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## Functional Design of the Woven Filters

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### 1. Introduction

The filtration process implies the physical separation of one or more components of a fluid that passes through or over a barrier which is permeable to only one or some of the fluid components. Therefore the fundamental element of the filtration process is the barrier which is permeable to only a part of the suspension or the solution applied to filtration. This barrier is named filter medium and the mechanical structure used to support it is named filter. The statement the heart of any filter is the filter medium is fully justified. The most ingenious filter is useless if does not have an adequate filter medium. A specific shape of a filter can use a wide variety of filter mediums to do the same or different separation.

Function of their purpose filtration processes are used to separate solid – gas, solid – liquid, liquid – liquid or solid – solid mixtures. Solid – gas separation domain is represented mainly by air filters also including gas processing. Solid – liquid separation is the usual area of mechanical filters from which a relevant part is the inertial separators. Liquid – liquid and solid – solid separations are complex and specialized areas of filters or separators typology.

Industrial installations frequently use as filtration media technical textiles obtained by weaving i.e. woven filters (Adanur, 1995; Harracks&Anand, 2000). To respond to imposed exigencies by the use in industrial installations, the fabrics utilized as filter media must comply with a wide range of demands which are for the most part determined by the fabrics own structural characteristics and partially by the fabric finishing methods (Marchiş et al., 1991; Cioară et al., 1991; L.Cioară&I.Cioară, 2001). Among these requirements the following are mentioned:

- high filtration capacity, high degree of filtered elements purification and minimum hydraulic resistance;
- good mechanical resistance and stability to chemical, thermal, corrosive and biological agents;
- a high degree of the filtering surface smoothness allowing an easy and total residue separation and filter regeneration;
- a firm and homogenous structure allowing a high filtering process fineness and quality throughout the service life of the filtering element.

The fields having a vital requirement for woven textile media filtration are in a continuous diversification and specialization. It is widely known that technical textiles represent viable alternatives for all economic and social life sectors. In this context the woven textiles filter media, a significant representative of technical textiles, find their application in various

fields from automobiles to space industries, in construction, in agriculture and environment protection (Adanur, 1995; Harracks&Anand, 2000).

Filtration processes are accomplished following two basic principles: depth filtration and surface filtration (Medar&Ionescu, 1986). Both forms of the filtering process imply the simultaneous occurrence, in different ratio of two physical phenomena:

- direct particles retention – do to this process filter medium stand for a mechanical barrier for particles bigger than the restriction;
- adsorption – particles retention by electrostatic forces or molecular attraction of the filter medium.

Principle of **depth filtration** and the specific mechanisms through which the particles are retained are shown in Figure 1.a. Direct interceptions take place when particles of a certain size are passing through larger pores and are trapped in the filter medium structure when meet smaller pores. Inertial forces cause particles to hit filter medium fibers the particles retention being obtained due to their penetration into the body of fibers or due to the fiber deformation.

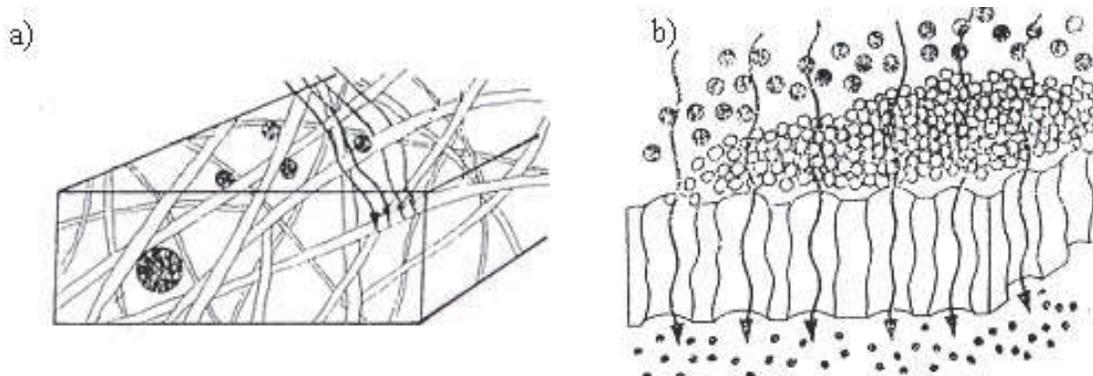


Fig. 1. Filtrations mechanisms

Inertial impaction is predominant when high fluid velocity or very dense filter medium is present. This type of filtration mechanism is most predominant when high gas velocity and/or dense packing of the filter media is present. Inertial impaction occurs also when an abrupt change in streamline take place. In this case the particle, due to its inertia, will continue along its original path and could be retained by the filter medium

Adsorption phenomena determine the attraction of small size particles by the filter medium fibers. The adsorption is favored by particles Brownian movement of the particles during the filtration process. Textile filter media that work by the depth filtration principle are: nonwoven fibrous layers, simple textiles made of spun or filamentary yarn, pile or felted, composite fabrics made as semi double, double or multiple layers structures.

**Surface filtering** implies that particles larger than the pore size are retained on the filter medium surface (Figure 1.b) Due to the adsorption forces particles smaller than pore size can be retained along the pore wall, reducing its transverse dimension causing blocked pores and filter medium clogging as a result. In the first phase of the clogging nominal fineness of filtration is reduced, the pressure difference increases and a combination of surface filtration with a pseudo-depth filtration take place (occurs).

Later on, as the degree of clogging increases, fluid flow through the filter medium is significantly reduced. Textile filter media which operate by surface filtration are monofilament yarns woven textiles.

The comparative analysis of the woven filter media working according to these two principles highlights their advantages and disadvantages (Table 1). In all cases the filter media is considered within the conventional filtering range ensuring the separation of particles over 1  $\mu\text{m}$  in size (Rouette, 2001).

Filtration fineness is influenced by filter medium structure. Pore size distribution is Gaussian for filter media that operates on depth filtering principle and covers a narrower range around the mean value for filter media that works on surface filtration principle. As a result, the particles retention set in the case of surface filtration is much more restrictive than in the case of depth filtration.

Depth filtration		Surface filtration	
advantages	disadvantages	advantages	disadvantages
low cost	hard to clean	possibility of cleaning and reuse	high cost
high efficiency	filter medium particles migration is possible	filter medium particles migration is excluded	low initial efficiency
high capacity to retain impurities	filtering performance is depending on the fluid viscosity	fatigue resistance, resistance to temperature or corrosive agents	limited capacity to retain impurities
	relatively large pressure drop	lower pressure drop	
	increased clogging	reduced clogging	

Table 1. Comparative analysis of filter media

## 2. Analysis of woven filter media functionality

Woven filter media are products that are differentiated by structure and properties in strict accordance with the requirements and particularities of the process in which they operate. The filter medium structure is necessarily associated with the principle used to separate the mixture particles (surface filtration or depth filtration).

