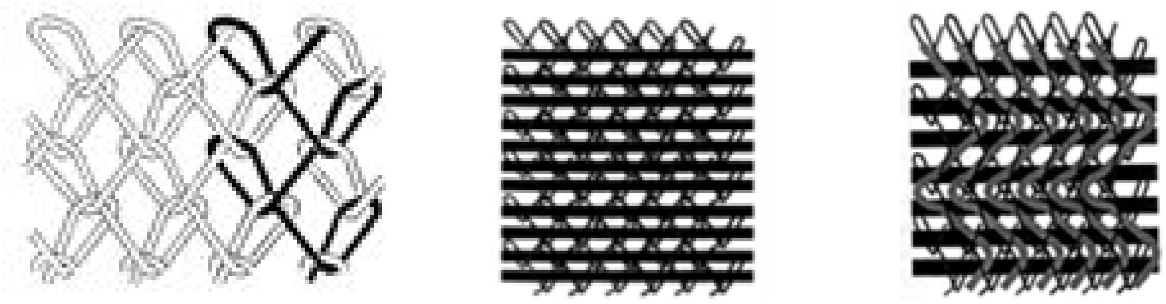
course direction — wale direction — stitch length — stitch pattern

Fig 1.9. Various possibilities of shaping

WARP KNITTED FABRICS

In warp knitted technology every loop in the fabric structure is formed from a separate yarn called warp mainly introduced in the longitudinal fabric direction. The most characteristic feature of the warp knitted fabric is that neighboring loops of one course are not created from the same yarn (Fig. 1.10a) [20]. To accomplish the warp knitted structure every needle along the width of the fabric must receive yarn from the individual guide. The function of the guide is to lead and wrap the warp yarn around the knitting needle during the knitting process. The loop structure in the warp knitted and weft knitted structure is similar in appearance.

The warp knitted structure is very flexible and regarding construction it can be elastic or inelastic. The mechanical properties are in many cases similar to those of woven structures. The best description of warp knitted fabrics is that they combine the technological, production and commercial advantages of woven and weft knitted fabrics [21]. While weft knitted technology is mostly involved in apparel production, warp knitted technology is substantially engaged in manufacturing structures for technical application. Of a special interest for technical applications are structures with inserted weft yarns called a weft inserted warp knitted fabric (Fig. 1.10b) and a multi bar weft knitted fabric (Fig. 1.10c) [22, 23].



a) b) c)

Fig. 1.**10.** Schematic presentation of warp knited structures: basic warp knit structure (a), weft inserted warp knit (b) and multibar weft inserted warp knit (c)

In the first structure reinforcing yarns are inserted in a weft direction, while in a latter structure-simultaneously in warp and weft directions. The reinforcing yarns are introduced in a structure with no crimp, thus maximizing mechanical properties making them comparable and even stronger than the woven fabric [24]. The warp knitted structure that has straight load bearing yarns introduced in a fabric structure in four directions (warp, weft and diagonal direction) is called a multiracial warp knitted structure or a DOS-directional oriented structure (Fig. 1.11). One set of machine operations lays down sheets of reinforcing yarns and then these are passed into the knitting zone, where they are held together by the stitches of knitting yarns. If the aim is to reinforce composite to withstand forces in all directions this structure is particularly suitable [25].

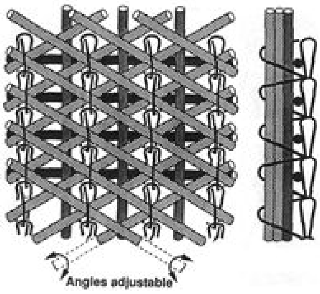


Fig. 1.**11.** Multiracial warp knitted fabric having inserted oriented yarns in warp, waft and diagonal directions

NONWOVEN FABRICS

Nonwoven technology is a newer one regarding other technologies of fibre forming assemblies. It is difficult to give a complete definition of the nonwoven fabrics since the range of the products is broad, the manufacturing techniques substantially differ and still the products are defined as nonwovens. A broader definition is that nonwoven is a flexible structure manufactured by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, thermal or solvent means and combination of thereof [26]. Manufacturers of nonwovens use a somewhat broader definition which enfolds a greater number of products. Nonwoven manufacturing can be generally divided into two stages: (i) the preparation of the fibers into forms suitable for bonding and (ii) the bonding process itself. There exist a number of techniques for preparing the form and for the bonding process that greatly influences the product features. By combination of the two stages a great range of manufacturing lines and a great range of final properties can be accomplished. General feature of the nonwoven process is that it is done in a continuous manner directly from the raw material to the finished fabric.

This means that manufacturing costs are low since there is no need for material handling as in older fabric forming technologies. Common element in the first stage of nonwoven technology is to make the first thin layer of fibers which is called a web. This is followed by the process of batt forming i.e. laying up several webs on top of each other. In the second stage the but goes to bonding.

Regarding the fibre arrangement in the but two possibilities exist: – batt with oriented fibres, mainly in one direction (parallel laying) and in two directions (cross laying); – batt with isotropic arrangement of fibres. Regarding the methods of but production the several techniques are known: – dry method (mechanical, aerodynamical or combination of both); – chemical method (spinning or extruding); – wet method (hydrodinamical). The bonding of the web can be accomplished using the following techniques: – mechanical bonding (needlepunching, stitch bonding, hydroentanglement, airentanglement etc.); – chemical bonding of fibres by adhesive agents with various techniques (injecting, partially or completely impregnation, application printing and other); – thermal technique of welding by application of thermoplastic fibres and bulking fibres, foils etc. [27]; – combination of various techniques. In the needle punching process, the batt first passes through a stripper plate for reducing the bulk, and then the needle board consisting of punching needles is lowered thus penetrating the web through the thickness resulting in dense, coherent mat. The needle punching nonwoven is employed in the production of brittle matrix composites.

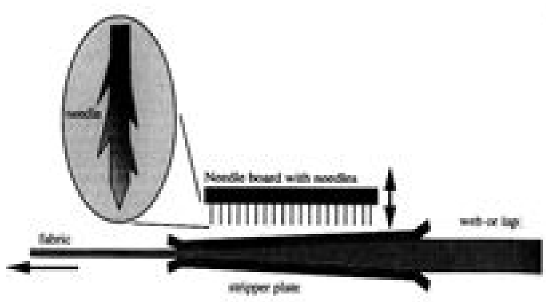


Fig. 1.**12.** Schematic illustration of the needle punch process

The nonwovens have a broad range of performance: from light materials for wadding and insulation where the fibre volume ratio equals only 2–3 %, to compact fabrics for reinforcement where the fibre volume ratio comes up to 80 %. Nowovens emerged in the middle of the previous century and have undergone a remarkable growth in the past twenty years, from disposable products of hard handle to high tech-purpose tailored products of different qualities, such as babies' napkins. The range of products is great [28]. The technology that made enormous progress in last few years is water jet bonding process also called spunlacing.

The production speed of the spunlacing pilot line is 400 m/min with productivity around 300 kg/h/m of card working width [29]. Spunbonded technology where filaments are deposited on a conveyor belt directly from the spinning manifold has also achieved very high production speed. The combination of these two technologies is regarded as enormous qualitative and quantitative development in the next few years. In searching for ecologically substitution of PUR foam material as composite component in the industrial textile, a new nonwoven needled spacer fabric was created [30]. This structure is produced by bonding two or three layers of prefabricated nonwoven fabrics by the bilateral insertion of a special barbed or forked needle and reciprocal insertion of fibre tufts formed into fibre grafts (Fig. 1.13)

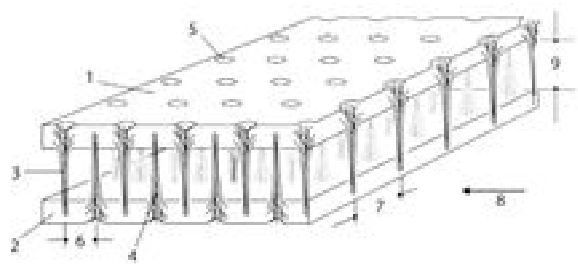


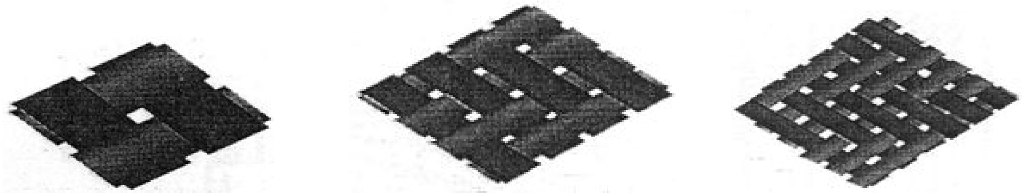
Fig. 1.13. Schematic diagram of the structure of a needled spacer nonwoven fabric:

1 and 2 – prefabricated nonwoven fabrics; 3 and 4 – fibre grafts from fabric 1 and 2; 5 – perforation; 6 – fibre grafts spacing; 7 – fibre grafts row spacing; 8 – production direction; 9 – fibre graft length, resulting form spacer width

The surface of the structure consists of prefabricated nonwovens 1 and 2, bonded by fibre grafts 3 and 4 resulting from bilateral needle penetration. If there is a need for absolute material separation, a third fabric (into which the fibre grafts from the two outermost fabrics will be anchored) could be axially incorporated. There is also a possibility of inserting various filling materials into the structure. A wide range of applications for needled spacer nonwoven are possible, from thermally and acoustically insulation to upholstery. The newest announcements that nonwoven hydroentangling technology is capable for production of fashionable articles opens broad new perspectives [31]. The spunlace finishing treatment gives a nowoven fabric softness and draping quality very similar to knitwear, especially if the natural fibres are included. When natural fibres are water jet bonded they greatly retain their properties. In that direction, the combination of cotton and water jet bonding offers new opportunities for many promising products.

BRAIDED STRUCTURES

Braided textile structures are manufactured with mutual interwining of yarns in a tubular form. There are three typical braid structures: diamond, regular and hercules (Fig. 1.13) [32].



a) b) c)

Fig.1.13. Schematic presentation of: diamond (a), regular (b) and hercules (c) braid strucuture

Diamond structure is obtained when the yarns cross alternatively over and under the yarns of opposite direction. The repeat notation is 1/1. Regarding this way of notification, the regular braid structure has notation 2/2 and hercules 3/3. The braids are mostly produced in a regular structure. Generally braids are produced in a tubular form of biaxial yarns direction. By insertion of longitudinally oriented yarns (middle-end-fibre) into the structure the 3 axial braid is obtained (Fig. 1.14a). Moreover in the center of the tubular braid, additional fibres called axial fibres can be inserted. When the number of braiding fibre bundles is the same, the tubular braid increases the fiber volume fraction more than the flat braid (Fig. 1.14b) [33].

a) b)

Fig. 14. Triaxial braid structure (a) and triaxial structure with axial fibres (b)

The main feature of the braid is the angle of interwining that can vary between 10–80° and depends on: the yarn fineness, the type of the structure (biaxial or triaxial), cover factor (tightness of the structure) and the volume ratio of the longitudinal yarns. Since the braids have tubular form, they are often replaced with the filament winding structures. In this respect it has been proven that the braids can be competitive regarding the price. The braid is a flexible product and can be adjusted to various shapes. With the special device called mandrel the braids can be shaped into various forms directly on the machine at the manufacturing stage [35].

Conclusion

1. Conventional woven fabrics consist of two sets of yarns mutually interlaced into a textile fabric structure.
2. Woven structures have the greatest history of application in textile manufacturing. Conventional woven fabrics consist of two sets of yarns mutually interlaced into a textile fabric structure.
3. Nonwoven technology is a newer one regarding other technologies of fibre forming assemblies.
4. Braided textile structures are manufactured with mutual interwining of yarns in a tubular form.

CHAPTER II. TECHNICAL TEXTILES, APPLICATION AND TYPES

2.1. Technical textiles

Globalization of Science and Technology has been propelled by three emerging technologies, viz, Bio-Technology, Micro-Electronics & Material Science. In the area of Material Science, products like micro fibres, optical fibres, high polymer plastics & resins, temperature resistant textile fibres, fibres reinforced composites etc. are used in greater volumes in the area of technical textiles. Technical textiles are used by industries of non-textile character in hi-tech and hi-performance applications like advertising, agriculture, automobile, aviation, civil engineering, chemical, electrical, industries, leather, medical, environmental protection, transportation etc. for their performance or functional characteristics rather than for their aesthetics.

