VLÁKNA A TEXTIL

2

Volume 23.
June
2016

ISSN1335-0617

Indexed in:

Chemical Abstracts,

World Textile Abstracts

EMDASE

Elsevier Biobase

Elsevier GeoAbstracts

FIBRES AND TEXTILES

VÚTCH CHEMITEX

Trenčianska univerzita Alexandra Dubčeka v Trenčíne
Fakulta priemyselných technológií v Púchove

VÚCHV

Spoločnosť priemyselnej chémie ZSVTS

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

STU FCHPT

Fibres and Textiles
Vlákna a textil

Published by	*Vydáva*
• Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology	• Slovenská technická univerzita v Bratislave, Fakulta chemickej a potravinárskej technológie
• Technical University of Liberec, Faculty of Textile Engineering	• Technická univerzita v Liberci, Fakulta textilní
• Alexander Dubček University of Trenčín, Faculty of Industrial Technologies	• Trenčianska univerzita Alexandra Dubčeka v Trenčíne, Fakulta priemyselných technológií
• Slovak Society of Industrial Chemistry, Bratislava	• Slovenská spoločnosť priemyselnej chémie, Bratislava
• Research Institute of Man-Made Fibres, JSC, Svit	• Výskumný ústav chemických vlákien, a.s. Svit
• VÚTCH – CHEMITEX, Ltd., Žilina	• VÚTCH – CHEMITEX, spol. s r.o., Žilina
• Chemosvit Fibrochem, JSC, Svit	• Chemosvit Fibrochem, a.s., Svit

http://www.ft.tul.cz/mini/Vlakna_a_textil

Editorial Office and distribution of the journal *(Redakcia a distribúcia časopisu)*	Ústav prírodných a syntetických polymérov Fakulta chemickej a potravinárskej technológie Slovenská technická univerzita v Bratislave Radlinského 9, 812 37 Bratislava, SK Tel: 00 421 2 59 325 575 e-mail: marcela.hricova@stuba.sk
Order and advertisement of the journal *(Objednávka a inzercia časopisu)*	Slovenská spoločnosť priemyselnej chémie, člen Zväzu vedecko-technických spoločností Radlinského 9, 812 37 Bratislava, SK Tel: 00 421 2 59 325 575 e-mail: marcela.hricova@stuba.sk

Order of the journal from abroad – excepting Czech Republic
Objednávka časopisu zo zahraničia – okrem Českej Republiky
SLOVART G.T.G, s.r.o. EXPORT-IMPORT
Krupinská 4, P.O.Box 152, 852 99 Bratislava, SK
Tel: 00421 2 839 471-3, Fax: 00421 2 839 485
e-mail: info@slovart-gtg.sk

Typeset and printing at — *Sadzba a tlač*

FOART, s.r.o., Bratislava

Journal is published 4x per year	Časopis vychádza 4x ročne
Subscription 60 EUR	Ročné predplatné 60 EUR

ISSN 1335-0617

Evidenčné číslo MKCR SR Bratislava EV 4006/10

Fibres and Textiles (2) 2016
Vlákna a textil (2) 2016
June 2016

Content

Obsah

THE DEVELOPMENT OF NEW FORMS OF SPECIAL CLOTHES BY DESIGN PROJECTING METHODS

O.V. Kolosnichenko, N.V. Ostapenko and M.V. Kolosnichenko

Kyiv National University of Technologies and Design, Nemirovicha-Danchenka str. 2, 01011 Kyiv, Ukraine
3212793@gmail.com

Abstract: *The article describes methods of design projecting, which allow to construct new compositionally – harmonic forms of thermo-safe special clothes (TSSC) for fireman. Using the principles of new forms development, it is possible to get a big quantity of new forms TSSC in the systems "Costume-person-environment" and "Colour-form-environment". The ways of improvement of designing and development of new forms of TSSC are defined.*

Key words: *methods of design projecting, harmonic forms of thermo-safe special clothes, improved aesthetic parameters, creative conception.*

1 INTRODUCTION

The item, which is designed in system "Costume-person-environment", must meet functional, constructional, economical, aesthetic and other requirements. It should be appropriate to environment and specific conditions of usage according to the list of its tectonic characteristics, such as: size, configuration in the space, materiality, colouring, etc. [1].

The modern clothes designing solve the problems of their comfort, harmonized unity of a person and environment. It is engaged in the development of new clothes forms. Using such methods of design-projecting, as combinatoric, modular, deconstructional, etc, clothes design offers new ways of clothes development in future. Technical and scientific progress is accelerated by new inventions and growing social demands and set more difficult tasks for designers. Sometimes during solving creative task, the usage of traditional construction methods doesn't give you new interesting solutions. That is why the activization of creative pursuit in designing is very important and it is aimed at the development of designer projecting thinking and intensification of the projecting process. The most important methods of modern projecting are put in (Figure1) [2].