### 2.1 Features woven filter media

The result of filter medium different properties combination sets up its quality and respectively its functionality. For an objective assessment of filter media quality (functionality) three groups of properties have been identified as follows:

- properties related to filter medium mounting system type. Those properties are important for the mechanical implementation of the filter respectively the filter medium set up on the support frame. Among the key properties of this group stated: stiffness, tensile strength, tear resistance, burst strength, abrasion resistance, vibration stability, elongation, the edges stability;
- properties related to the application type that are taking in consideration the compatibility between the filter medium and the processed medium. In this category falls the following properties: chemical stability, thermal stability, biological stability, dynamic stability, adsorption, absorption, operational safety and security, electrostatic characteristics, reuse capability, price;

- properties addressing specific filtrations process particularities underlining the filter medium capacity to comply with required demands. The most important properties of this group are: the smallest particle retained, retention efficiency, the structure of filter media, particle shape, filtering mechanisms used, flow resistance, porosity of filter media, permeability, tendency to clog, filter-cake discharge characteristics.

Symbol	Function name	Technical dimension	Function type
F1	to separate the phases of a heterogeneous mixture	porosity permeability	primary, objective, necessary, general
F2	to ensure filtration fineness	shape, size and pore distribution	primary, objective, necessary, specific to filter principles
F3	to be dimensionally stable during operation	elastic and residual tensile strain	primary, objective, necessary, specific to filter principles
F4	to withstand the action of mechanical factors during operation	tensile strength burst resistance	primary, objective, necessary, specific to filtration process
F5	to withstand the erosive effects of the environment	chemical resistance	primary, objective, necessary, specific to filtered fluid
F6	to ensure filtration velocity	active filtration surface	primary, objective, necessary, specific to filter principle
F7	to withstand the erosive action of the filtered fluid	abrasion resistance	secondary, objective, necessary, specific to filtration process
F8	mechanical durability	fatigue resistance	secondary, objective, necessary, specific to filter type
F9	shouldn't clog	filter structure, pores shape	secondary, objective, necessary, specific to filter type
F10	easy to clean and rebuild	filter structure raw material	secondary, objective, necessary, specific to filter type
F11	easy to fabricate	filter structure, fabrication technology	secondary, objective, necessary, specific to filter type
F12	easy to install and replace	filter shape and dimensions	secondary, objective, necessary, specific to filter type

Table 2. The functions of woven filter media

For each filter medium, depending on field of use and the requirements in service only some of these properties are necessary. As a result, the design of woven textiles intended to be used as filter media must be made in accordance with functionality criteria ensuring priority to the properties requested by the process utilized.

The relation structure – properties – use value is the design criterion for woven filters. Value engineering is a method of research and systemic design according to which the functions of the product studied (filter medium) must be designed and carried out with minimum expenditure in terms of highest quality, reliability and performance (Condurache et al., 2004). Value engineering instrumentation methodology implies the following stages:

- functional analysis: answers the questions what is and what the product does; the function list of the analyzed product is completed;
- classification of functions: answers the question how important the function is and how well meets the user requirements; function's relative importance, intrinsic and technical dimension terms are ascertained; functions classification for the analyzed product is finalized;
- product design or redesign based on required functions.

Function is considered an essential attribute of the studied product expressed in terms of medium and user. In the same time, the function can be regarded as a characteristic of the product that determines a particular utility. The list of function classification is the starting point of value engineering studies.

Product functions are determined by importance, the measurement method, its contribution to achieving use value and the degree of generality.

Drawing up the list of filter medium functions is based on defining the filter medium and the conditions under which it works. In principle woven filters are intended to be used in filtration.

Based on such considerations the functions considered to be necessary for the filter medium, their technical elements of assessment and their typology classified by standard criteria are shown in Table 2 (I.Cioară&L.Cioară, 2009).

## 2.2 The hierarchy functions woven fabrics filter

After developing the list of all functions their classification is done in order to establish the importance and weightiness of each function in rapport to all functions the product offers. The classification of the function is done using Value Engineering methods such as the Expertise Method or Imposed Decision Method. Regardless of the method used the classification is done considering all filter media functions or, selectively, group of functions, classified according to their typology.

Imposed Decision Method presents a high degree of objectivity (Condurache et al., 2004). To apply this method the following steps must be achieved: comparing the functions in pairs, calculating the importance coefficient for each function and classifying the functions by their importance coefficient value. By comparing the environmental functions as a filter to obtain decisions (0-1), (0.5-0.5) or (1-0). Scoring are considered: 0 considered less important function, 1 for the function considered more important, compared to 0.5 when the functions are valued as important. D total number of decisions resulting from the comparison of the n features of the filter is calculated with:

$$D = C_n^2 = \frac{n \cdot (n - 1)}{2} \quad (1)$$

I importance factor for each sample is calculated function the relationship:

$$I = \frac{N}{D} \quad (2)$$

where: N is the sum of points awarded;

D - total number of decisions.

The filter media 12 functions obtained by weaving defined in Table 2 were divided into two groups: 6 primary and 6 secondary functions. Apply for group relationship of the main functions, which will be used to design, to establish the number of decisions as follows:

$$D = C_6^2 = \frac{6 \cdot (6-1)}{2} = 15 \quad (3)$$

Func-tion	Decisions															N	I
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
F1	0.5	0.5	1	1	0.5											3.5	0.233
F2	0.5					0.5	1	1	0.5							3.5	0.233
F3		0.5				0.5				0.5	0.5	0.5				2.5	0.166
F4			0				0			0.5			0.5	0		1	0.066
F5				0				0			0.5		0.5		0	1	0.066
F6					0.5				0.5			0.5		1	1	3.5	0.233

Table 3. Coefficient calculation Ranking

The name of the function	Specific technical dimension	Structural characteristics of fabric
to separate the phases of a heterogeneous mixture	pore size	fineness and density of yarns
to ensure filtration fineness	pore shape and distribution, filter medium fineness	fineness and density of yarns, weave
to ensure filtering velocity	adequate filtering active area	fineness and density of yarns
to be dimensionally stable during operation	structural and mechanical characteristics of yarn and fabric	the mechanical characteristics of the of yarns
to withstand the action of mechanical factors during operation	tensile strength burst resistance	the mechanical characteristics of the of yarns
to withstand the erosive effects of the environment	chemical resistance	the nature of raw material

Table 4. Priority functions of the filter media and their assessment criteria

In Table 3 are comparative analysis, two by two principal functions. The last column of the table are shown the importance scores and values of each corresponding functions. Based on

the values of the coefficients of importance to obtain the hierarchy of the main functions in the following sequence: F1, F2, F6, F3, F4, F5.

Priority functions set out in this way are taken into consideration when designing or redesigning filter media weaved in accordance with functionality criteria. In this respect the assessing criteria of woven filter media priority functions are summarized in Table 4.

The parameters specific to the woven filter with simple structure that will provide functional design criteria are: the relative porosity, pore shape and size, the pore distribution, the active filtering surface.

The structural characteristics of woven fabric, which determine the parameters of filter fabric are: yarns count, thread density and weave.

### **3. Structural and functional characteristics of the fabric filters with simple structure**

Characterization and use of the fabric estimating filters with simple structure can be made by means of specific structural and functional characteristics (Behera, 2010; Cioară, 2002). Among these characteristics are mentioned: porosity, pore size and architecture, active filtering surface environment and filter fineness.