Technical textiles include textiles for automotive applications, medical textiles (e.g., implants), geotextiles (reinforcement of embankments), agrotextiles (textiles for crop protection), and protective clothing (e.g., heat and radiation protection for fire fighters, molten metal protection for welders, stab protection and bulletproof vests), and spacesuits.

Technical textiles play an important role worldwide than is commonly acknowledged. A study conducted by David Rigby Associates, UK on Technical textiles reported an estimate that world consumption of technical textiles in 2000 amounted to just over 16.7 mn tons of fibre and polymer with a finished textile product value of US$92.9 bn. In weight terms, this represents over one-quarter of the estimated 62.2 mn tons of fibres consumed across all end-uses in that year

David Rigby Associates has projected an average growth rate of 4% for technical textiles during the period 1995-2005. In most of the developed countries, technical textiles already account for over 40% of the textile production. Even in many developing countries, the proportion is well above 10 to 15%. Within Asia, Japan & China account for maximum consumption followed by

Korea and Taiwan. However, demand is forecast to grow at an unprecedented rate over the next 10 years, driven by:

**increased real incomes and consumer spending

**consumer lifestyles favouring convenience and pre-packed foods

**changing legislation to prevent food contamination.

Table 2.1, which summarizes the world forecasts from 1995 to 2010, indicates a rather higher growth rate over the second half of the current decade than for the first. Forecast average growth rates (in volume terms) of 3.5% per annum between 1995 and 2005, and 3.8% per annum from 2005 to 2010 remain relatively attractive, especially in comparison with most other, non-technical, textile markets.

Table-2.1

Forecast World Technical Consumption, 1995-2010, volume (000tons)

Application Area	**Years**				**Compound Annual Growth Rate%**		
	1995	**2000**	**2005**	**2010**	95-00	00-05	05-10
Agrotech	1,173	1,381	1,615	1,958	3.3%	3.2%	3.9%
Buildtech	1,261	1,648	2,033	2,591	5.5%	4.3%	5.0%
Clothtec	1,072	1,238	1,413	1,656	2.9%	2.7%	3.2%
Geotech	196	255	319	413	5.4%	4.6%	5.3%
Hometech	1,864	2,186	2,499	2,853	3.2%	2.7%	2.7%
Indutech	1,846	2,205	2,624	3,257	3.6%	3.5%	4.4%
Medtech	1,228	1,543	1,928	2,380	4.7%	4.6%	4.3%
Mobiltech	2,117	2,479	2,828	3,338	3.2%	2.7%	3.4%
Packtech	2,189	2,552	2,990	3,606	3.1%	3.2%	3.8%
Protech	184	238	279	340	5.3%	3.3%	4.0%
Sporttech	841	989	1,153	1,382	3.3%	3.1%	3.7%
Totals	**13,971**	**16,714**	**19,683**	**23,774**	**3.7%**	**3.3%**	**3.8%**
Of which Oekotech	161	214	287	400	5.9%	6.0%	6.9%

Source: David Rigby Associates

The DRA study has identified 150 technical end-use products and grouped them into the following 12 Application Areas.

Agrotech : agriculture, horticulture, forestry and fishing

Buildtech : building and construction

Clothtech : functional components of shoes and clothing

Geotech : geotextiles and civil engineering

Hometech : products used in the home; components of furniture and floorcoverings

Indutech : filtration and other products used in industry

Medtech : hygiene and medical

Mobiltech : transportation construction, equipment and furnishing

Oekotech : environmental protection

Packtech : packaging and storage

Protech : personal and property protection

Sporttech : sports and leisure technical components

Table 2.2 indicates the region wise consumption of technical textiles and it appears that the consumption in Asia would be doubled by 2010 from that of 1995.

Table-2.2

World end-use consumption of technical textiles by broad region 1995-2010 (000tons)

Region	**Years**				**Compound Annual Growth Rate%**		
	1995	**2000**	**2005**	**2010**	95-00	00-05	05-10
America	4,228	5,031	5,777	6,821	3.2%	2.8%	3.4%
Europe	3,494	4,162	4,773	5,577	3.6%	2.8%	3.2%
Asia	5,716	6,963	8,504	10,645	4.0%	4.1%	4.6%

Row	473	558	628	730	3.3%	2.4%	3.1%
Totals	**13,971**	**16,714**	**19,683**	**23,774**	**3.7%**	**3.3%**	**3.8%**

Source: David Rigby Associates

Overview of Jute Used for Technical Applications

Jute is a natural and eco-friendly fibre. For decades, it is used for manufacturing packaging materials. Jute fibre has some unique physical properties like high tenacity, bulkiness, sound & heat insulation property, low thermal conductivity, antistatic property etc. The contribution of jute fibres for technical applications is limited at present. Due to renewed interest for eco-friendly products, use of jute fibres for manufacturing technical textiles is expected to increase in future.

Efforts of IJSG

In order to promote jute production, uses and exports, it is necessary to stimulate new demand in consumer markets, both to retain the present market share for the commodity and to regain part of the market lost to polypropylene. Central planks of the IJSG strategy in this respect are to utilize novel production routes and to diversify into both old and new end-use sectors where there is the potential for consumption of jute in significant volume.

The Common Fund for Commodities (CFC), Amsterdam has also been making strong efforts in collaboration with the International Jute Study Group (IJSG) in this regard. Considerable progress has been made, in recent years, in developing diversified jute products for various end-uses for commercialization. Research and development projects which have been financed by the CFC have result in identifying different end-uses where jute has competitive advantages in both woven-woven product sectors.

2.2. Geotextiles and Geotextile Products

The IJSG implemented an important project on "Technical Specification and Market Study of Potentially Important Jute Geotextile Products".

Geotextiles are defined as all woven, Nonwoven and knitted textile materials used to provide a range of functions such as support, drainage and separation at or below ground level. Geotextiles are used in a wide range of applications including the construction of buildings, bridges, dams, roads, railways and paths as well as embankments and sub-sea coastal engineering projects.

The main objective of the project was to expand the demand for specified jute geotextile products by proving the existence of an economically secure niche in the global market for geotextiles.

The objectives included:

a) Development of technical specifications of jute geotextile products;
b) Conducting a market study to establish economic viability and potential demands for specified jute geotextile products;
c) Preparation techno-economic manuals for identified end uses and dissemination of information through a Workshop.

The project's findings in the areas of (i) erosion control and vegetation establishment; ii) agro-plant mulching and (iii) rural road pavement construction have been encouraging and it was diffused to interested international participants at a Workshop held in Dhaka, Bangladesh in 1996. A Technical Manual with technical information was also published.

Whilst the Geotextile market is a high growth sector, however, it remains a relatively small end-user of textiles compared with other application areas. In volume terms geotextiles accounted for little more than 250,000 tons in 2000, just 1.5% of the overall technical textile market. In value terms (US$0.75 bn) the segment represents the smallest application area by a considerable margin. The Geotextile market is highly susceptible to changes in economic growth.

Geotextiles is forecast to have the highest growth rates of any of the twelve technical textile application areas. A rate of 4.6% per annum between 2000 and 2005 is set to increase to 5.3% p.a. during the five years up to 2010.

Potentials of existing jute products for rural road pavement construction:

- Jute may represent a temporary, biodegradable separator during consolidation of rural and even urban roads in developing countries.
- Potential markets exist in countries where infrastructure is developing rapidly.
- Appropriate widths of fabric (up to 5m) can be made if carpet backing looms are used in the manufacture of geo-textiles.
- Prefabricated bituminized Hessian fabric was highly successful during the 2nd World War in creating temporary access roads. Over 8 million yd^2 was produced up to the end of the war.
- Treating jute fabrics on-site will reduce the costs of the fabric to the end user: costs may be added to the total road building expenditure.
- Composites containing jute (jute/natural; jute/synthetic; jute woven/non woven) may have potential in this end use.

Geotextiles are used in reinforcement of embankments or in constructional work. The fabrics in geo textiles are permeable fabrics and are used with soils having ability to separate, filter, protect or drain. The application areas include civil engineering, earth and road construction, dam engineering, soil sealing and in drainage systems. The fabric used in it must have good strength, durability, low moisture absorption and thickness. Mostly nonwoven and woven fabrics are used in it. Synthetic fibers like glass, polypropylene and acrylic fibers are used to prevent cracking of the concrete, plastic and other building materials. Polypropylene and polyester are used in geo textiles and dry/liquid filtration due to their compatibility.

The IJSG has taken initiative to undertake a follow up project on 'Development and Application of Potentially Important Jute Geo-textiles' involving Collaborating Institutions from UK, India and Bangladesh. An International Conference was organised to elicit opinion on various aspects of jute geo-textiles to be addressed in the project. Some of the recommendations of the conference are as follows:

- Specific types of JGTs were found to have effectively controlled soil erosion, mitigated land slides, stabilized mine spoils and successfully improved performance / durability of roads.
- Identification of potentially effective types of JGT for rural road construction and soil erosion control is essential
- Application-specific and site-specific design JGTs and methodologies should be developed
- Formulation of specifications and technical parameters of JGTs for each specific application
- Comparative Environmental Impact Assessment for construction with JGT should be carried out
- Policy support from the national Govts. different govt. bodies and industry
- Guidelines and Specifications required for rural road construction and erosion control considering various field conditions (to be obtained from concerned Government bodies like PWD, Dept. of Soil Conservation, Water Development Board, Irrigation & Flood Control etc.)
- Aggressive marketing effort with appropriate market strategy is required.
- Successful use of JGT would assure bulk demand of raw jute and would be helpful for the jute growers.

2.3. Nonwovens and manufacturing techniques

The IJSG implemented a project on '**Specific Applications Development of jute based Nonwovens to enable Commercialisation'** through BTTG, UK that proved the suitability of non-woven technology for jute fibre processing and in identifying promising new end-uses like matting, geotextiles, shoe insoles and carpet backing non-wovens to enable commercialization.

The Project was designed:

a) To develop and commercialize new products applications and technology for jute, and to help arrest the continuing structural decline of export markets for traditional woven jute packaging and carpet backing.

b) To re-introduce jute as a prime raw material in the general field of technical textiles, and to introduce the fibre to the European non woven industry.

Different nonwoven manufacturing techniques like stitch bonding, hot calendaring, needle punching, hot-air thermal bonding, oven bonding, hydro-entanglement etc. were used and assessed. The most promising Nonwoven manufacturing techniques were identified to establish and extend the scope of jute in the production of Nonwoven structures.

Project Achievements:

a) Stitch-bonding

Results and characteristics of stitch-bonded jute Nonwovens showed that 100% jute fleeces can be stitch bonded to produce Nonwovens in a range from 150gsm to 500gsm. Incorporation of about 20% synthetic or man-made fibre enables the production of fabrics having weights lower than 150gsm, say 100gsm. Jute or jute blend Nonwovens would prove cost effective owing to their lower percentage yarn content. By judicial selection of synthetic fibre type and content, stitch density, yarn type and subsequent thermal-bonding treatment, it is possible to produce jute Nonwovens with properties varying within a wide range. Stitch type and coloration of yarn used can also provide a degree of design and pattern in the resulting products

Yarn cost is the most important element in the cost of stitch-bonded fabrics, and therefore heavier jute or jute blend Nonwovens would prove cost effective owing to their lower percentage yarn content. By judicial selection of synthetic fibre type and content, stitch density, yarn type and subsequent thermal-bonding treatment, it was possible to produce jute Nonwovens with properties varying within a wide range. Stitch type and coloration of yarn used can also provide a degree of design and patterning in the resulting products.

b) Hydroentanglement

Results indicated that 100% jute fleeces weighing 100 gsm or less did not respond well to the hydroentanglement process or gave unacceptable results However, it indicated that hydroentanglement became more effective as the fleece weight increased from 75 gsm to 200 gsm and, therefore, a 100% increase in fabric weight produced a four-fold rise in the fabric strength.

c) Thermal bonding

Nonwoven fabrics composed of a jute/synthetic blend were successfully produced in a weight range from 50 gsm to 300 gsm

d) Needle punching

The strength of needle-punched jute nonwoven samples showed a gradual and substantial increase of about 10 times (i.e. from 2kg to 20kg) as the needling intensity was increased gradually from 12 to 200 penetrations/cm^2.