The choice of design-projecting method was based on statements of creative concept, which is based on constructivism of the 20th century, as at that time design of functional working clothes became one of the main design trends. Constructivism is characterized by purity, geometry, shape laconism, unity of an appearance.

Constructivists state that the basis of image is a construction, not a composition; they offered objectless ornament for printed fabrics, which consists of simple geometric shapes; new graphic application – simplification, escape from inessential details in order to make the form more expressive; decorative design, connected with construction. The main characteristics of special clothes (SC) were functionality and appropriateness. Constructivism became a soviet functionalism the basic principle of which "the form follows the function" (Figure2) [3].

Soviet constructivist (O. Rodchenko, V. Stepanov and others) were founders of combinatoric methods in clothes projecting. While projecting special clothes they used programmable methods of shape creation combination of standard elements of simple geometric forms; combination of different decorative elements transformation of clothes in the process of exploitation; combination of standard ready-made objects. The project trend of soviet constructivists of the 20th was used in this work, as the specific of combinatorics is close to natural shape forming and gives an ability to use construction elements economically and has the direct relation to uniform mass production [4].

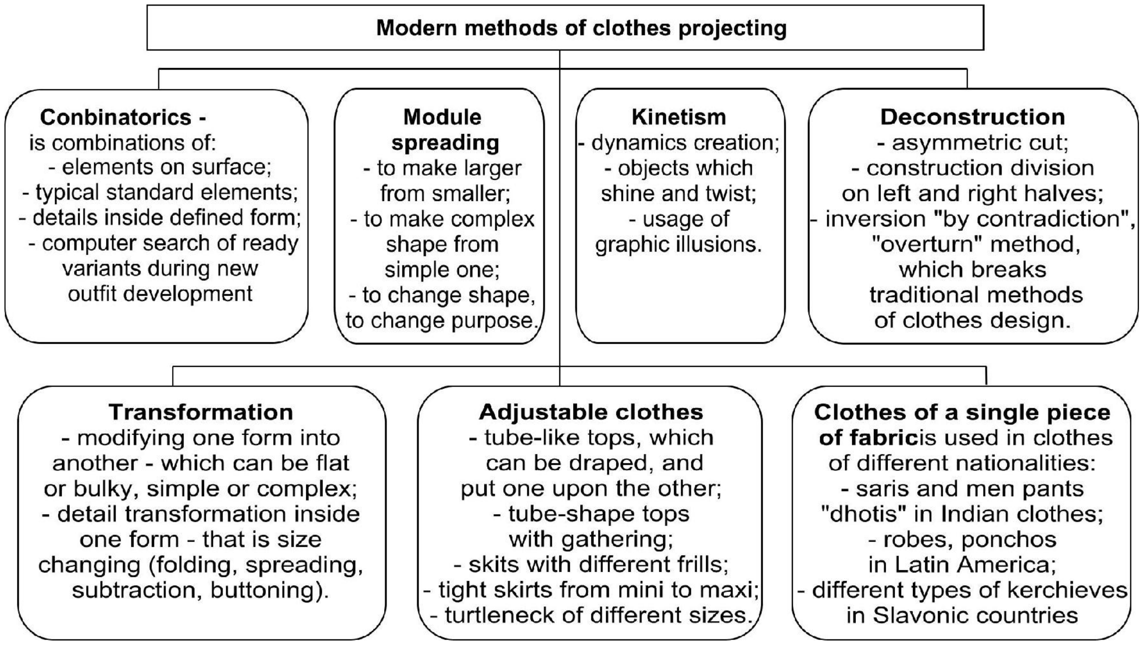


Figure1 The classification of modern designing methods

2 EXPERIMENTAL

The object of research - is the process of projecting TSSC with improved aesthetic parameters in the system “costume - person - environment” which describes object of projecting as a system of interlinked material-functional and sociocultural elements. This approach needs the establishment of strict functional links between environment, its elements and processes which are created commonly with a person. This projecting results in creating of system object [5].

The purpose of the research is to develop new composite and harmonized thermo-safe special clothes for firemen and to improve the process of designing of these new forms using new forms of design-projecting. General methodology of systematic approach to the special clothes designing, the method of polling, analysis and synthesis as theoretical methods of scientific investigation have been used in the research work [6]. Modern methods such as combinatorics which is based on the search studies and application of regularity of the option alterations of space, constructive functional and graphic structures have been used as clothes designing from typified elements [7].

The given task has been achieved by determining the creative concept and development of design features taking into account the ergonomic component, which is essential in rescue overalls.