#### **3.1 Porosity**

Porosity, feature size filter material is the property of having pores in their structure (Medar&Ionescu, 1986; Cay et al., 2005). In connection with the porosity are two distinct notions:

- relative porosity, apparent or open, when taking into account only pores that communicate with each other;
- absolute porosity, effective or real, if we take into account all the pores, i.e. those who are isolated.

Fluid flow through uniform or uneven spaces created by the filter medium, while maintaining the quality of filtration, filtration efficiency and smoothness and filtering capacity are issues directly related to the porosity of filter media.

Fluid movement across the filter medium is described by the filtration rate, defined as the maximum volume of fluid passing per unit time through unit area of filter. Porosity refers to the filter media pore volume per unit volume and is typically seen in relative units. Generally, the textile filtering media are inhomogeneous because the filter permeability changes during the exploitation. The medium in homogeneity can be bigger or smaller, depending on the structure of woven filter.

#### **3.2 Pore dimensions and architecture**

An important feature of each filter surfaces is the existence of pores which penetrate the entire thickness of the filter and retain solid particles larger than the pores in the cross section of their most narrow, but allow passage of fluid that carried them. Small pore is a void within a solid body. After dimensions are distinguished (Medar&Ionescu, 1986) : fine pores with a diameter greater than 20  $\mu\text{m}$  (invisible to the naked eye) and coarse pore diameter greater than 20  $\mu\text{m}$  (visible to the naked eye). The way of communication with the outside pores can be:

- open, when communication with the outside;
- closed, when no communication with the outside.

Dimensional uniformity and stability of pores of a filter medium directly influences the process of filtering performance (Gabrijelcic et al., 2009). Pore size and shape of woven textile filter media are dependent on the basic structural parameters of fabric: the fineness of yarns, thread density and the weave.

Pore's characteristics which is assessed functional performance of a fabric filter are: side pore, pore area, architecture and distribution of pores in the fabric plane.

Side and pore area are geometric features of woven fabric due to its basic structural parameters.

In terms of basic structural parameters, the woven fabrics with simple structure can be balanced or unbalanced in fineness and density yarns, and the resulting pores have square or rectangular form.

In Figure 2 are defined pore geometry of a woven fabric with simple structure. In the balanced woven fabric (Figure 2.a), the warp and weft, have the same fineness and density, the same diameter  $d$  and the same density  $P$ . Therefore to obtain a filter fabric with square pores. In the unbalanced woven fabric (Figure 2.b), the warp and weft have different count, expressed by  $d_u$ ,  $d_b$ , and different density threads expressed by  $P_u$ ,  $P_b$ . As a consequence to obtain a fabric filter with rectangular pores.

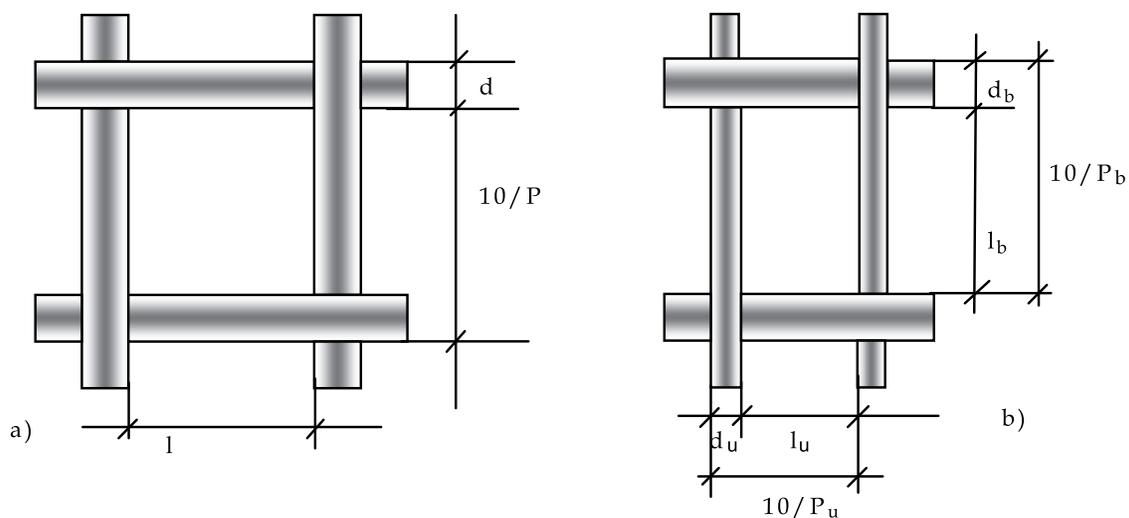


Fig. 2. Pore geometry

### 3.2.1 Pore side

Pore side is the distance between two consecutive threads of the fabric measured in the projection on the horizontal fabric's plan.

For structures balanced (Figure 2.a), pore side it could be calculated with:

$$l = \frac{10}{P} - d \quad (\text{mm}) \quad (4)$$

For structures unbalanced (Figure 2.b), pore sides,  $l_u$  and  $l_b$ , is defined by relations:

$$l_u = \frac{10}{P_u} - d_u \quad (\text{mm}); \quad l_b = \frac{10}{P_b} - d_b \quad (\text{mm}) \quad (5)$$

### 3.2.2 Pore area

Pore area is defined as the projection on the horizontal plan of the fabric's pore.

For balanced structure (Figure 2.a) the pore area  $A_p$  is calculated with:

$$A_p = l^2 \text{ (mm}^2\text{)} \quad (6)$$

For unbalanced structure (Figure 2.b) pore area is calculated by the relationship:

$$A_p = l_u \cdot l_b \text{ (mm}^2\text{)} \quad (7)$$

### 3.2.3 Pores architecture

Pores architecture is a characteristic determined by the fineness of yarns, threads density, mechanical and rheological characteristics of yarns and weave used. The segments of the yarn which constitute the pore sides can be considered, like a beam in one of two situations:

- passing from one side to another fabric,
- above or under the opposite yarn system.

Under these circumstance, the pores' shape and size depend not only on yarn count and density, but also on the positions of the yarns in the weave.

For this purpose an analysis is presented which highlights the fact that the weave determines the distribution of requests in the yarns and the default form of pores. The analysis is done on three woven fabrics filter, whose characteristics are presented in Table 5.

The weave used in implementing the three fabrics are shown in Figure 3. To the right of each weave are represented by pores with a distinct architectural (Cioara et al., 2003).

Woven filter	Weave	Raw material	Yarn diameter (mm)	Thread density (yarns/cm)
Filter 50 mesh	Plain	Polyamide	0.14	20
Filter 22 mesh	Twill D2/2	Polyamide	0.45	9
Filter 24 mesh	Twill D3/1	Polyamide	0.45	9.5

Table 5. Variants of filter fabrics

After examining the shape of pores in the three weave can be made the following observations and interpretations:

- at the fabric filter with plain weave (Figure 3.a) all the pores have the same architecture; the threads have a similar position in the pore sides (all threads are crossing from one side to another of the fabric). Under these conditions the fabric structure creates the potential formation of uniform pores in the shape of their; the pores I, is identical in structure with pores II;
- at the fabric filter with twill weave D 2/2 (Figure 3.b) pores of the report have the same structure. Shapes and sizes of the four types of pores are identical. It creates the conditions to achieve a uniform structure with a high degree of homogeneity to ensure a quality filter; pores numbered I, II III IV is identical in structure;
- at the fabric filter with twill weave D 1/3 (Figure 3.c) is classified in four types of pores. The four distinct architecture creates pores with different shapes and volumes that the

conditions for the flow through it are differentiated; pores numbered II, is identical in structure with pores IV, pores I and III is different.