A comparison of jute nonwovens and commercial ones showed that needled and/or oven bonded jute nonwovens and perhaps calendared ones should find several applications in dry filtration. Filtration of river and sewage waters is another area where jute nonwovens may find applications.

In all cases investigated, the inclusion of a synthetic fibre component improves processability, efficiency and also resulted in products with enhanced properties meaning higher tensile, tear and burst strengths, increased extensibility and resistance to abrasion, higher uniformity and surface cover, and also better appearance and handle.

Achievements also include the following:

a) Fibre sources of supply, prices and deliveries were identified.

b) Non woven producers in Europe, India and Bangladesh along with target end-users were identified.

c) Products were developed.

d) Collation of data for the technical manual.

It was recommended that 1) In order to exploit current market opportunities, and bring added value benefit downstream; there is a strong case for the establishment of a state-of-the-art Nonwoven plant in either/both India and Bangladesh.

The plant may set out to produce footwear and automotive components, but should be sufficiently flexible to enter other markets, such as geotextiles and filtration, or even to process man-made fibres as a fall-back market position. 2) It also recommended to extend to other end-uses for jute based Nonwovens, such as high and low matrix Composites, pultrusions for the construction industry, wet dry filtration media, furniture and mattress substrates, and geotextiles/agro-textiles.

Most potential functional markets identified for jute Nonwovens are: Carpet underlay, Thermal insulation, Air filters, Cushion backing for furniture, Upholstery, Base for jute composites etc.

Jute blended Nonwovens were found competitive with enhanced performance properties such as excellent sound insulation, odour, lack of contaminant fumes, acoustic absorption and smooth moulding properties etc. Jute Nonwovens are increasingly used in making jute based composites in making various parts of automotives in India and other developed countries.

Conclusions

Textile Industry is becoming ecologically aware. The producers of technical textiles have begun to eco-label their products. Jute, being eco-friendly in nature, has opened up a new avenue for manufacturing technical textiles. Areas where the jute fibres have also good promise include upholstery fabrics, soft luggage, decorative fabrics, canvas cloth and soil saver fabrics. The following points help expand the market share:

1. Design is to be carried out using national or International Codes of Practice.

2. Generic specifications developed by Government Organisations, Industry Groups and Construction Associations are to be used.
3. Accreditation and Certification Processes are to be developed with International Organizations.

Research and development institutions, policy makers and above all industrial enterprises are urged to promote the up-take of the uses of jute in the geo-textile and in other potential areas, in order to sustain the development of the jute industry and the means of livelihood of millions of low income farmers.

CHAPTER III. TECHNICAL CALCULATION OF FABRICS

3.1. Calculation of warping process

Count: - 3 Systems to Calculate Count

1. Indirect System
2. Direct System
3. Universal system

Differentiation of warp from weft

1. Selvedges will be there on two edges of cloth
2. Reed denting gaps can be seen as straight lines in the cloth
3. Warp ends will be sized, if both warp and weft is of single yarn
4. Double yarns are used in warp
5. Strength will be more for warp yarn
6. TPI is given more for warp yarn.
7. Quality of yarn in warp will be good.
8. Finer yarns are used as warp
9. Ends per inch will be more in warp than wefts
10. Stripe direction in design shirting

1. Machine Efficiency $E = \frac{R \times 100}{R + S}$

R = Uninterrupted running time for 1,000 meters (in sec)

$$= \frac{1000 \times 60}{\text{Machine speed in mtr/min.}}$$

S = Total of time in seconds for which the machine is stopped for a production of 1,000 meters

$$= R + \frac{B \times N \times T1}{400} + \frac{T2}{L} + \frac{T3}{L \times C} + T4$$

B = Ends breaks/400 ends/1,000 meters

N = Number of ends

L = Set length in 1,000 meters т

C = Beams per creel

Timing of activities in seconds are :

T1 = To mend a break

T2 = To change a beam

T3 = To change a creel

T4 = Miscellaneous Time loss/1,000 mtrs.

2. Production in metres per 8 hrs. (K) = 480 x mtrs/min x E/100 kgs.

3. Production in Kgs. per 8 hrs. = (K x N)/(1693 x English Count)

4. Warping Tension = 0.03 to 0.05 x Single thread strength

3.2. Calculation of sizing process

1. Warp weight (in kg.) = $\frac{\text{Length in metre} \times 1.094 \times \text{Total ends}}{840 \times 2.204 \times \text{Warp count}} \times 100$

2. Size pick-up % = $\frac{\text{Sized warp weight} - \text{Unsized warp weight}}{\text{Un-sized warp weight}} \times 100$

3. Weight of size = Warp Weight x Size pick up %

4. Stretch % = $\frac{\text{Sized warp length} - \text{Unsized warp length}}{\text{Un-sized warp length}} \times 100$

5. Sized yarn count = $\frac{\text{Total-ends x Warp length in yards}}{\text{Sized warp weight (lbs) x 840}}$

6. % of Moisture content= $\frac{\text{Wt. of sized yarn - Wt. of oven dried yarn}}{\text{Wt. of sized yarn}} \times 100$

7. % of Stretch = $\frac{\text{Deliver counter reading - Feed counter reading}}{\text{Feed counter reading}} \times 100$

8. % Droppings on loom = $\frac{840{,}000 \times D \times C}{454\, Y \times N \times P} \times 100$

D = Dropping in gms.

C = English Count

Y = Length woven (yds.)

N = Number of Ends

P = % size add on

9. Invisible Loss%

= $\frac{\text{Amount of size material issued - Amount of size added on yarn}}{\text{Amount of size issued}} \times 100$

Steam, Consumption (Sizing M/c) = 2.0 kg/kg of sized yarn

(Cooker) = 0.3 kg/kg of liquor

(Sow box) = 0.2 kg/kg of yarn

10. Max. Speed of machine = $\frac{\text{No. of Cylinder x 1,000 x English count}}{\text{Number of ends}}$

(metres/min)

11. Wt. of warp in gms/mtr = $\dfrac{\text{Number of ends} \times 0.6}{\text{English count}}$

3.3 Weaving calculation

1. Reed Count : It is calculated in stock port system.

Reed width = $\dfrac{\text{EPI}}{1 + \text{Weft crimp \%age}}$

No. of dents in 2 inches is called Reed Count

2. Reed Width :

Reed width = Cloth width x $\dfrac{100 + \text{Weft crimp \%age}}{100}$

3. Crimp % :

Warp Crimp %age = $\dfrac{\text{Warp length - Cloth length}}{\text{Cloth length}} \times 100$

Weft Crimp %age = $\dfrac{\text{Weft length - Cloth length}}{\text{Cloth length}} \times 100$

4. Warp cover factor = $\dfrac{\text{EPI}}{\sqrt{\text{Warp Count}}}$

5. Weft cover factor = $\dfrac{\text{PPI}}{\sqrt{\text{Weft count}}}$

6. Cloth cover factor = Wp.C.F. + Wt.C.F. - $\dfrac{\text{Wp.C.F. x Wt. C.F.}}{28}$

7. Maximum EPI for particular count :

a. For plain fabrics = 14 x √Count

b. For drill fabrics = √Count x 28 x 4/6

c. For satin fabric = √Count x 28 x 5/7

d. Other design = $$\frac{\text{Ends/repeat x 1 / yarn diameter}}{\text{No. of intersections / repeat + ends/repeat}}$$

8. Yarn diameter = $$\frac{1}{28 \text{ x } \sqrt{\text{Count}}}$$

Weave Density

1. Warp density = Ends/cm x √Tex x K

= < 250

2. Filling density = Picks/cm x √Tex x K

= < 350

3. Weave Density = 50 + $$\frac{\text{(Warp density - 100) x F.D.- 100}}{\text{(Weft density - 100) x F.D.- 100}}$$

4. Effective weave density = W.D. x K of loom width x K of Design = < 72

3.4. Count table

To change the count and number of thread/inch, keeping the same denseness of the fabric :

1. To change the EPI without altering the denseness :

Exp.Cloth = $$\frac{\text{EPI in given cloth x } \sqrt{\text{Warp count in expected cloth}}}{\sqrt{\text{Warp count in given cloth}}}$$

2. To change the count without altering the denseness :

EPI in exp. cloth2

EPI in exp. cloth = **………………………………**x Count in given cloth

EPI in given cloth

Warp requirement to weave a cloth :

Total ends x 1.0936 x 453.59 x crimp%

1. Warp weight in gms/mtrs. =**………...**x Wasteage%

840 x Count

2. Weft weight in gms/mtrs.

R.S. in inches x 453.59 x PPI

=**………………………………**x Crimp % x Waste %

840 x Count

3. Cloth length in mtrs.with the given weft weight

Weft wt. in kgs. x Weft count x 1848 x 0.9144

=**……………………………………………………….**

PPI x R.S. in inches

For Silk and Polyester :

1. Warp weight in gms/mtrs.

Total ends x Count (Denier)

= **…………………………….............**x Crimp% x Waste %age

9000

2. Weft weight in gms/mtrs.

$$= \frac{\text{RS in inches} \times \text{PPI} \times \text{Count (Denier)}}{9000} \times \text{Crimp\%} \times \text{Wasteage\%}$$

<u>Allowance for count in Bleached and Dyed Fabric :</u>

- Count becomes 4%
- Finer Dyed counts become max.6% Coarser

3.5. Fabric production

1. Loom speed $= \text{Motor RPM} \times \frac{\text{Motor pulley diameter}}{\text{Loom pulley diameter}}$

2. Loom Efficiency % $= \frac{\text{Actual production}}{\text{Calculated production}} \times 100$

3. Moisture Regain % $= \frac{\text{Yarn weight - Dryed yarn weight}}{\text{Dryed yarn weight}} \times 100$

4. Moisture Content % $= \frac{\text{Yarn weight - dried yarn weight}}{\text{Yarn weight}} \times 100$

5. Warp weight in Kg. $= \frac{\text{Total ends} \times \text{Tape length in metre}}{1693.6 \times \text{Warp count}}$

6. Weft weight in Kg. $= \frac{\text{RS in centimetres} \times \text{Coth length in metres} \times \text{PPI}}{4301.14 \times \text{Weft count}}$

7. Cloth weight in GSM = $\left(\frac{\text{EPI}}{\text{Warp count}} + \frac{\text{PPI}}{\text{Weft count}}\right) \times 25.6$

8. Oz (Ounce) per sq.yard = $\frac{\textbf{GSM} \text{ (Grams per sq. metre)}}{34}$

Material measurement :

For calculating of length of any rolled fabrics :

$$L = \frac{0.0655\,(D - d)\,(D + d)}{t}$$

Where,

L = Length of material (feet)

t = Thickness of fabrics (inches)

D = Outside diameter (inches)

d = Inside diameter (inches)

Weight of yarn in a cloth :

The weight of cloth manufactured on loom depends upon the weight of yarns in the warp and weft : ends/inch, picks/inch and the weight of size on the warp.

Therefore, **Cloth weight** = Weight of warp + Weight of weft + Weight of size (All in lbs.)

Where as Weight of warp in lbs = $\frac{\text{Total No. of Ends} \times \text{Tape length in yds.}}{840 \times \text{Warp yarn count}}$

Also Weight of weft in lbs.