1. Creative conception of the research work is constructivism and functionalism of the 20th century.
2. The development of the theoretical and graphic models of making thermo-safe special clothes based on the analysis of the requirements to their making, determination of the basic properties of the item depending on the purpose, analysis of the complete sets of clothes in the market give us the possibility to develop a model of thermo-safe special clothes of general quality.
3. Creation of new composite and harmonized firms of thermo-safe special clothes on the basis of combinatorics designing method being the ground of creative conception allows to solve the problem of clothes comfort and harmonized unity of a man and environment.
4. The development of a new colour palette, patterns and fabric textures for thermo-safe special clothes are mode on the basis associative perception of the environment of the fireman (Figure 3).
5. The development of informative signs for rises the sign level of the thermo-safe special clothes sets and quarantines identification of these workers and the level of composite unity of the form and substance of the set.
6. Creation of CAD system information data base using constructive and decorative elements matrix, and invariant method of mathematical data processing give the possibility to solve the problem of the development of the TSSC assortment range automatically and in less time.

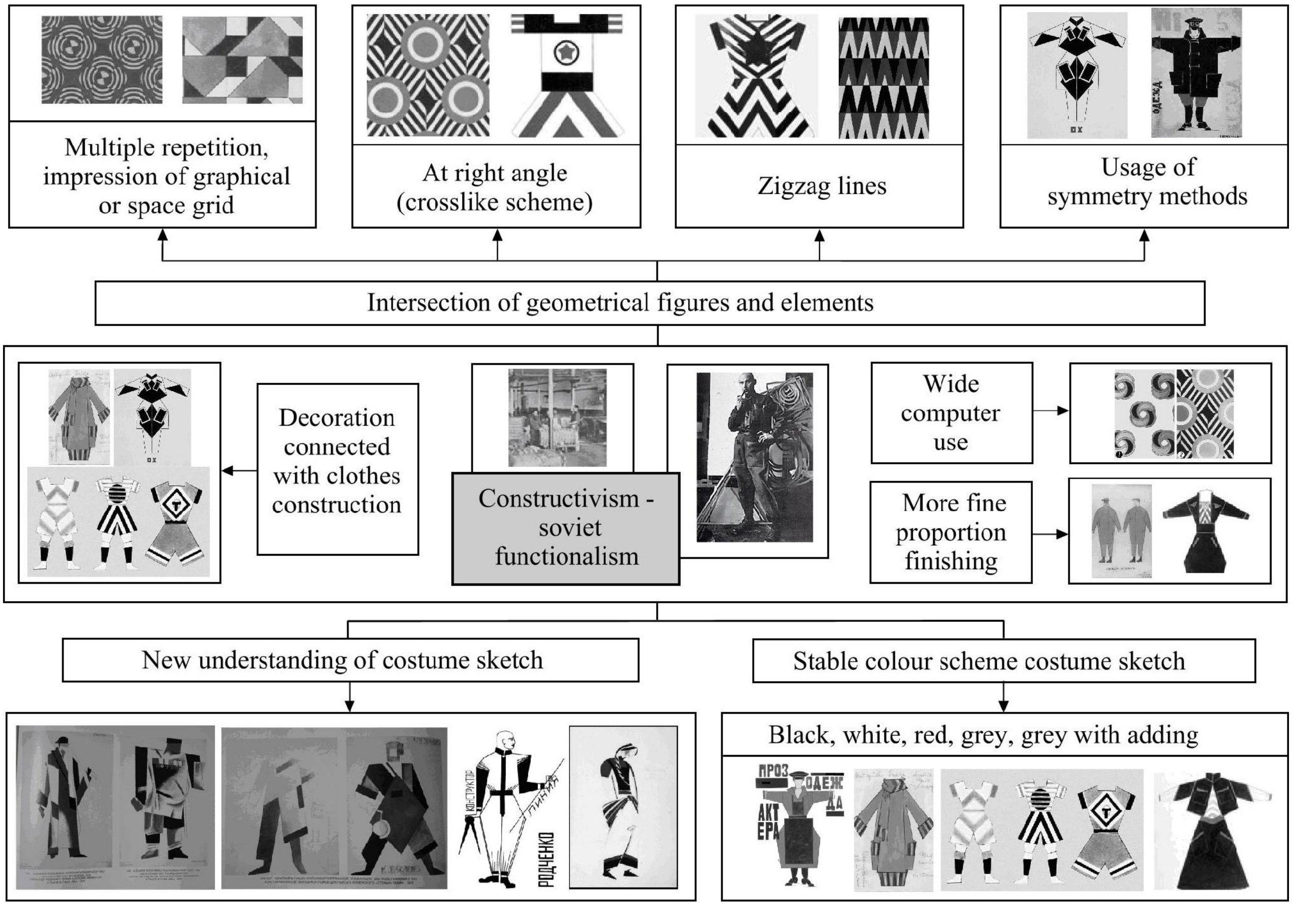


Figure 2 Principles of projecting costume new form based on the theory of constructivism