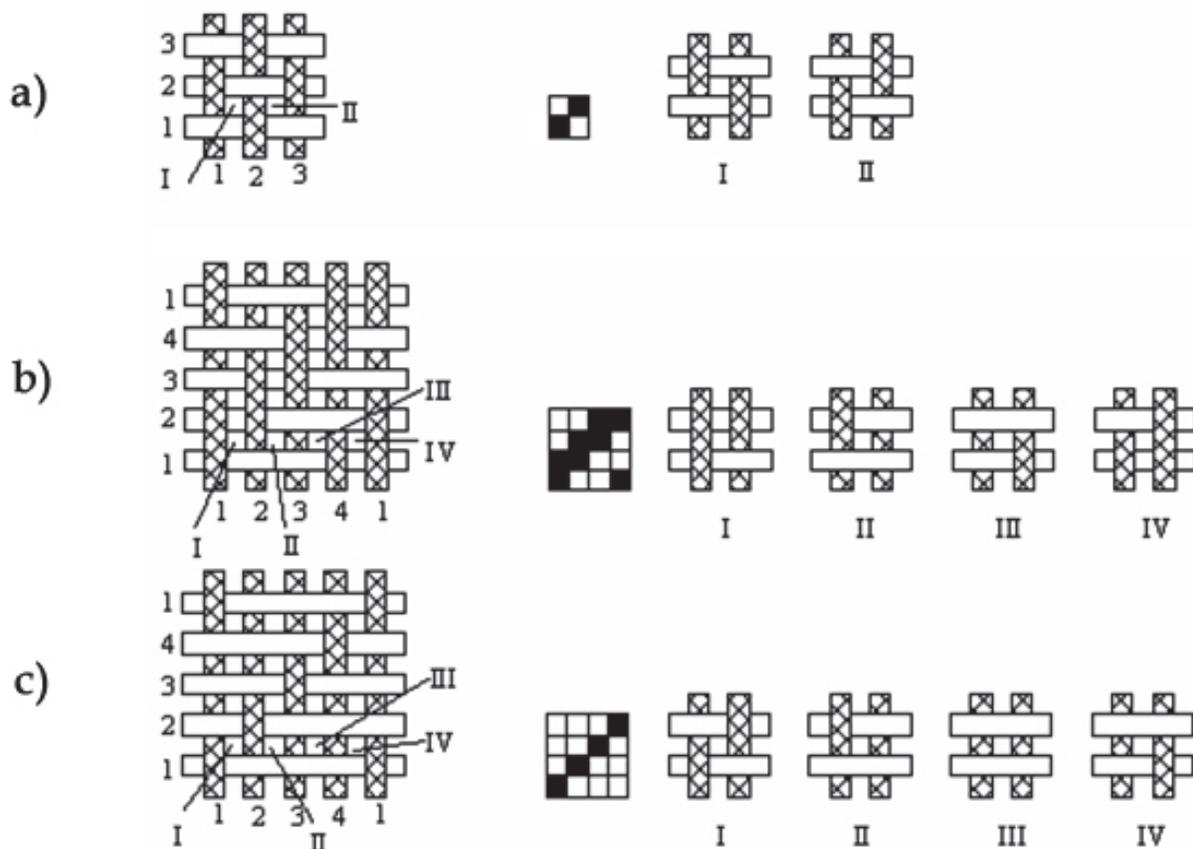


Fig. 3. Type of pores

To support these interpretations, on the three types of fabric filter were performed measurements of area pores, using a specialized program. Measurements were made on the fabric images captured with a stereo microscope with digital camera.

These images are presented in Figure 4, 5 and 6. In each figure is shown a fragment of the microscopic image of the fabric filter with the contours measured pore, the statistics of individual value of area and pore distribution curve.

To facilitate analysis of information provided by research, in Table 6 were centralized statistical processing on the string values of individual values of the areas measured.

Weave	Mean area (mm <sup>2</sup> )	Min. value (mm <sup>2</sup> )	Max. value (mm <sup>2</sup> )	Range (mm)	Std.Dev. (mm)	CV (%)
Plain	0.1021164	0.0841335	0.1120637	0.0279302	0.0064476	6.31
Twill D2/2	0.2104919	0.1555840	0.2731934	0.1176094	0.0310180	14.73
Twill D3/1	0.3233822	0.1810607	0.4755648	0.2945041	0.0722753	22,34

Table 6. Statistical evidence

The analysis of microscopic images shows that the filter fabric with plain weave (Figure 4) pores are relatively uniform shapes and sizes. This is supported on the one hand, the low dispersion of individual values ( $s=0.00644$ ) and, on the other hand, the restricted

distribution of individual values around the average. Extreme values, minimum and maximum, with reduced weight, have a deviation of up to 10% of the average pore area. At the fabric filter with twill weave D 2/2 (Figure 5) is observed as architecture, two types of pores with greater irregularity than plain weave. Pore area shows a greater variation, which is confirmed by the dispersion value ( $s=0.03101$ ) and the pore distribution curve shape. Even if the pore area varies widely, up to 25% from the mean, the woven filter is estimated that the structure is uniform. Extreme values are numerous and, consequently, the distribution curve is wider.