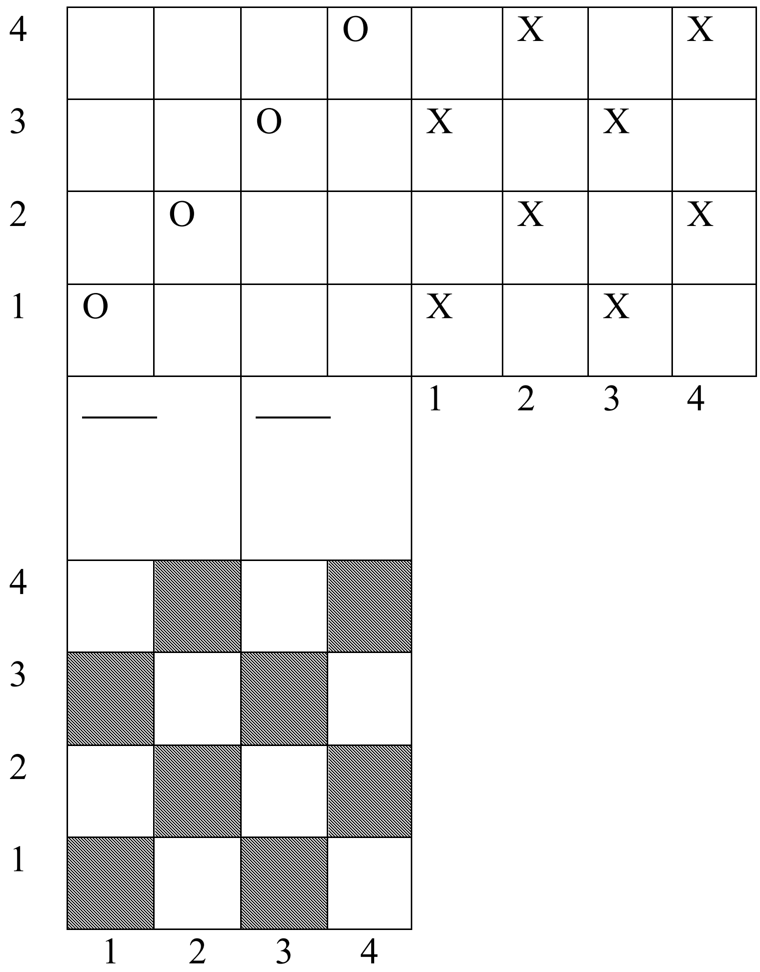
$$= \frac{\text{Length of cloth (yds)} \times \text{Picks/inch in cloth} \times \text{Reed width (inch)}}{840 \times \text{Weft yarn count}}$$

3.6 Technological calculation of project fabrics

Two-layer heavy fabric, cotton yarn, textile rising bond linear density Tt = 72 cotton text, untie the rope and the linear density is equal to Ta = 280 tex. The density of the tissue in the body Pt = 240 threads / dm rope, Pa = 70 threads / dm. Tandabo'yicha linear density of the fabric.

The density of the tissue surface m^2 = 184 g / cm^2. Tissue popular of the high demand. This tissue, mainly in the production of towels.

Draw -in scheme of fabrics



$R_T=2$
$R_a=2$
$t_T=2$
$t_a=2$
$r_T=2$
$r_a=2$
Pattern type - Plain

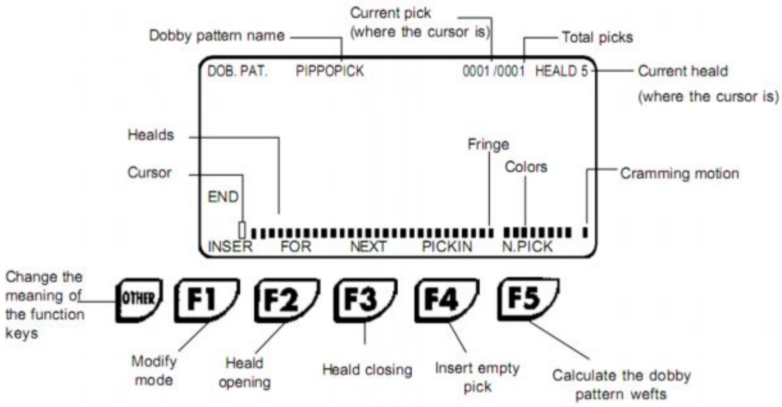


Table 3.1

Technological dates of fabrics

11255	1	Fabrice Article	
Brezent	2	Fabrice Name	
90	3	Fabric width, sm	Count,tex
72 cotton	4	T_w	
280	5	T_{wf}	
72 cotton	6	T_c	
3480	7	For all	The number of yarns in
48	8	Selvage	
240	9	P_w	Density of fabrics
70	10	P_{wf}	
12	11	a_w	Contraction
6,5	12	a_{wf}	
60	13	Reed width /dm	edge

4	14	Z_f	
1	15	Z_{cf}	
Plain	16	Pattern type	
ATT	17	Weaving loom type	
422+29	18	Density of the surface, g/m^2	
	19	Warp by waste, %	
	20	Weft by waste, %	

Warp weight in Kg

$$M_{yp} = \frac{n_{yм} \cdot T_T + n_m T_m + n_{cm} \cdot T_{cm}}{10^6 (1 - \frac{a_T}{100})(1 - \frac{B}{100})} \cdot 100 = \frac{3372 \cdot 72 + 72 \cdot 4}{10^6 \cdot (1 - \frac{12}{100})(1 - \frac{0}{100})} \cdot 100 = 27{,}523$$

Weft weight in Kg.

$$M_a = \frac{P_a \cdot 10 \cdot l_a \cdot T_a}{10^6} \cdot 100 = \frac{70 \cdot 10 \cdot 1{,}58 \cdot 280}{10^6} \cdot 100 = 30{,}968$$

Cloth weight

$$M_m = \frac{M_t + M_a}{100} = \frac{27{,}523 + 30{,}968}{100} = 0{,}584$$

Number of Reed

$$N_\delta = P_{yp} \frac{(1 - \frac{a_a}{100})}{Z_{yp}} = 240 \frac{(1 - \frac{6{,}5}{100})}{4} = 56{,}1$$

Summary table of technical calculation

№	Name	Unit	Quantity
1.	Cover factor		14,78
2.	Widht of fabric	sm	150,3
3.	Warp yarns	yarn	3360
4.	Selvage yarns	yarn	4
5.	Leno selvage	yarn	24
6.	The total number of warp yarns	yarn	3388
7.	Number of reed	tooht/dm	60
8.	Density of healds	heald/sm	5,80
9.	Density of droops	drop/sm	3,65
10.	Warp weight	kg	27,523
11.	Weft weight	kg	30,968
12.	Cloth weight	kg/m	0,584
13.	Weight per sq	kg/m^2	0,417

Conclutions

1. Selvedges will be there on two edges of cloth.
2. Reed denting gaps can be seen as straight lines in the cloth.
3. Warp ends will be sized, if both warp and weft is of single yarn.
4. Strength will be more for warp yarn
5. TPI is given more for warp yarn.
6. Quality of yarn in warp will be good.
7. Finer yarns are used as warp
8. Ends per inch will be more in warp than wefts

CHAPTER IV. RESEARCH OF POROSITY OF THE FABRIC

4.1 Analyse of porosity of the fabric

Flat textiles play an important role in clothing and as component of composites. Besides of that, it would be difficult to imagine the processes of filtration without the flat textiles. They can be divided into three main groups: woven fabrics, knitted fabrics and non-woven textiles if their design is disregarded. The quality of the flat textiles can be defined by many parameters. In this chapter, we will focus on one of them - the porosity. What is porosity? How could we define it? Way and where is it important? Usually we have more questions than answers. The porosity in flat textiles is defined as a void part of the textile's full volume. The full textile's volume is usually occupied by a mixture of three components: fibres, air and water. The part of the volume that is occupied by fibres is constant. On the contrary the portion of the volume that is occupied by water may vary considerably. For instance, there is no water in the absolutely dry flat textile, and in the absolutely wet condition, air is replaced by water. The water content in the textiles plays very important role in the clothing insulation due its effect on the clothes' thermal resistance. The coefficient of the thermal resistance of air is much larger than the coefficient of the fibres or water. Hence, it is extremely important to keep the clothing dry in a cold weather. The coefficient of the thermal conductivity scales in the inverse manner with the coefficient of the thermal resistance and both are frequently used in the literature. The coefficient of the thermal conductivity is not solely influenced by the porosity in terms of its water content in the still weather, but also by the moving air - windy weather - that can penetrate the pores in the flat textiles.

The porosity can be defined by several parameters. The pore distribution is an important parameter and it is seldom well known. Even the average pore size is difficult to estimate. Yet, our aim was to describe the pore distribution by it attributes: average pore diameter, number of pores and distribution of pore diameters in a histogram form. The method that is capable of providing us with all these data is described in this chapter. The surface of the flat textile open to the flow of the fluid is of the interest as well. Additionally, the velocity of the fluid flow through the flat textile, driven by the pressure difference between textiles surfaces, is important when analysing the process of filtration or the properties of clothing. In the latter case the fluid is air. Clothing has certainly a specific role in our life. It protects us against cold, wind, rain and sun radiation. Clothing must be suitable in the dry and wet, cold and hot weather and in the windy weather. Only one set of clothing can't be enough for all these situations – we do not have the universal clothing. Instead, we use clothing composed in layers. Problem may arise as energy or heat is produced by our metabolism. Heat production depends on the intensity and sort of the activity. Sweating is the body response on its own temperature rise and it is wetting the clothes. The thermal resistance coefficient of the wet clothing is smaller that the dry one. The similar effect can be observed when wind velocity increases. The influence of the temperature, water and wind velocity on the thermal coefficient is show in equation (1) for a flat surface (Jakšić, 2004).

$$R_s = \frac{d_c}{\lambda_0(1 + k_T \Delta T_c + k_w \Delta G_c) + bc_a \gamma_c V_a d_c} + \frac{0.0429}{0.4 + 2.0\sqrt{v}}$$

where Rs stands for the clothing's coefficient of thermal resistance, dc for the thickness of the clothing, λ_0 for the coefficient of thermal conductivity of clothing in the standard environment, kT for the coefficient of direction curve temperature - the thermal resistance of the clothing, ΔTc for the difference of the clothing temperature regarding the temperature in the standard environment, kw for the coefficient of direction curve for the content of water in clothing - the thermal resistance of the clothing, ΔGc for the change of the water content in the clothing, b for the coefficient, which describes the tightness of the clothing (if the value is 1, the air flows through the surface of clothing layers and not through the holes in the clothing, ca for the specific heat of the air, γc for the specific mass of the air, Va for the volume of the air which penetrate through the clothing due to the velocity v of the air flow. The use the flat textile in the composites and as the geo textiles, the diameters of pores are also very important. For example, in a composite structure the diameters of pores must allow resin a good connection between the layers of the flat textile. The pores must simply be large enough to allow resin penetration. On the other hand, the diameters of pores in woven fabrics used as geo textiles must be small enough to effectively filtrate earth particles. Pores in the woven fabrics are voids between threads of the warp and weft and the light can go directly through. This sort of material is not suitable for use in the masks destined for protection against viruses. Viruses are extremely small and we can't get pores in textiles to be smaller.

Hence, non-woven fabrics are used for the masks design in spite of the fact that the pores are many times larger than the viruses. The walls of pores are defined by fibres, and not by treads, in the non-woven fabrics. Pores change direction many times from one surface of the non-woven fabrics to another. The probability for the aerosol flowing through such a pore to deposit fine solid or liquid particles including bacteria and viruses on the fibres is extremely high, even 100% for some limited time. The micro fibres, which diameter is about 1 to 2 micrometers, must be used for this purpose. The porosity of the non-woven fabrics is high enough to enable us to breathe normally. The protection against microbes and viruses are tested in the special laboratories. However, if we could measure the composition and the porosity of masks, the number of those tests would be reduced. It would be enough to estimate porosity only, but it is not so strait forward without a suitable method. We have developed a method for the assessment of the parameters of the porosity in all flat textiles. The method is relatively simple and efficient at the same time. The apparatus for measuring the airflow through a flat textile sample due to the pressure difference is needed. The application software has been developed on a basis of the method's algorithm.

4.2. Methods for estimating the porosity of the flat textiles

There are several different methods available for the assessment of the parameters of porosity, such as: geometrical methods (Matteson & Orr, 1987), (Piekaar & Clarenburg, 1967) and (Dubrovski & Brezocnik, 2002), liquid intrusion methods (Dosmar et al., 1993), (Rucinski et al., 1986) and (Rebenfeld & Miller, 1995), liquid extrusion methods (Miller & Tyomkin, 1986a), (Miller & Tyomkin, 1986b) and (Rushton & Green, 1968), liquid through methods (Hssenboehler, 1984), etc. Some of them can only give truly very approximate values, which may not be accurate enough. On the other hand some of them are not capable of estimating all the relevant porosity parameters. A lot of work has been done over the years to overcome the mentioned shortcomings. We have developed a method for estimation of the parameters defining the textile's porosity. The method is suitable for all types of flat textiles: woven fabrics, knitted fabrics and non-woven fabrics (Jakšić, 2007). We have named it J-method after the first letter of authors' surname. Main feature that set J-method apart of the other methods is that J-method is also suitable for the non-woven fabrics.