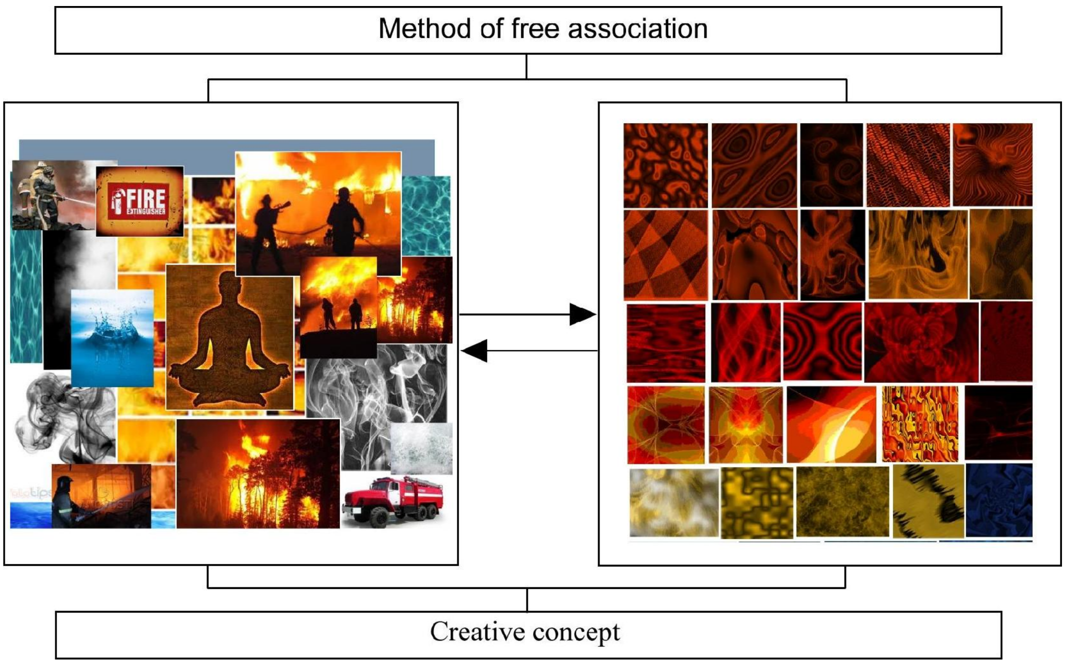


Figure 3 Compositional solution of materials textures and figures for TSSC clothes for fireman

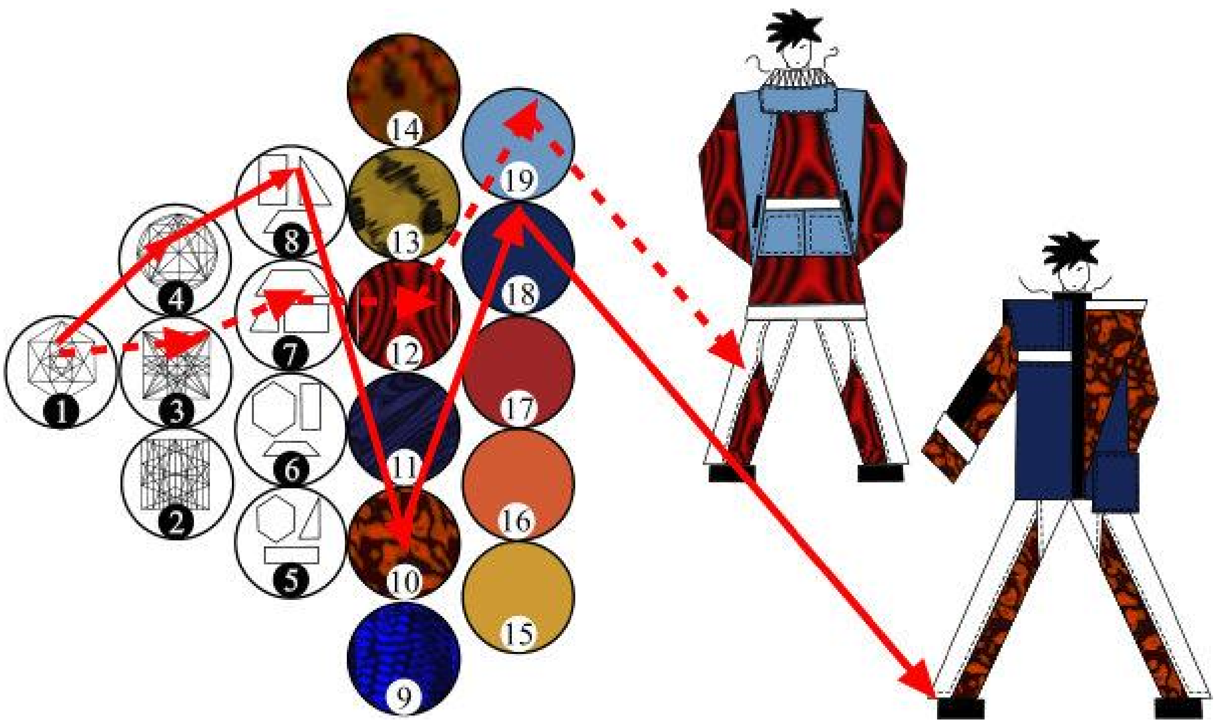


Figure 4 regularities Hierarchical structural scheme of obtaining new models in thermo-safe special clothes