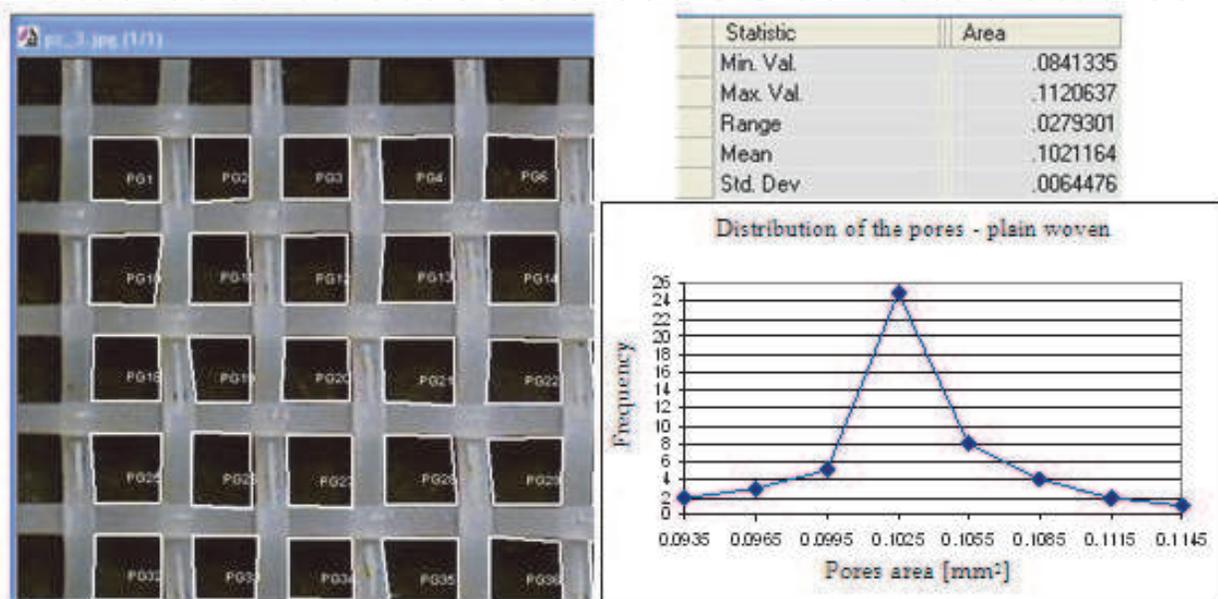


Fig. 4. Pore architecture of the woven filter - plain weave

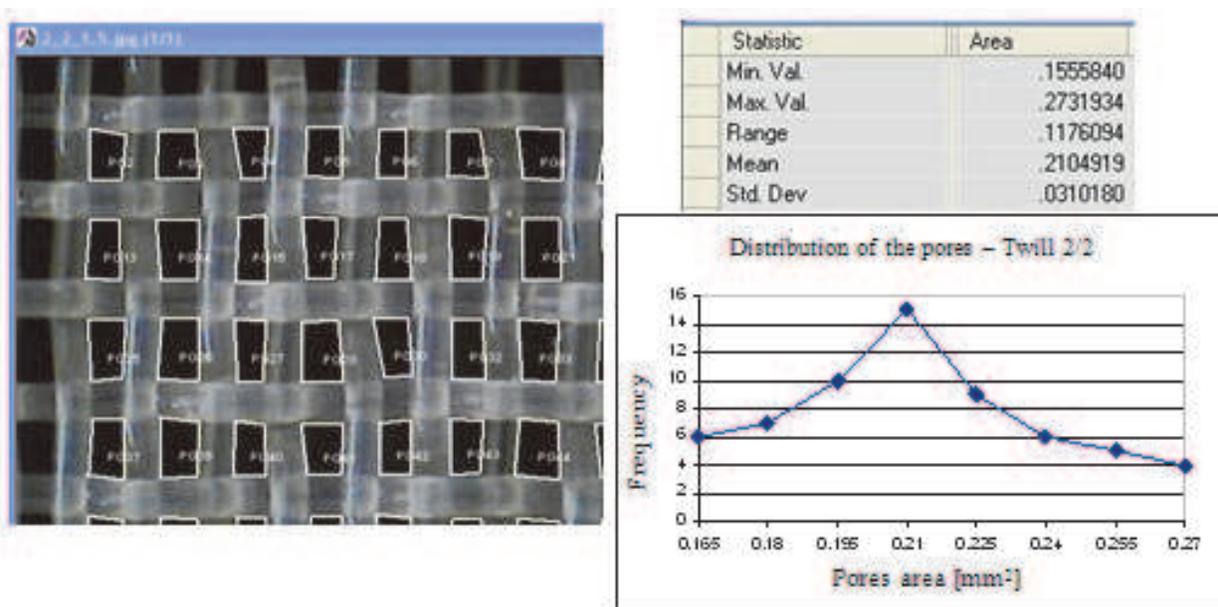


Fig. 5. Pore architecture of the woven filter - twill D 2/2

At the fabric filter with twill weave D 3/1 (Figure 6) is observed as architecture, the four specific types of pores. The dispersion of measured values ( $s=0.07227$ ) indicates large variation in pore area, which is emphasized by the distribution curve. Pore area varies widely, with over 50% of the mean value and the structure of a fabric filter has emphasized the uneven character.

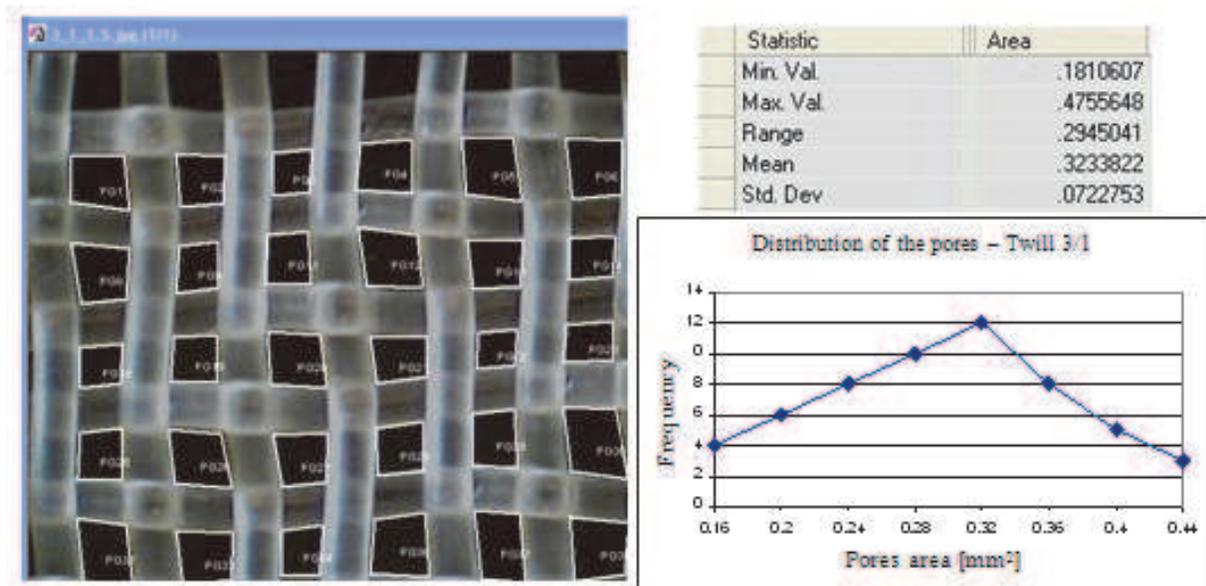


Fig. 6. Pore architecture of the woven filter - twill D 3/1

### 3.3 The active filtering surface

This parameter provides information about the porosity of the woven filter and resistance to fluid flow through it. Active filtering area was defined as the ratio of pore area,  $A_p$ , and area of fabric element,  $A_{et}$ , is calculated from the relationship:

$$S_a = \frac{A_p}{A_{et}} \cdot 100 (\%) \quad (8)$$

### 3.4 Filter fineness

The woven filter fineness is a nominal identification, which is expressed by the number of pores per unit length or number of pores per unit area. The filter fineness is calculated by the following relations:

balanced woven filter fabrics:

$$F = P \text{ (pores / cm)} \quad (9)$$

$$F_m = 2.54 P \text{ (pores / inch)} \quad (10)$$

$$F_a = P^2 \text{ (pores / cm}^2\text{)} \quad (11)$$

unbalanced woven filter fabrics:

$$F_d = P_u P_b (\text{pores / cm}^2) \quad (12)$$

#### 4. Algorithms for functional design of filter. Examples of application

The last stage of the value engineering technique is to design or redesign based priority functions. Based on the conclusions presented in the above analysis were developed five functional design algorithms for simple structure filter fabrics balanced and unbalanced in fineness and/or density (I.Cioara & L.Cioara, 2010). Always choose the algorithm is done according to known elements (input data) and the requirements process of filtering (output data) to design, redesign or verification. Following the sequence of calculation steps is different from one algorithm to another.