4.3. Theoretical bases for J-method

A flat textile product gets wet and the fluid pushes the air out of the product - especially from voids, if the product is immersed into a fluid. These voids are formed out of pores between fibres in the non-woven fabrics, as well as out of pores between threads in the woven and knitted fabrics. The pores between the threads of the warp and weft in the woven fabrics, figure 10a, are the most interest from the practical point of view. The pores between the threads of the warp and weft are well defined in textile fabrics made of monofilament and of some multifilament yarns. The pores can be counted on a defined area in such cases. This is not the case with the fabrics made of wool yarn where some fibres jut out of the yarn and thus cover the pores. A pore is thus divided into several smaller pores. It is thus impossible to ascertain the exact number of pores in the non-woven fabrics. The porosity parameters that are needed in most of the cases are: the pore size distribution, the average hydraulic pore diameter, the open area for fluid flow and the air volume velocity as a function of the air pressure. The method under consideration is able to provide mentioned parameters with sufficient accuracy. The method is based on selectively squeezing the fluid in the pores out of the wet fabrics by air pressure and on the presumption that a pore is approximated with a cylinder. The selectivity is assured by the fact that the fluid is squeezed out of the pores with a certain hydraulic diameter providing that the precise value of the air pressure is applied. The air pressure is inversely proportional to the hydraulic diameter of the pores (see equation (3)). Latter is important, while the process of squeezing out the fluid contained in the pores of the wet fabrics is under examination. There is always a small amount of the fluid that remains at the edges of pores if such edges exist. The pore cross-section is approximated by a circle of the diameter d. The parameter d is the hydraulic diameter of the pore. It is defined by equation (2) where f denotes the surface of the cross-section of the pore, *o* the circumference of the cross-section of the pore *w*, the width of the pore cross-section and *l* denotes the length of the pore cross-section.

$$d = \frac{4f}{o} = \frac{2wl}{w+l}$$

The pressure difference pi between the opposite surfaces of the flat textile, equation (3) and (4), results in squeezing the fluid out of the pores, which diameter is equal or larger than d_i. The fluid is characterised by the surface stress α.

$$d_i \geq \frac{4\alpha}{p_i}$$

$$p_i = \rho g h_i \; ; d_i \geq \frac{4\alpha}{\rho g h_i}$$

The fluid is first squeezed out from pores, which have the largest hydraulic diameter. The flow of air will establish itself through these pores that are now empty. The volume flow rate of air through the flat textile can be described by equation (5)

$$V_i = Ap_i^b = Pap_i^b = Pv_i$$

where Vi stands for the air volume flow rate through the sample at the air pressure pi, A for a regression coefficient when fitting equation (5) to the measured dry data, P for the open surface, vi for the linear air flow velocity, a for the coefficient and b for the exponent. The parameters a and P are unknown and they have to be estimated as well. The solution of the problem is enabled by equation (6) by putting the velocity vi in the relationship with the air pressure pi. The value for the exponent b is bounded between 0.5 and 1.0. The air volume flow rate depends on the degree of porosity of the flat textile fabrics and the air pressure difference between the two surfaces of the fabrics. Larger porosity means larger air volume flow rate through the fabrics at the constant pressure. The last part of equation (6) holds in the ideal circumstances, when all of the energy dissipation mechanisms are neglected.

$$v_i = a_0 p_i^b = 1.28 p_i^{0.5}$$

Suppose that the fluid is squeezed out from the largest n1 pores with hydraulic diameter of d1 at the pressure difference p1. The volume flow rate of V1 is thus established through empty pores, equation (7).

$$V_1 = \frac{\pi d_1^2}{4} n_1 v_1 = \frac{\pi}{4} a p_1^b n_1 d_1^2$$

Additional n2 pores will open at p2, p2 > p1, and the volume flow will rise to value V2, equation (8).

$$V_2 = \frac{\pi}{4} a p_2^b (n_1 d_1^2 + n_2 d_2^2)$$

The pressure value can be increased incrementally till all pores are opened. Hence at the i th incremental step the volume flow rate is Vi, equation (9).

$$V_i = \frac{\pi}{4} a p_i^b \sum_{j=1}^{i} n_j d_j^2$$

The selective squeezing out the fluid from pores as described in equations from (3) to (9) enables us to compute the number of pores at each interval defined by the incremental pressure growth. The number of pores of the first interval n1 can be estimated as

$$n_1 = \frac{4V_1}{\pi a p_1^b d_1^2},$$

for the second interval as

$$n_2 = \frac{4}{\pi d_2^2} \left[\frac{V_2}{a p_2^b} - \frac{\pi d_1^2}{4} n_1 \right],$$

and for the i th interval as

$$n_i = \frac{4}{\pi d_i^2} \left[\frac{V_i}{a p_i^b} - \frac{\pi}{4} \sum_{j=1}^{i-1} d_j^2 n_j \right].$$

It is clear from the equation (9) that

$$\frac{\pi}{4} \sum_{j=1}^{i-1} d_j^2 n_j = \frac{V_{i-1}}{a p_{i-1}^b}$$

The air volume velocity through the wet sample depends on the air pressure and on the open surface of the sample. As the pressure increases, the open surface increases as well due to the squeezing the fluid out of pores with smaller hydraulic diameter. Hence, the rise of the air volume flow rate is consequence of the open surface and the pressure growth. As a consequence the sequential pore opening of the wet sample is achieved by increasing the air pressure gradually when testing. When the pressure is increased then the open surface and the linear velocity of the airflow is also increased.

This enables us to calculate the portion of air volume flowing through the empty pores and to calculate the number of pores in i th pore's diameter interval by starting from the first interval with the pores with the largest hydraulic diameter, equation (7), where p1 and V1 stand for the air pressure and the volume flow rate respectively when the first air bubble is spotted during the testing of the wet sample. The presumption of the equal regime of the airflow through the wet sample's open area and the dry one at the same pressure is taken into account. Small values of the Reynolds number, $Re < 50$, in the extreme causes (maximal hydraulic diameter of pore), support that presumption. The airflow is either laminar through open pores in the wet sample and through all pores in the dry sample, or the type of the airflow is the same. This is the criterion for using the exponent b, which is estimated when equation (5) is fitted to the measured dry data, in the process of determining the pore distribution from the measured wet data. The method's algorithm can be presented in step-by-step scheme:

1. The measurements of the air volume velocity flowing through a dry sample as a function of the air pressure at several distinct air pressures produce the "dry data".
2. The measurements of the air volume velocity flowing through a wet sample as a function of the air pressure at several distinct air pressures produce the "wet data".
3. The weighted power approximation is fitted to the dry data, and thus the exponent b is estimated, see equation (5).

4. The approximating cubic splines are fitted to the wet data thus smoothing it.

5. The porosity parameters are computed with the help of b, estimated in the step 3, and with the help of smoothed wet data together with equations (2) – (4) and (6) – (15).

6. The procedure is repeated at step 3 on the portion of measurements (at the pressure interval) where pores were identified in the first algorithm sweep.

When the dry and wet data are measured (steps 1 and 2) the numerical data processing can start. A computer application was built for that purpose to enable one to interactively carry out the porosity parameters numerical computation. A user interaction with the application is needed at steps 3 and 4 when choosing weights to the approximations used to fit the dry and wet data and at the step 5 where a user chooses between two procedures for computing porosity parameters and defines the length of the base interval of the pore diameter distribution (histogram). At step 6 the algorithm is repeated from the step 3 on. The exponent b is computed on the portion of the dry data measurements (pressure interval) where pores were identified in the first algorithm sweep. The upper limit is the pressure, which squeezes the fluid from the smallest hydraulic pore detected by the first algorithm sweep. The first procedure is totally valid for the monofilament woven fabrics, which have the same or similar density of the warp and weft and have threads of the yarn of the similar size (yarn count) and quality. It can be used for monofilament and multifilament fabrics, which have similar density of the warp and weft and if the coefficient a0, equation (6), is smaller then 1.28 (theoretical maximum). A single pore between threads of the warp and the weft can be counted for several hydraulic pores if pores are of rectangular shape (sample b) due to the differences in the densities of the threads of the warp and the weft or due to differences in fineness of the yarn and possibly due to the binding. The value of the coefficient a0 is greater than theoretical maximum and the computation of the porosity, is continued by using the second procedure. As a rule, the second procedure should be used if the number of pores is unknown or a0 is larger than 1.28 or the type of fabrics unsuitable for the first procedure is used. The number of pores in intervals are computed first by using equations (10) and (15) and using maximal value of the coefficient a (a1 = 1.28). The computed number of pores is minimal and so is the corresponding estimated open surface. If the computed coefficient a0 is larger than 1.28 then the true value of the coefficient a, is computed as quotient between a1* and a0'. Whole procedure is repeated with newly computed a. For example a1' = 1.28; a0' = 8; a0'/1.28 = 6.25; a1/6.25 = 0.2048 = a; a1*/a0' = 0.2048 = a; a0 = 1.28.

4.4. Experiment

Four different samples were used for the method's testing, which practically encompasses all the fabric types that the method is suitable for. The basic design parameters of the woven fabrics are presented in table 1. They are made of monofilament, multifilament and cotton yarn. The measured average pore's hydraulic diameters of the textiles are in the interval of 18 up to 200 micrometers. The wide assortment of textiles is thus covered.

Table 4.1

Samples used in the testing of J-method

Sample	Description	Interval of measurement [μm]	Numbers of pores per cm^2	Warp/weft, threads per cm
(a)	Cotton woven fabric	160 – 20	452	22/21
(b)	Thick monofilament fabric	80 – 10	2200	55/40
(c)	Multifilament woven fabric	270 – 140	960	32/30
(d)	Very thick monofilament woven fabric	24 – 12	32400	180/180

Table 4.1. Samples used in the testing of J-method The results of the textile's porosity tests are presented in table 2 and in figures 1 – 8. The first procedure is used for all four samples. The second procedure was used for porosity parameters estimation of samples (a) and (b) due to large value of the parameter a0. We worked under two presumptions: • The regime of the airflow through the dry and the wet sample is the same at same pressure difference regardless of the size of the open area of the wet sample. • The number of the hydraulic pores is not the same as number of pores between threads of the warp and weft if the ratio of the rectangular sides, which represents real pore's cross-section, is at least 3:1.

The first presumption applies that the airflow regime through all pore's should be the same regardless of their diameter. This is certainly true for sample (d) due to the fact that the 90% of all pores are in the interval between 18 and 20 micrometers. If the regression parameters of the air flow through dry samples are obtained on the measurement's interval of pressures where pores actually exist then the values of the pore's average diameter obtained by the microscope and the scanning-electron microscope are in good agreement with those obtained with the method presented here indicates justification of the presumption of the same regime of the air flow through dry and wet sample at the same pressure difference.

This holds for all tested samples due to low Reynolds number. Reynolds numbers have values 12 and 39 for flow through sample (d) and sample (c) respectively, if we take into account the average hydraulic diameters of 18.78 μm for sample (d) and 199 μm for sample (c). Hence, the flow through all samples is laminar and the exponent b, which is estimated by equation (5), can be used in equations (7) – (11).

The nomenclature in table 2 – b stands for the exponent in equation (5), h [μm] for the width of the interval of the pore distribution, m for the number of the distribution intervals, nt for the true number of pores between the threads of the warp and the weft per cm2, n for the computed number of hydraulic pores between the threads of the warp and the weft per cm2, when the true number of pores (or number of hydraulic pores) is unknown (second procedure), d for the average hydraulic diameter of pores, dt for the optically measured average hydraulic pore diameter – for samples (b), (c) and (d); the pores are ill-defined in sample (a), P [%] for the average open hydraulic flow area, Pt [%] for the average open flow hydraulic area computed on the bases of the optical experiment, a0 for the coefficient a, equation (5), at presumption that exponent b has minimal value (b = 0.5).