Modern harmonized forms of TSSC were obtained using the silhouette forms on the combination of simple geometric figures, new colour and fabric variants having been proposed, and combinatorics method, being the basis of the creative conception.

In the result of the analysis of the TSSC new forms sketches a number of regularity of their development have been determined. These regularities are given in the form of hierarchy in order of natural numbers rising (Figure 4).

The first stage of the module-scheme includes position 1 which means the object to be complicated on the geometrical principal being characteristic for developed creative conception.

The next stage (positions 2, 3, 4) is the main point of systematization of invariant methods of harmony. These are Indo-Tibetan, Egyptian and European canons, which in their turn comprise the complex of anthropologic, composite and morphological regularities. European and Tibetan canons are connected with the proportion of the "Golden Section", but Indo-Tibetan canon can be pictured in the form of a net consisting from the triangles and rhombus. The second stage of harmonization of the project development can be characterized by finding the connection between the whole and its parts as well as determination of the character of the geometric form and its parameters.

At the third stage (positions 5-8) a number of geometric figures are used, that is structural links forming the designing objects. These are a rectangle, triangle, trapezium and hexagon, which in different combinations one by one give the possibility to get a wide assortment range of new models of TSSC for firemen.

The fourth stage of designing (positions 9-14) is oriented on the texture option of the fabric for the costume, the texture being developed by method of free association.

The fifth stage (positions 15-19) lies in choosing fabric-partner to the main fabric that is the precondition for creating the whole costume composition. It is shown on Figure 4 in which way using different principles and methods of harmonization and different compositional operations new forms of TSSC can be obtained. The receiving assortment range of models may be widen by adding to the given model-scheme new textures and colour of fabrics, new geometric forms and their combinations, and also new methods and principles of composition.

3 RESULTS AND DISCUSSION

After the development of theoretical and graphic models of TSSC creation for firemen the formation of creative conception in new clothes forms designing, using the hierarchy structural scheme of regularities of new TSSC models obtaining, modern harmonized forms of TSSC in the system "costume-man-environment" (Figure 5) and elements of corporate style (Figure 6) was created, and new ways of the improvement of the process of TSSC designing with the use of cad was proposed in the work.

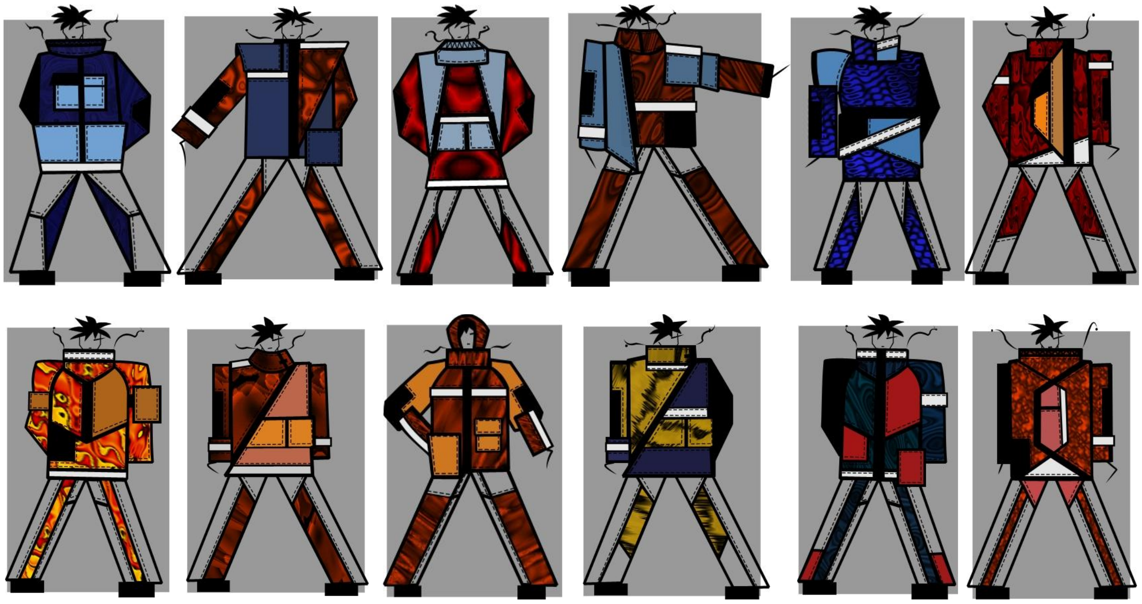


Figure 5 Sketch of new forms of TSSC

Figure 6 Proposed elements of corporate style TSSC

4 CONCLUSION

The approaches for the creation of compositional-harmonized TSSC forms using new methods of design-projecting were proposed in the work. It gives the possibility in future to create protective sets with the raised aesthetics characteristic, functionality, commissioning and ergonomics.