##### 4.1 Algorithms for functional design of filter

In Tables 7 and 8 shows the deployment of the calculations according to data input and output, these calculations are completed to the mass of fabric filter.

In the relationships of calculating the parameters of qualitatively appraising the simple structure woven fabrics used as filtering media the significance of the employed symbols is the following:  $d$  - yarn diameter in the balanced structures (mm);  $d_u$ ,  $d_b$  - warp and weft diameter (mm);  $A$  - tabled constant for the diameter calculating;  $A_p$  - pore area, (mm<sup>2</sup>);  $A_{et}$  - woven fabric element area, (mm<sup>2</sup>);  $T_{tex}$  - yarn count in the balanced structures, (g/km);  $T_{texu}$ ,  $T_{texb}$  - warp and weft count, (g/km) ;  $P$  - threads density in the balanced structures, (yarns/cm);  $P_u$ ,  $P_b$  - warp density and weft density, (yarns/cm);  $l$  - square pore side, (mm);  $l_u$ ,  $l_b$  - the pore side in the warp and weft direction, (mm);  $F$  - balanced structure filter fineness, (pores/cm);  $F_m$  - balanced structure filter fineness, (pores/inch);  $F_d$  - filter fineness, (pores/cm<sup>2</sup>);  $M$  - woven fabric mass, (g/m<sup>2</sup>);  $a$  - crimp yarn in the woven fabric, (%);  $m$  - factor of unbalanced for threads density.

##### 4.1.1 Algorithm I. Design of simple filters based on the density and fineness of yarn (Table 7)

In this case we consider as known the basic structural characteristics of fabric: warp and weft yarn diameters ( $d_u$ ,  $d_b$ ) and their densities ( $P_u$ ,  $P_b$ ). The algorithm is used to identify specific characteristics of woven fabrics filters: the filter fineness, the pore side and area, the active filtering surface.

Based on of factors identified can be appreciated if appropriate filter fabric filtration process characteristics. Depending on the conclusions formulated after verification can be redesign the fabric to match the outlays.

##### 4.1.2 Algorithm II. Design of simple filters based on the yarn diameter and filter fineness (Table 7)

In this case it is considered known diameters of the warp and weft of yarns ( $d_u$ ,  $d_b$ ) and fineness filter fabrics. The algorithm is used to design a filter of woven fabrics density unbalance. The yarns density, the pores sides and surface, the active filter area and the fabric weight are determined by calculations.

Since by changing the density unbalance factor the pores shape and dimensions are also modified ensuring an appropriate filtering fineness. The algorithm can be additionally used to re-design according to given requirements.

#### 4.1.3 Algorithm III. Design of simple filters based on the yarn diameter and side of pore (Table 7)

Algorithm I	Algorithm II	Algorithm III
1. Input data: $d_u, d_b, P_u, P_b$	1. Input data: $d_u, d_b, F_d$	1. Input data: $d_u, d_b, l_u, l_b$
2. Yarn count $T_{tex} = \frac{d^2}{A^2}$	2. Yarn count $T_{tex} = \frac{d^2}{A^2}$	2. Yarn count $T_{tex} = \frac{d^2}{A^2}$
3. Filter fineness balanced structures $F = P_u = P_b$ pores / cm $F_m = F \cdot 2.54$ pores/inch unbalanced structures $F_d = P_u \cdot P_b$ pores/cm <sup>2</sup>	3. Thread density $P = f(F_d)$ $P_u \cdot P_b = F_d$ $\frac{P_u}{P_b} = m$ $P_u = \sqrt{F_d \cdot m}$ $P_b = \frac{P_u}{m}$	3. Thread density $P = f(l_p, d)$ $P_u = \frac{10}{l_u + d_u}$ $P_b = \frac{10}{l_b + d_b}$
4. Pore side $l_u = \frac{10}{P_u} - d_u$ $l_b = \frac{10}{P_b} - d_b$	4. Pore side $l = f(P, d)$ $l_u = \frac{10}{P_u} - d_u$ $l_b = \frac{10}{P_b} - d_b$	4. Filter fineness balanced structures $F = P_u = P_b$ pores / cm $F_m = F \cdot 2.54$ pores/inch unbalanced structures $F_d = P_u \cdot P_b$ pores/cm <sup>2</sup>
5. Pore area	$A_p = f(P, d)$ $A_p = \left( \frac{10}{P_u} - d_u \right) \cdot \left( \frac{10}{P_b} - d_b \right)$	
6. Filtering active surface	$S_a = f(P, d)$ $S_a = (10 - P_u \cdot d_u) \cdot (10 - P_b \cdot d_b)$	
7. Woven fabric mass	$M = \frac{P_u \cdot T_{texu}}{10} \cdot \frac{100}{100 - a} + \frac{P_b \cdot T_{texb}}{10} \cdot \frac{100}{100 - a}$	

Table 7. Specific elements for algorithms design I, II, III

Algorithm IV	Algorithm V
1. Input data: $d_u, d_b, S_a$	1. Input data: $l_u, l_b, S_a$
2. Yarns count $T_{tex} = \frac{d^2}{A^2}$	2. Pore area $A_p = l_u \cdot l_b$
3. Thread density for balanced structures of cover factory: $P_u \cdot d_u = P_b \cdot d_b$ $P = f(S_a, d)$ $P_u = \frac{10 - \sqrt{S_a}}{d_u}$ $P_b = \frac{10 - \sqrt{S_a}}{d_b}$	3. Thread density $P = f(S_a, l_p)$ $S_a = \frac{A_p}{A_{et}} \cdot 100 \Rightarrow A_{et} = \frac{A_p \cdot 100}{S_a} = \frac{10}{P_u} \cdot \frac{10}{P_b}$ $P_u \neq P_b ; \frac{P_u}{P_b} = m$ $P_b = \sqrt{\frac{S_a}{m \cdot A_p}}$ $P_u = P_b \cdot m$
4. Filter fineness balanced structures $F = P_u = P_b \text{ pores / cm}$ $F_m = F \cdot 2.54 \text{ pores/inch}$ unbalanced structures $F_d = P_u \cdot P_b \text{ pores/cm}^2$	4. Filter fineness balanced structures $F = P_u = P_b \text{ pores / cm}$ $F_m = F \cdot 2.54 \text{ pores /inch}$ unbalanced structures $F_d = P_u \cdot P_b \text{ pores/cm}^2$
5. Pore side $l = f(P, d)$ $l_u = \frac{10}{P_u} - d_u$ $l_b = \frac{10}{P_b} - d_b$	5. Yarns diameter $d_u = \frac{10}{P_u} - l_u$ $d_b = \frac{10}{P_b} - l_b$
6. Pore area $A_p = f(P, d)$ $A_p = \left( \frac{10}{P_u} - d_u \right) \cdot \left( \frac{10}{P_b} - d_b \right)$	6. Yarns count $T_{tex} = \frac{d^2}{A^2}$
7. Woven fabric mass $M = \frac{P_u \cdot T_{texu}}{10} \cdot \frac{100}{100 - a} + \frac{P_b \cdot T_{texb}}{10} \cdot \frac{100}{100 - a}$	