Table 4.2

Parameters of porosity estimated with J-method

Porosity test procedure	Parameter	Samples			
		(a)	(b)	(c)	(d)
Porosity parameters when the number of pores is known (first procedure)	b	0.5794	0.6647	0.8329	0.7174
	h [μm]	14	10	13	2
	m	10	7	10	7
	n_t	452*	2200	960	32400
	d [μm]	45.04	31.37	200.45	18.84
	d_t [μm]	53	30	199	18.78
	P [%]	0.98	2.07	31.32	9.06
	P_t [%]	1.00**	3.43	29.84	8.98
	a_0	9.4074	2.3872	0.28	0.8791
Porosity parameters when the number of pores is unknown (second procedure)	d [μm]	45.00	31.35		
	P [%]	6.96	3.87		
	n	3314	4115		
	a_0	1.28	1.28		

Table 4.2. Parameters of porosity estimated with J-method for all four samples. * – the number corresponds to the product of the warp and weft. ** – corresponds to the 452 measured pores – between the threads of warp and weft only one typical pore was measured in each void between the threads of warp and weft.

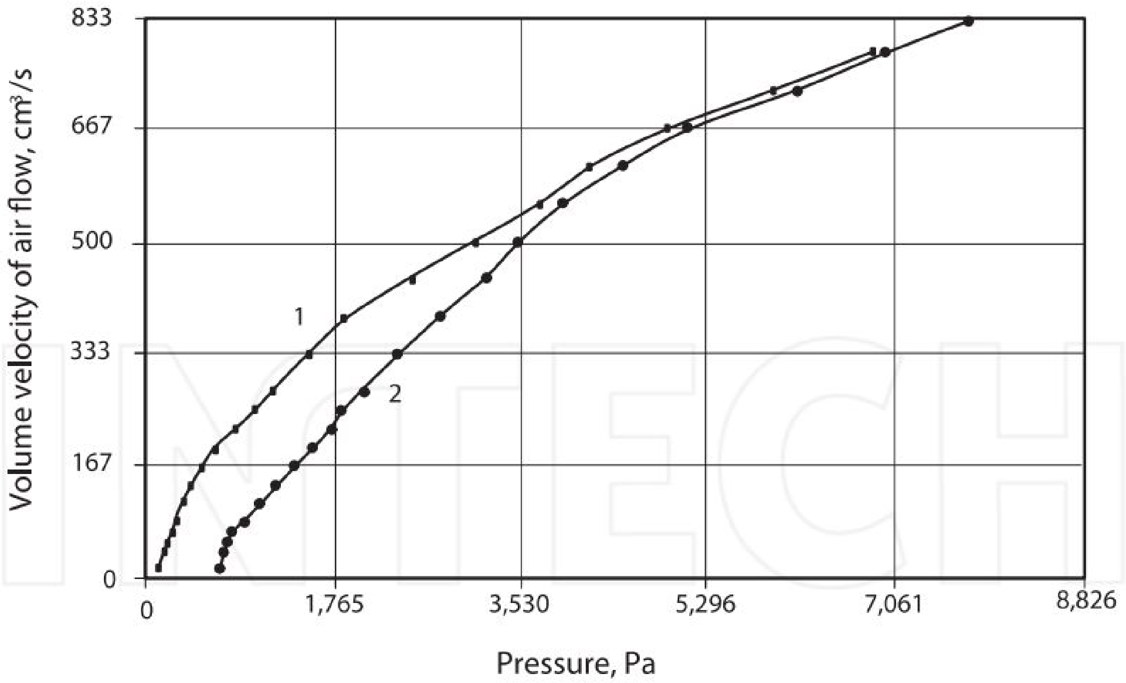


Fig.4.1. Diagram of the volume velocity

Fig.4.1. Diagram of the volume velocity flow through open area of the sample (b) as a function of the pressure difference; 1 - velocity of flow air through the dry sample; 2 - velocity of the air flow through the wet sample

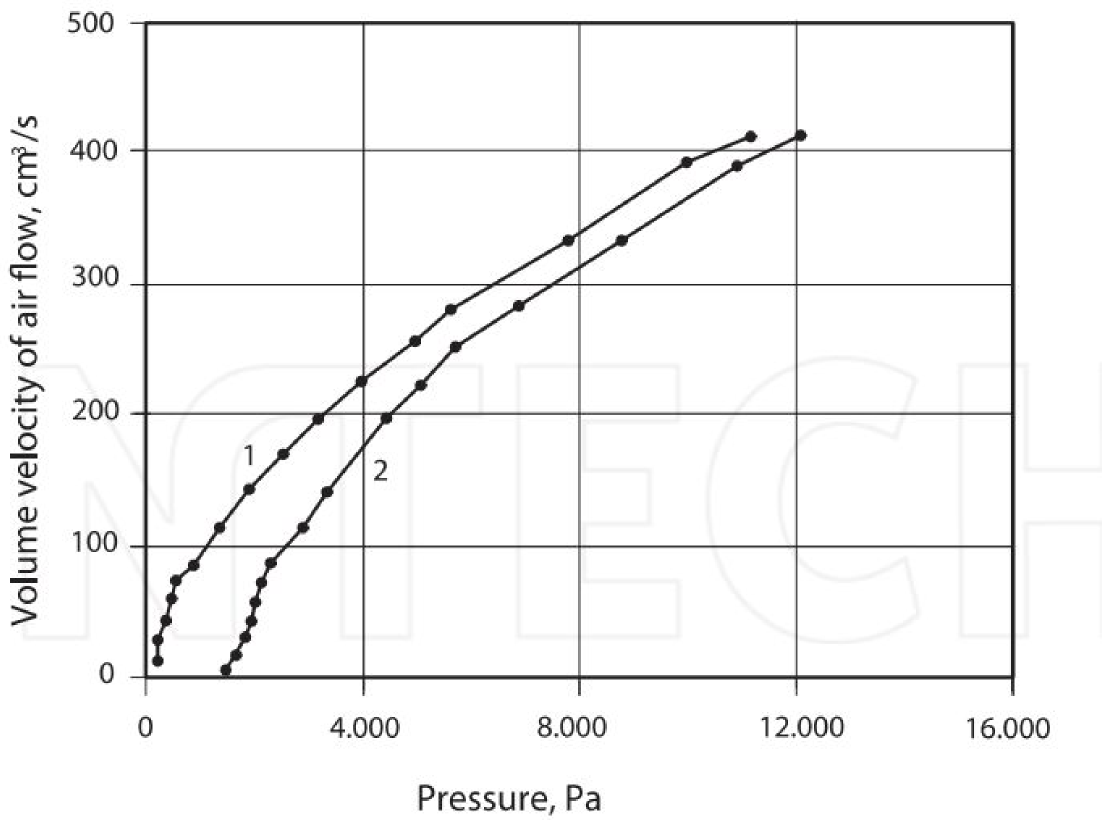


Fig. 4.2. Diagram of the volume velocity

Fig. 2. Diagram of the volume velocity flow through open area of the sample (b) as a function of the pressure difference; 1 - velocity of flow air through the dry sample; 2 - velocity of the air flow through the wet sample

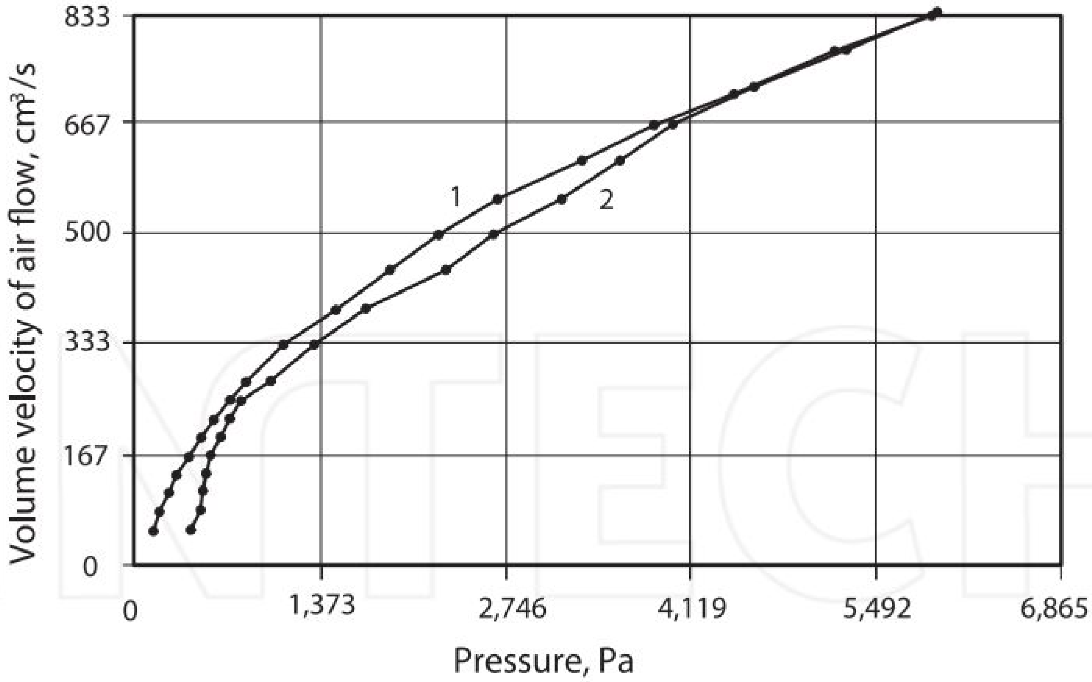


Fig. 4.3. Diagram of the volume velocity

Fig. 3. Diagram of the volume velocity flow through open area of the sample (c) as a function of the pressure difference; 1 - velocity of the air flow through the dry sample; 2 - velocity of the air flow through the wet sample

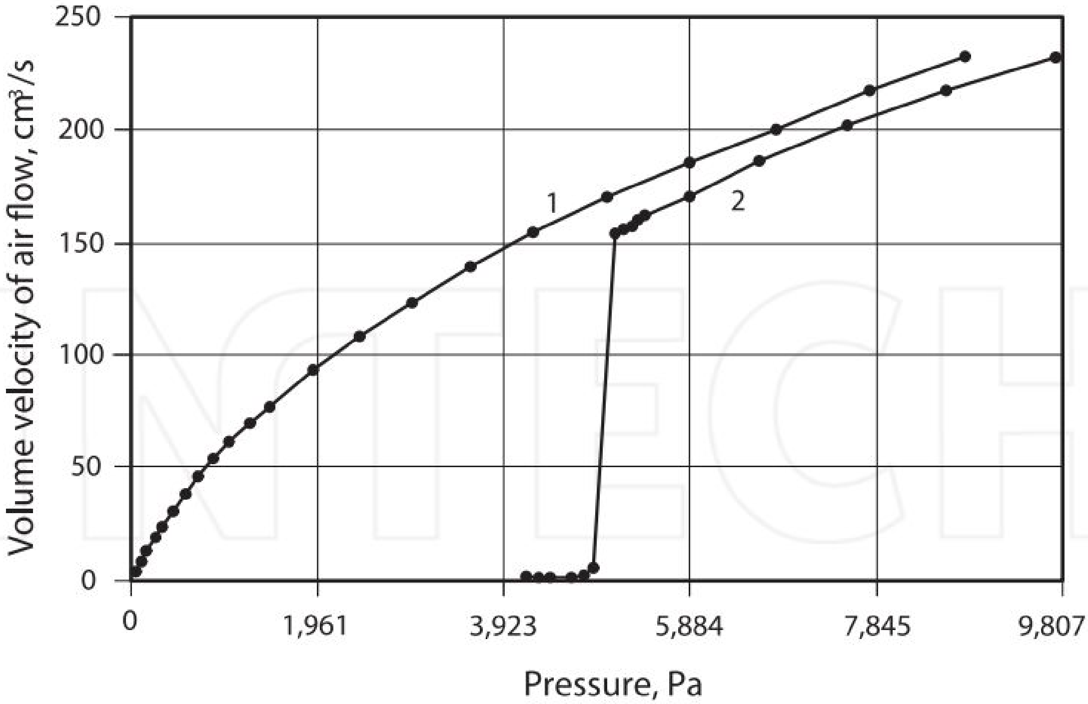


Fig. 4.4. Diagram of the volume velocity

Fig. 4. Diagram of the volume velocity flow through open area of the sample (d) as a function of the pressure difference; 1 - velocity of the air flow through the dry sample; 2 - velocity of the air flow through the wet sample