The possibility of obtaining of a great number of different forms of TSSC sets with the help of combinatorics methods by compositional-harmonized features of forms, colour, pattern, texture of materials was researched.

According to research produced experimental samples of thermo-safe special clothes with removable protective elements in the areas of shoulders and knees to make the depreciation of properties and increase the heat-shielding characteristics of clothes.

The practical importance of scientific research is in the active use of modern scientific designing methods, which formed on the boarded of fundamental and applied sciences, mathematics and arts, and also in generating of scientific and meaningful ideas in order to create technologies, conceptual know-how and items characterized by novelty and ability to be patented.

5 REFERENCES

1. Kolosnichenko M.V., Zubkova L.I., Pashkevich K.L., Polka T.O., Ostapenko N.V., Vasileva I.V., Kolosnichenko O.V.: Ergonomics and design. Designing of modern types of clothing, PP "NVC"Profi", Kiyiv, 2014, p. 386

2. Malinska A.M., Pashkevich K.L., Smirnova M.R., Kolosnichenko O.V.: Design clothing collections, PP “NVC”Profi”, Kiyiv, 2014, p. 140
3. Suprun N.P., Kolosnichenko M.V., Suvorova O.K.: Decoration textiles, Kyiv: KNUTD, 2012, p. 133
4. Nikolaeva T.V.: Tectonics shaping the costume, "Aristey", Kyiv, 2011, p. 340
5. Haiduk L.M., Vasileva I.V.: Modern technology design and artistic decoration of clothes, Kyiv, KNUTD, 2008. p. 132
6. Bozhko Y.G.: Architectonics and combinatorics formation, Kyiv: Vishcha school, 1991, p. 245
7. Pashkevich K.L.: Designing clothes tectonic forms based properties of tissues, PP “NVC”Profi”, Kiyiv, 2015, p. 364

THE PRINCIPLES OF HEXAGONAL CELL FORMATION IN WARP KNITTED FABRIC

Olena Kyzymchuk and Inna Ermolenko

Kyiv National University of Technologies and Design, 2, Nemirovich-Danchenko str., Kiev, 01011, Ukraine
Kyzymchuk_knutd@ukr.net, Kyzymchuk.o@knutd.com.ua

Abstract: *Mesh fabric is widely used for different purposes especially in the technic and medicine. Warp knitting with its fillet interlooping is the most common technology for mesh production. The vast majority of fillet structures has typical mesh macrostructure and provides the wide range of cell's shapes and sizes, which affect the physical-mechanical properties and basic density of knitted fabric. It's possible to change the cell's size from the minimum to the maximum at a constant shape and constant technological conditions of knitting in warp knit fabric with hexagonal cells that is preferred for technical textiles. For this reason, the two tasks have been solved in this research: to establish rules of the hexagonal cells formation in the fillet knit structure and to determine the factors that influence the cells size.*

The basic principles of formation of hexagonal cells in fillet warp knitted structures have been formulated in this article as a result of the theoretical analysis of geometrical models. The analytical dependences of the cell's size on the number of tricot and chain courses in the interlooping repeat and of the cell's square on the width and height of cell have been defined based on experimental data. They confirm the theoretical positions of this research.

Key words: *Fillet interlooping, hexagonal cell, warp knitting, tricot loop, chain loop, cell size*

1 INTRODUCTION

Mesh fabric is widely used for different purposes especially in the technic and medicine [1, 2] such as geotextile grid, agro mesh and nets for fishing, filtering and packaging materials, as well as finishing materials in the automotive, shipbuilding and aircraft industries. Scrim and personal protective equipment are very important military applications for knitted mesh now.

It should be noted that warp knitting with its fillet interlooping is the most common technology for mesh production. In fillet structure, there exist no links between separate neighboring wales in one or several courses in succession [3]. The vast majority of fillet structures has typical mesh macrostructure and provides the wide range of cell's shapes (diamonds, hexagons, etc.) and sizes, which affect the physical-mechanical properties and basic density of knitted fabric.