Table 8. Specific elements for algorithms design IV, V

The algorithm is used to design the fabric characteristics in compliance with the parameters of the filtering process. The input data are warp and weft yarn diameters ( $d_w$ ,  $d_b$ ) and pore sizes ( $l_w$ ,  $l_b$ ). Imposing pore side means the particle to be retained is known, the filter being a calibrated restriction. The required yarn density and all the specific characteristics of the filter are obtained by calculations.

#### 4.1.4 Algorithm IV. Design of simple filters based on the yarn diameter and active filter area (Table 8)

Active filter area is a feature that determines the permeability of the fabric and filter potential to withstand the fluid flow. This algorithm is considered known following elements: the warp and weft yarn diameters ( $d_w$ ,  $d_b$ ) and active filtering surface ( $S_a$ ).

The algorithm allows the calculation of specific characteristics of the filter: pore area and pore side, which determines the filtration fineness and efficiency.

#### 4.1.5 Algorithm V. Design of simple filters based on the pore side and active filter area (Table 8)

In this case filter fabrics design is based on filtering process requirements. Input data are: pore sizes ( $l_w$ ,  $l_b$ ) and active filtering surface ( $S_a$ ). Active filter area determines the filter permeability and influences the flow velocity. The pore side determines the size of the retained particle and influences the filtration fineness and efficiency. The structural characteristics of the fabric are obtained by calculations.

### 4.2 Examples of application

Further gives examples of the implementation of the five algorithms to design filter woven fabrics with simple structure made from monofilament yarns.

To facilitate the calculation has been made a computer assisted design program (Cioara et al., 2008).

Sequence with the principal program menu is shown in Figure 7. At the top of the screen, interactive buttons, the corresponding input data are highlighted five algorithms. The dates presented in Figure 7 are typical application example of the algorithm I (Table 9).

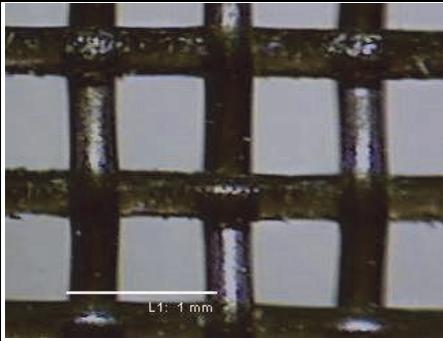
Sample filter	Parameter	Symbol	Value	UM
	Yarns diameter	$d$	0.31	mm
	Thread density	$P$	11.0	threads/cm
	Filter finess	$F$	11.0	pores/cm
	Filter finess mesh	$F_m$	27.94	pores/inch
	Pore side	$l$	0.599	mm
	Pore area	$A_p$	0.3589	mm <sup>2</sup>
	Filtering active surface	$S_a$	43.43	%
	Dimensional factor	$A$	0.0392	-
	Yarns count	$T$	62.54	tex
	Crimp yarn	$a$	4	%
	Woven fabric mass	$M$	143.32	g/m <sup>2</sup>

Table 9. Balanced structure - designed with algorithm I (weave plain)

The program has the possibility of saving data Input and account for the different variants. These data are provided to the operator in the form of tables. In this way the designer can to compare specific elements of the different variants and select the variant that best corresponds to requirements process of filtering.

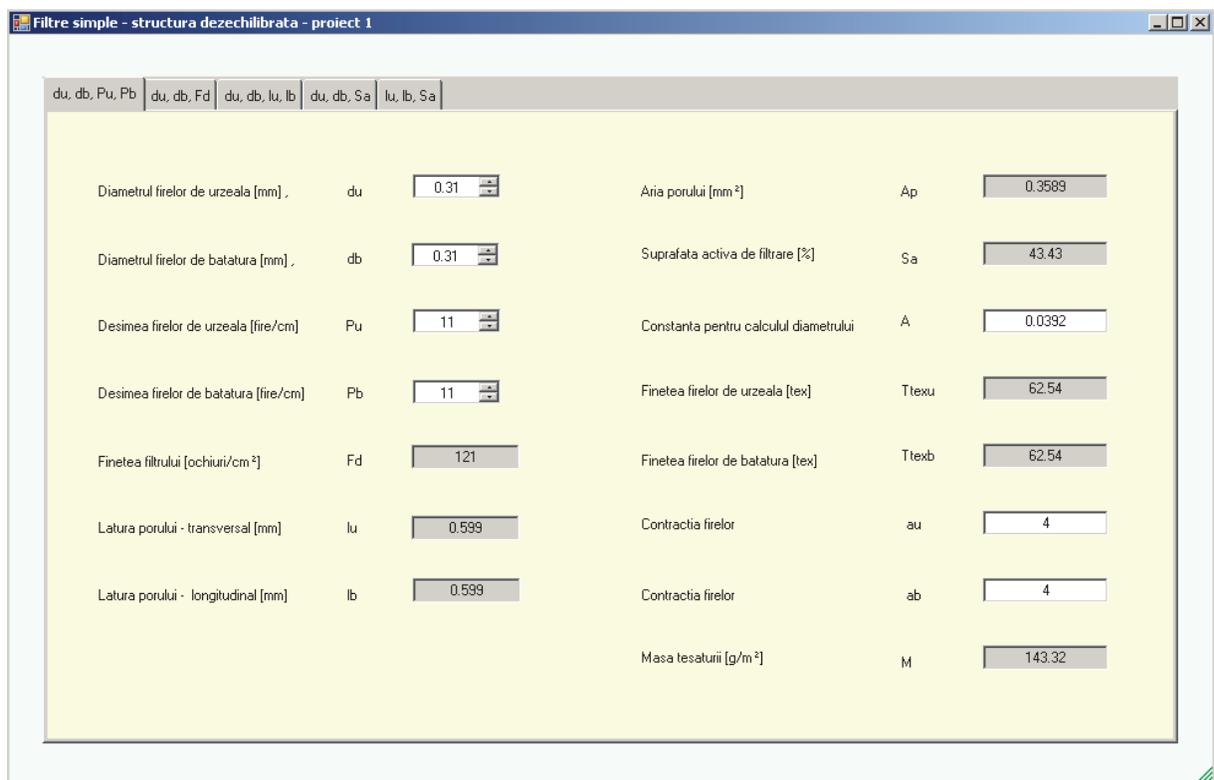


Fig. 7. The main menu of the program

Sample filter	Parameter	Symbol	Value	UM
	Yarns diameter	d	0.29	mm
	Filter finess mesh	Fm	36	pores/inch
	Filter finess	F	14.2	pores/cm
	Thread density	P	14.2	threads/cm
	Pore side	l	0.414	mm
	Pore area	A <sub>p</sub>	0.1716	mm <sup>2</sup>
	Filtering active surface	S <sub>a</sub>	34.6	%
	Dimensional factor	A	0.0392	-
	Yarns count	T	54.73	tex
	Crimp yarn	a	2	%
	Woven fabric mass	M	158.61	g/m <sup>2</sup>

Table 10. Balanced structure - designed with algorithm II (weave - hopsack 2/2)

The applications are presented in Tables 9, 10, 11, 12, 13. These applications are made for woven fabrics filters with finesse and densities balanced structures, made with weave plain, weave - hopsack 2/2, weave- irregular sateen and weave - twill 2/2.