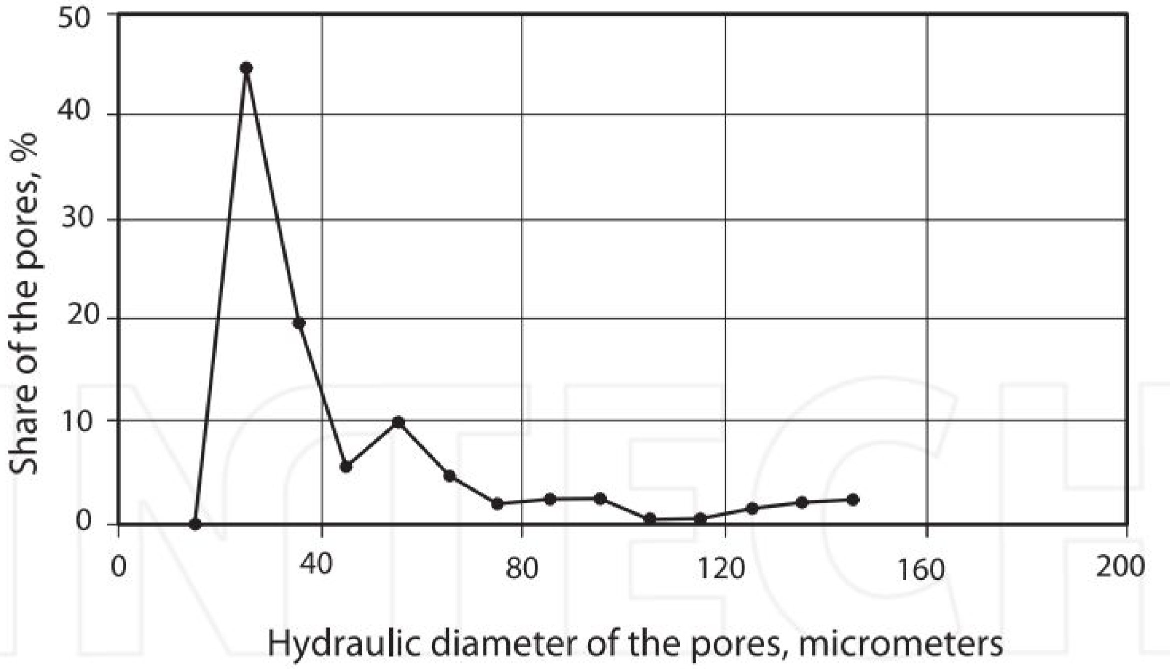


Fig. 4.5. Diagram of pore's distribution in sample

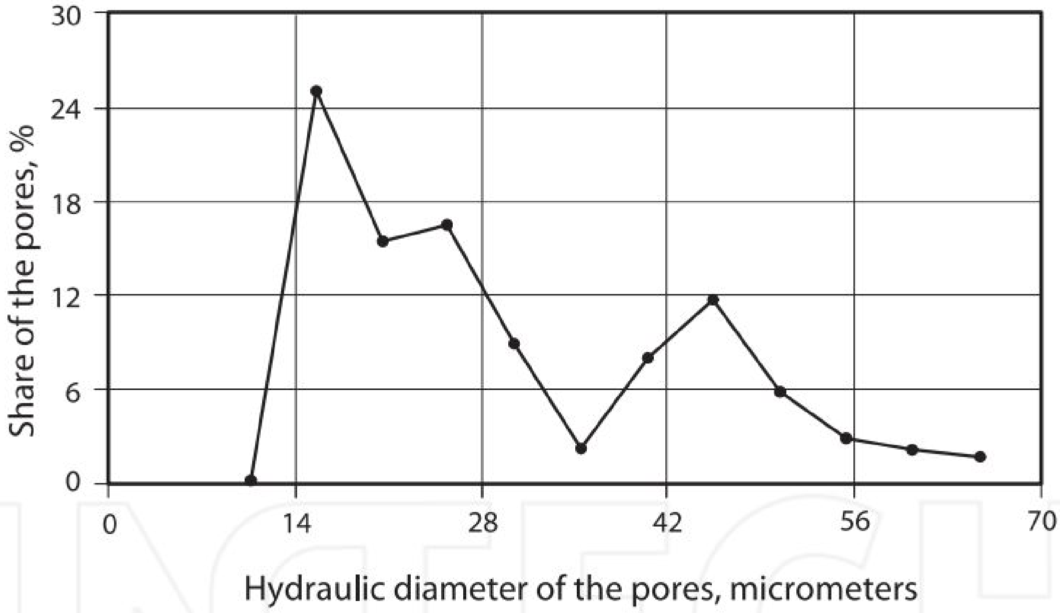


Fig. 4.6.Diagram of pore's distribution in sample (b)

Table 4.3

Results of the scanning-electron microscope pore's shape

Statistic parameters	w [µm]	l [µm]	d_t [µm]	$P_{real} = w*l$ [µm²]	P_{hydr} [µm²]	l/d_t
Mean	20.13	66.06	30.00	1364.67	786.29	2.50
Standard deviation	7.77	13.75	10.19	664.13	461.38	1.19
Minimum	4.76	23.81	8.82	287.12	61.07	1.04
Maximum	34.92	87.3	46.91	2519.68	1727.43	6.86
Total				68233.43	39314.56	

Table 4.3. Results of the scanning-electron microscope pore's shape and open area measured on 50 pores of the sample (b)

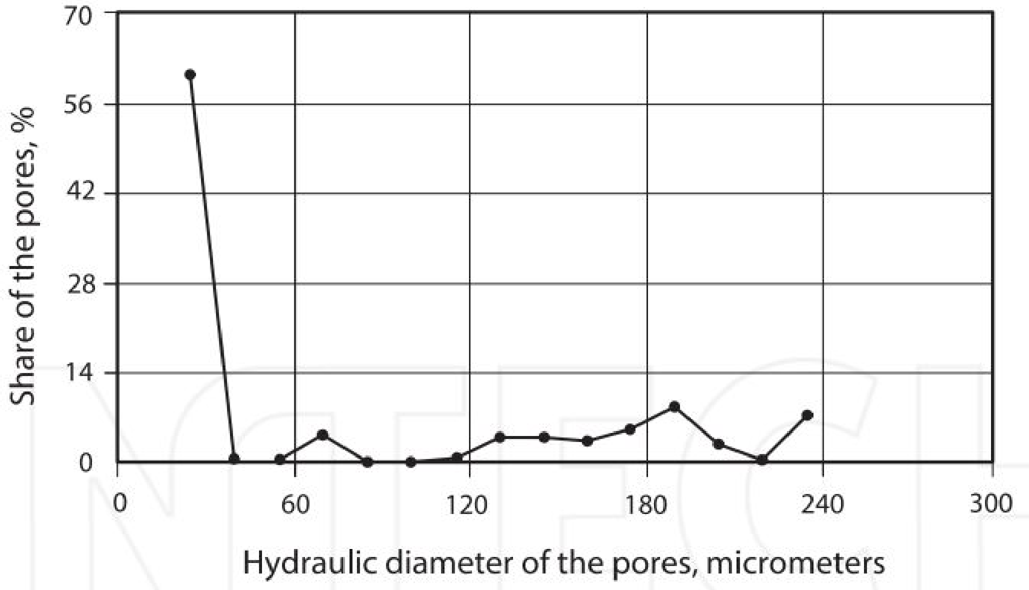


Fig. 4.7. Diagram of pore's distribution in sample (c)

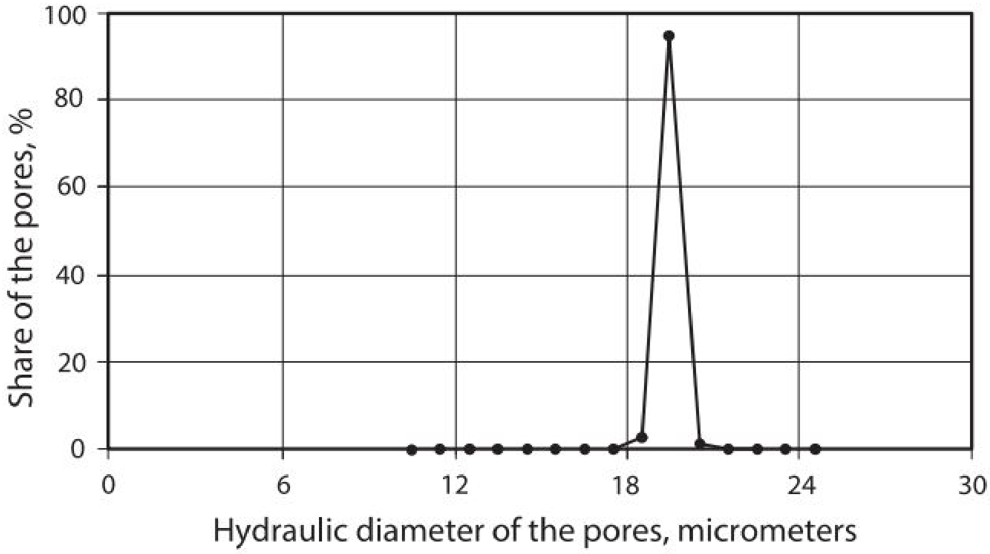


Fig. 4.8. Diagram of pore's distribution in sample (d)

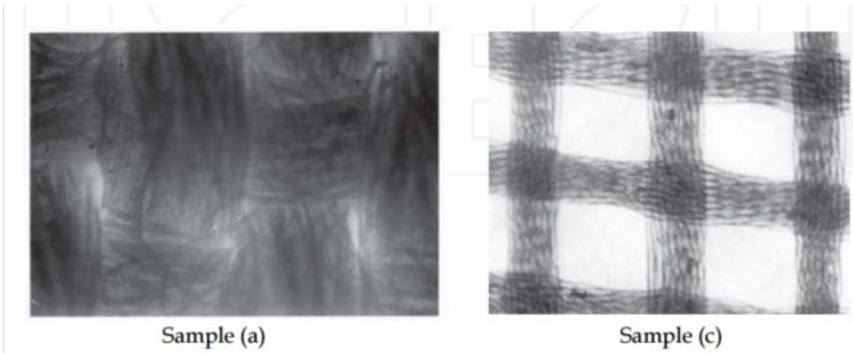


Fig. 4.9. The photos of tested samples (a) and (c)

When dealing with the sample (b), the average ratio l/w, equation (2), in table 3 is 66.06/20.13 = 3.23, see also figures 9 – 11. Hence, the criterion of having more than one hydraulic pore in a pore between threads of the warp and weft, figure 12, is thus met. The maximum value of the ratio between the value of the longer rectangular side l and the hydraulic diameter belonging the same pore is 6.84. This results in almost doubling in number of hydraulic pores – from the 50 pores measured by the scanning-electron microscope with magnification of 630, a detail can be seen in figure 11b, to estimated 99 hydraulic pores. The real number of hydraulic pores is thus 4356, if the results in table 3 are extrapolated to the test area of 1 cm2, which is in good agreement, with 4112 hydraulic pores estimated by the J-method by using the second procedure, see table 2, sample (b). The difference in number of hydraulic pores is only 4.5 %. The true open area of pores extrapolated from results in table 3 to the test area of 1 cm2 is 3.01 % and the true hydraulic open area 3.34 %. The estimated open area obtained by the method is 3.87 %, table 2, or 12.83 % more than true hydraulic open area, and 28.57 % more than true open area.