Fillet knit can be divided on one, two or three guides' structure depending on number of guide bars that take part in manufacturing of fabric [4]. Prof. L. Kudryavin and prof. I. Shalov [3] proposed to classify the fillet structures depending on the number of guide bars, their drawing-in and underlapping movements on the following types: simplest, simple, combined and complex.

It is interesting to consider the possibility of creating a specific cell's shape in the each type of fillet knitted structure. So by the using one guide bar and simplest fillet interlooping it's possible to create triangular (Figure 1a) and quadrangular configuration of cells. By the using two guide bars (simple and combined fillet interloopings) square (Figure 1b), hexagonal (Figure 1d) and diamond-shaped (Figure 1c) cells are formed. Rectangular cells (Figure 1f) are formed by using three guide bars one of which is inlaying extra weft yarn for connection the vertical ribs. Thus, mesh fabrics with cells of various shapes can be produced with fillet interloping [4].

Today the more important issue in mesh production is a creation the structure with cells which sizes can be changed easily. In fillet warp knitted structure, the cell that is formed by wales interconnected by loops or segments of filaments have the limited size [5, 6]. It is well known that at the same interlooping the cell's size depends on the gauge of knitting machine, type and linear density of the yarn or filament and technological condition: yarn tension of each guide bars and drawing-out force. Moreover, at the same technological conditions of knitting the cell's size can be varied by the interlooping repeat.

The fillet knit structure that is formed by a combination of tricot and t-tricot loops is showed on Figure 1d. The shape of the cells is similar to the hexagonal honeycomb [3]. It is obvious that an increasing of the number of tricot courses results in lengthening of vertical ribs of the cell and the cell's elongation. From the other side an increase of the number of t-tricot courses results in growing the areas where the wales are linked, so the distance between cells walewise increases too.

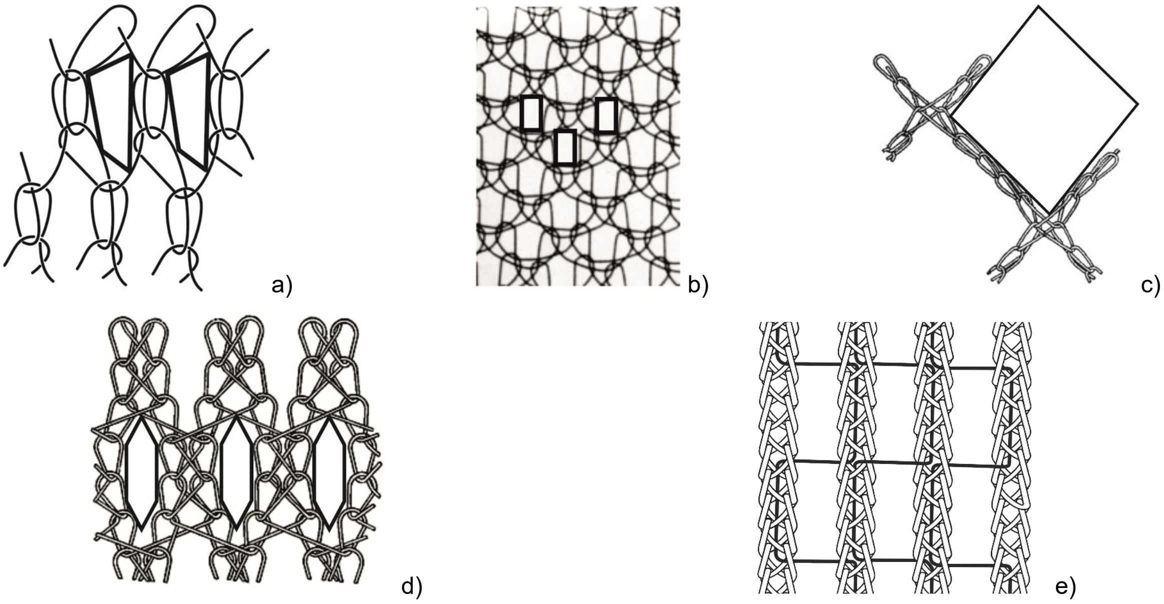


Figure 1 Fillet knitted structures

Knit structure of combined fillet interlooping that is formed by alternating of chain and tricot courses is shown at Figure 1c. Such structure is used for manufacturing knotless knitted nets with cells of unlimited dimensions [3]. In this knitted structure, the knots are formed by mutually crossed tricot closed loops and the carcasses are formed by chain loops. It is obvious that an increase of the number of chain courses in the repeat leads to extension of the cell's rib and the cell's size increases too, but cell's shape is constant

It's possible to use the same principles for changing the cell's size from the minimum to the maximum at a constant shape and constant technological conditions of knitting in warp knit fabric with hexagonal cells that is preferred for technical textiles. For this reason, the two tasks have been solved in this research: to establish rules of the hexagonal cells formation in the fillet knit structure and to determine the factors that influence the cells size.