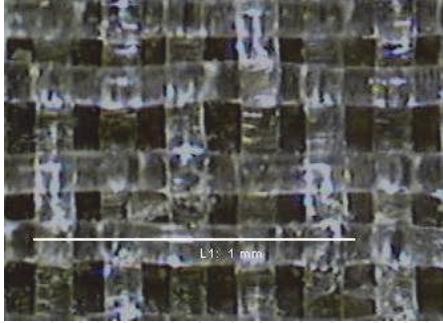
Sample filter	Parameter	Symbol	Value	UM
	Yarns diameter	d	0.11	mm
	Pore side	l	0.11	mm
	Thread density	P	45.5	threads/cm
	Filter finess	F	45.5	pores/cm
	Filter finess mesh	F <sub>m</sub>	115.57	pores/inch
	Pore area	A <sub>p</sub>	0.0121	mm <sup>2</sup>
	Filtering active surface	S <sub>a</sub>	24.95	%
	Dimensional factor	A	0.0392	-
	Yarns count	T	7.87	tex
	Crimp yarn	a	4	%
	Woven fabric mass	M	74.6	g/m <sup>2</sup>

Table 11. Balanced structure - designed with algorithm III (weave- irregular sateen)

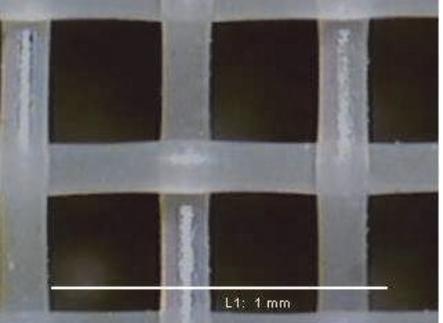
Sample filter	Parameter	Symbol	Value	UM
	Yarns diameter	d	0.14	mm
	Filtering active surface	S <sub>a</sub>	49	%
	Thread density	P	21.4	threads/cm
	Filter finess	F	21.4	pores/cm
	Filter finess mesh	F <sub>m</sub>	54	pores/inch
	Pore side	l	0.327	mm
	Pore area	A <sub>p</sub>	0.107	mm <sup>2</sup>
	Dimensional factor	A	0.0392	-
	Yarns count	T	12.76	tex
	Crimp yarn	a	5	%
	Woven fabric mass	M	57.49	g/m <sup>2</sup>

Table 12. Balanced structure - designed with algorithm IV (weave - plain)

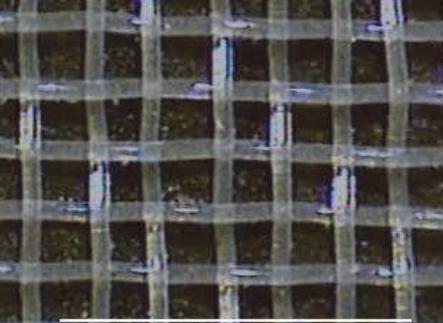
Sample filter	Parameter	Symbol	Value	UM
	Pore side	l	0.1	mm
	Filtering active surface	S <sub>a</sub>	31	%
	Pore area	A <sub>p</sub>	0.01	mm <sup>2</sup>
	Thread density	P	55.7	threads/cm
	Filter finess	F	55.7	pores/cm
	Filter finess mesh	F <sub>m</sub>	141.4	pores/inch
	Yarns diameter	d	0.08	mm
	Dimensional factor	A	0.0392	-
	Yarns count	T	4.16	tex
	Crimp yarn	a	6	%
	Woven fabric mass	M	49.3	g/m <sup>2</sup>

Table 13. Balanced structure - designed with algorithm V (weave - twill 2/2)

Each table is presented as a fabric filter microscopic image and the list of parameters supplied by the computer program. Same time, the tables are highlighted input data specific to each algorithm separately.

In each example there is a good correlation between the elements provided by the computer program and structural characteristics shown on the microscopic image of the fabric made. This aspect allows us to say that the proposed algorithms achieve a better modeling of the structural parameters and specific functional of woven fabrics filters with simple structure.

## 5. Conclusion

The woven fabrics which are used as filter fabrics, have the functionality imposed for the filtration process. Structure and properties of the woven filter fabrics are adequately differentiated, for the principles of the filtering process. The paper defines the structural and functional elements that are specific to the filtering woven fabrics, which have a structure that is simple, balanced and unbalanced in yarn count and thread density.

The methods of filter design for the fabrics with simple structure is based on the specific geometry of the structure elements fabrics. To achieve filter fabric with uniform pore (size and shape), is recommended of use, weaves balanced with equal segments and uniform distribution (plain, twill D 2/2, hopsack 2/2). Five algorithms of designing the filtering woven fabrics having a simple structure were elaborated, which can be differentially applied depending on the initially introduced elements.

By using computer aided design program to obtain a set of variations of the designer select the optimal variant, which corresponds better to the needs of field exploitation.

## 6. Acknowledgment

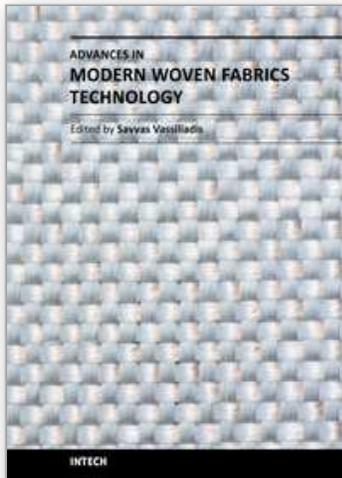
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## **Advances in Modern Woven Fabrics Technology**

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The importance of woven fabrics increases constantly. Starting from traditional uses mainly in clothing applications, woven fabrics today are key materials for structural, electronic, telecommunications, medical, aerospace and other technical application fields. The new application fields of the woven fabrics is directly reflected in the contents of the book. A selected collection of papers in the technological state-of-the-art builds the book "Advances in Modern Woven Fabrics Technology". It is written by internationally recognized specialists and pioneers of the particular fields. The chapters embrace technological areas with major importance, while maintaining a high scientific level. This interdisciplinary book will be useful for the textile family member as well as for the experts of the related engineering fields. The open access character of the book will allow a worldwide and direct access to its contents, supporting the members of the academic and industrial community.

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