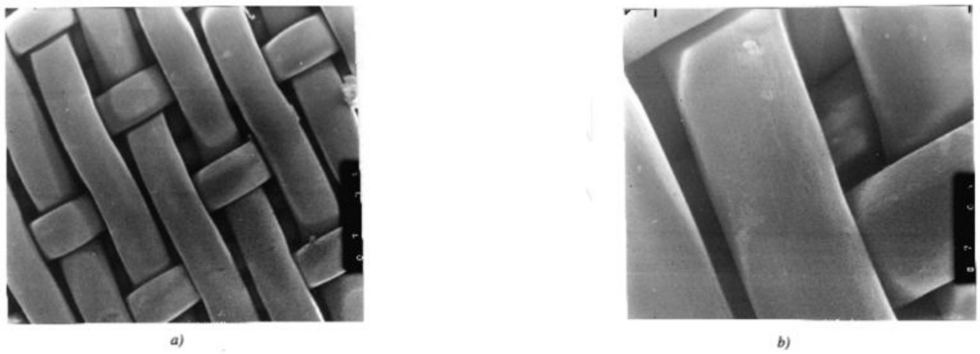


Fig. 4.10. Sample (b): a) magnification 63x, b) magnification 190x

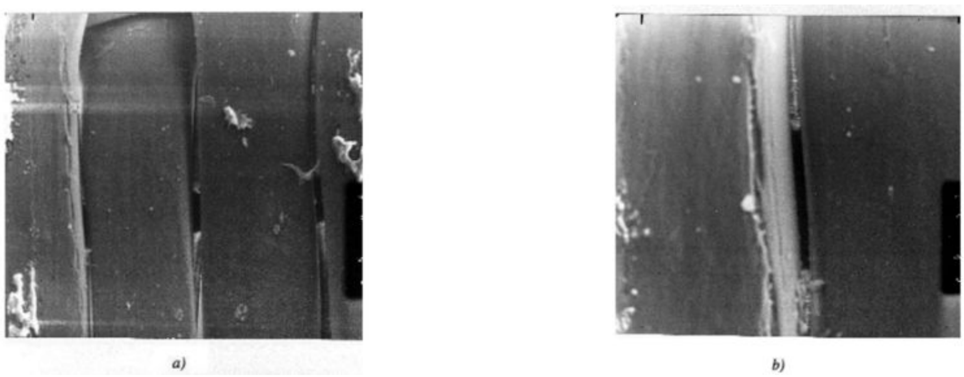


Fig. 4.11. Sample (b): a) magnification 190x, b) magnification 630x

The fibres that jut out of the yarn enmesh the pores between the threads of the warp and weft and thus dividing them into smaller pores with no regular geometrical shape if the textile is made of spinning yarn e.g. cotton woven fabric such as sample (a).

The values of the porosity parameters of the cotton fabric obtained by the first procedure are shown in table 2. The most distinctive pore in voids between the threads of the warp and weft is taken into account when inspecting the fabric with a microscope and thus obtaining the number of pores of 452 and the average pore's hydraulic diameter of 53 micrometers.

The lower value of the pore's hydraulic diameters set to 20 micrometers when computing the porosity parameters in this case. The value of a0, is high as well as the value of a1 (a1 = 1.7416), see equation (6). Both values are higher than theoretical maximum at b = 0.5. The number of pores is inversely proportional to the value of the coefficient a, equation (5), and the maximal value of the coefficient a, is 1.28. Hence, the porosity parameters of the samples (a) and also (b) are computed with the second procedure.

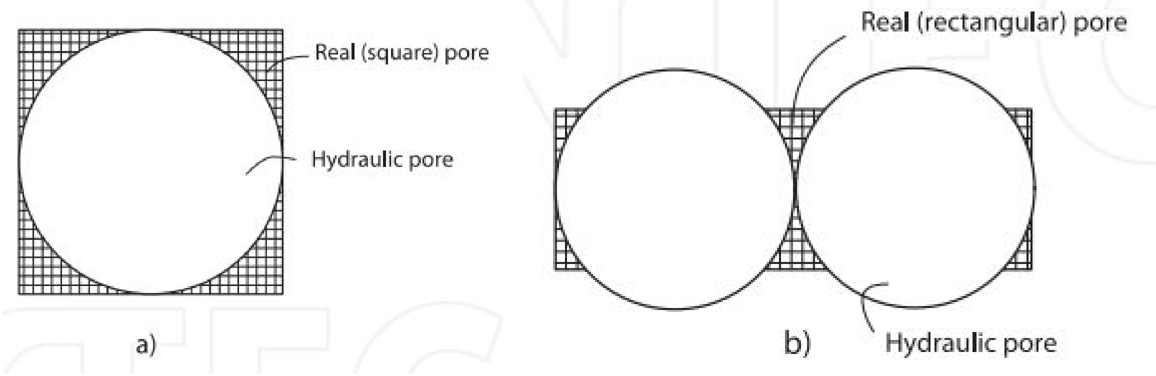


Fig. 4.12. Influence of the form of pores on the number of hydraulic pores in one pore between threads of the weft and warp in the woven fabric: a) square real pore, b) rectangular real pore

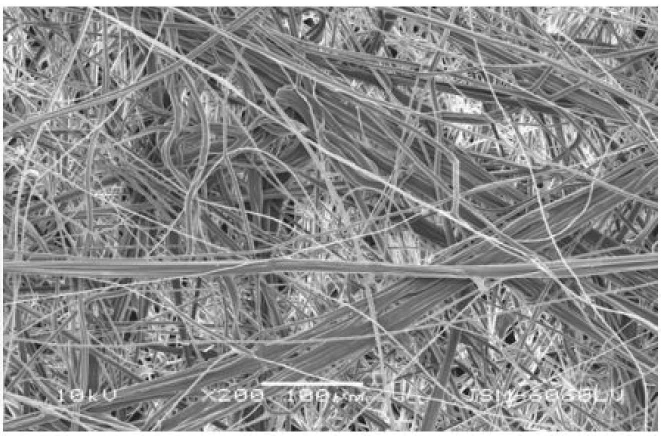


Fig. 4.13. The inner non-woven layer in the medical mask

The non-woven flat fabrics are extremely difficult to characterise in terms of porosity due to their irregular structure. The structure makes them better, more effective filtration media in comparison to the woven fabrics. Hence, the challenge is to estimate their porosity parameters. The experimental results presented in table 1, especially sample (b), proved that the porosity of the non-woven flat textiles can be estimated by J-method. We have applied J-method in order to characterise the porosity of a medical mask. The mask fabric, figure 13, is composed of three layers. The data of layers is presented in table 4. The outer layer and the layer suite on the face of subject are composed from fibres which diameter is 18 μm. The inner layer is composed from microfibers which diameter is 2 μm. In this layer the fibres are arranged in 37 layers. The walls of pores are defining by fibres. In contrast to a woven fabric, where pores are straight from one surface to the opposite one and where the length of pores is equal to thickness of the fabric, the pores in the non-woven fabric changes its direction and are thus much longer than the fabric's thickness. It is this property that makes them an excellent filtration media and at the same time, very difficult to characterise. Even though the viruses are much smaller than the hydraulic diameter of pores, the configuration of pores allows for 100% filtration efficiency.

The schematic airflow through the medical mask is shown in figure 14. The air flows through pores in a complex pattern. It is fairly difficult to developing a real theory of filtration due to that fact. The number of the pores on 1 cm2 is estimated as 63970, the maximal diameter of pores is 30.19 μm and the open area (free for air flow) is 8.42%. The results for porosity parameters estimated by J-method are presented in table 5 and the pore distribution in table 6. The coefficient a (regression equation (5)) - flow air through dry sample is 0.0890 and the exponent b (regression equation (5) - flow air through dry sample) is 0.7521. The mean hydraulic diameter of pores is estimated to the value of 12.46 μm, table 5. The nomenclature of table 5 is as following: dmax stands for the average pore diameter of the first interval (the largest pores), dmin stands for the average pore diameter of the last interval (the smallest pores), dp stands for the average pore diameter of the sample and P stands for the average open hydraulic flow area

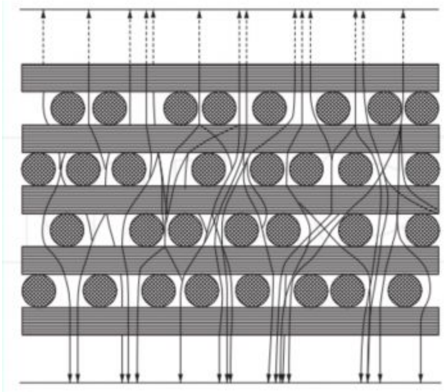


Fig. 14. Stream of air through the non-woven mask due to the respiration

Table 4.4.

Comparison of chosen physical parameters of the fibres

Non-woven layer	Mass [g/m²]	Thickness [µm]	Numbers of the fibres layers	Thickness of the fibres [µm]	Active surface (not blocked whit resin) [%]	All surface of non-woven [cm²]
Outer	17.6	92	5	18	87	160
Inner	20.4	74	37	2	100	160
Outer on the subject face	19.1	120	7	18	75	160

Table 4.4. Comparison of chosen physical parameters of the fibres from different layers, that the mask is made of.

Table 4.5.

Parameters of porosity for all three non-woven layers of mask

Parameters of porosity	Outer non - woven layer	Inner non - woven layer	Outer on the subject face	Mask (all three non-woven layers)
The biggest pore [μm]	305	38	211	30
dmax [μm]	275	28	195	28
dmin [μm]	15	8	15	8
dp [μm]	83.2	12.46	76.3	12.61
b	0.6183	0.7313	0.6143	0.7521
a	0.249	0.0889	0.2925	0.089
P [%]	27.71	8.43	25.32	8.42
Width of the classes [μm]	13	2	18	2
Number of the classes	13	10	10	10
Number of pores/cm^2	3745	64016	4506	63970

Table 4.5. Parameters of porosity for all three non-woven layers of mask; the surface of samples: 1 cm2; liquid in the pores: n-butanol

Table 4.6.

Parameters of porosity for mask

Meas. num.	Limits of the gradual classes [μm]	Hydraulic diameter of pores [μm]	Pressure [kPa]	Volumes flow [cm^3/s]	Number of pores	Portion of pores [%]
1	26-28	27	0.360	0.924	136	0.36
2	24-26	25	0.389	2.115	184	0.19
3	22-24	23	0.423	4.412	388	0.57
4	20-22	21	0.463	9.833	1029	1.61
5	18-20	19	0.512	21.504	2488	3.97
6	16-18	17	0.572	41.916	4859	7.75
7	14-16	15	0.649	74.346	8770	13.82
8	12-14	13	0.748	113.669	11324	17.70
9	10-12	11	0.884	157.730	10611	16.59
10	8-10	9	1.081	219.088	24281	37.96

Table 4.6. Parameters of porosity for mask (for all three non-woven layers)

Conclusions

J-method of porosity assessment of the flat textiles is presented here. It enables us to compute maximal and average hydraulic diameter of pores and relative distribution of pore's diameters regardless of the type of the flat textile by using both procedures. It is also possible to compute distribution of pore's diameters and true value of the hydraulic open surface if the number of pores is known and first procedure is used. If the number of pores is unknown the second procedure should be used. In that case the distribution of pore diameters and true value of the hydraulic open surface are determined approximately but well enough to meet most requirements. The results are in good agreement with those obtained by the microscope and scanning electron microscope. Considering the results obtained when testing woven fabric we have concluded that the method could be used to determine the porosity parameters of knitted fabrics and thinner non-woven fabrics. Method is suitable for assessment parameters of porosity in textiles filters, if the average hydraulic diameters are in interval 5 to 200 μm (Jakšić, 2007).

Conclusion

Research and development institutions, policy makers and above all industrial enterprises are urged to promote the up-take of the uses of jute in the geo-textile and in other potential areas, in order to sustain the development of the jute industry and the means of livelihood of millions of low income farmers.

1. Conventional woven fabrics consist of two sets of yarns mutually interlaced into a textile fabric structure.
2. Woven structures have the greatest history of application in textile manufacturing. Conventional woven fabrics consist of two sets of yarns mutually interlaced into a textile fabric structure.
3. Nonwoven technology is a newer one regarding other technologies of fibre forming assemblies.
4. Braided textile structures are manufactured with mutual interwining of yarns in a tubular form.

It is also possible to compute distribution of pore's diameters and true value of the hydraulic open surface if the number of pores is known and first procedure is used. If the number of pores is unknown the second procedure should be used. In that case the distribution of pore diameters and true value of the hydraulic open surface are determined approximately but well enough to meet most requirements. The results are in good agreement with those obtained by the microscope and scanning electron microscope. Considering the results obtained when testing woven fabric we have concluded that the method could be used to determine the porosity parameters of knitted fabrics and thinner nonwoven fabrics.

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