2 THEORETICAL PART

Cell's shape primarily depends on the shape and size of loops, their combination and mutual position in the knitted structure. At the equal conditions, the size and shape of single loop of warp knit depend on the type of loop and the positioning of the skeleton and the junctures that was analyzed in detail by Moiseenko [7]. He found that width of closed loop with one-sided arrangement of junctures increases and its height is reduced as a result of elastic forces of bent filament. In the knitted structure that is formed by one full set yarn's system, the skeletons of closed loop are inclined in relation to the wales in the opposite direction to the junctures position. The degree of loop inclination increases with the yarn elasticity and density of knitted fabric. Furthermore, in such structure loop's skeletons can be rotated from the frontal plane of knitted fabric to the perpendicular plane depending on the junctures' lengths. In the matter of open loops with two-sided arrangement of junctures, it was investigated [7] that skeleton's width decreases and its height increases. In the knitted structure, the open loops are inclined in the opposite direction to outcoming juncture. In general, the open loop has a smaller slope in the frontal plane of the fabric and does not rotate to the perpendicular plane of the fabric.

However, such arrangement of loops is characteristic for the single warp knitted structure that is produced with one full set guide bar. Fillet interlooping has following features of manufacturing: the using of multiple systems of threads, the partial drawing-in of guide bars, and the presence of few different types of loops in the interlooping repeat (open and closed with different junctures length). Therefore, it is advisable to consider the shape and position of each loop in the repeat of fillet structure.

To achieve the mesh with hexagonal cells it is rational to use the fillet warp knitted structure [8] that is produced by using two guide bars with partial drawing-in and symmetric movement. The interlooping repeat is formed by alternating tricot and atlas courses [9, 10]. In this case, one set of yarn forms a closed tricot loops 1, 4 and 5 with one-sided arrangement of junctures and open tricot loop 8 with two-sided arrangement of junctures (Figure 2a). The second guide bar performs the symmetrical movement and forms similar closed tricot loops 2, 3 and 6 with one-sided arrangement of junctures and open tricot loop 7 with two-sided arrangement of junctures.

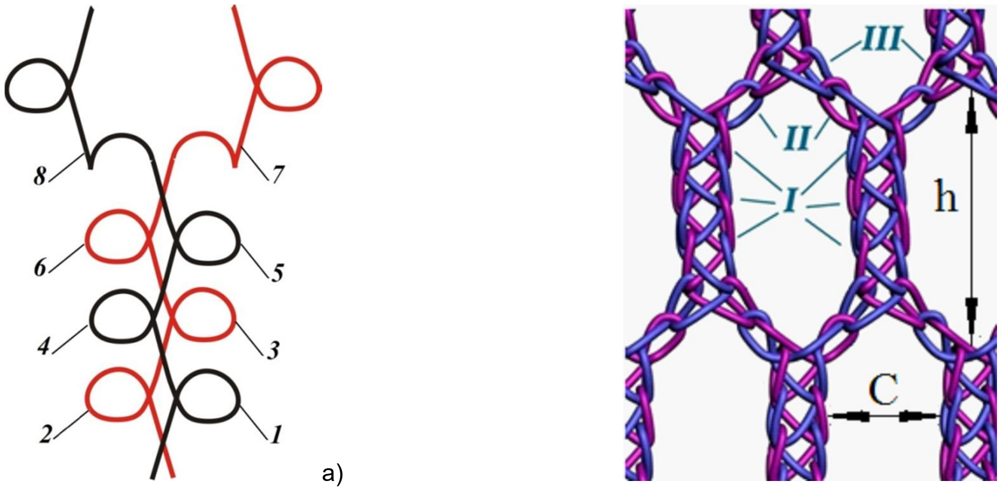


Figure 2 Fillet structure with hexagonal net

The inclination of the closed tricot loop 1 is prevented by the closed tricot loop 3 of the next course. The pressure force of loops 1 balances the reaction force of loop 3, so there is no general inclination of loop 1 in the plane of the fabric. The same force balance is between closed loops 3 and 5. Therefore, the closed tricot loops 1 and 3 as well as closed tricot loops 2 and 4 are positioning vertically in the knitted structure (type I, Figure 2b). Nevertheless, skeletons of those loops are rotated in a perpendicular plane, so that we will see only one of the arms in the frontal plane of fabric. These loops of type I form the vertical ribs of cells.

The closed tricot loops 5 and 6 are followed by the open tricot loops 7 and 8 at the next course that is why there is no similar balances of forces. The skeletons of closed loops 5 and 6 are inclined in an opposite direction of junctures positions. Thus, tricot closed loops 5 and 6 (type II, Figure 2b) are arranged obliquely at the beginning of diagonal rib. The forces balance in open loops 7 and 8 are caused with a smaller inclination of the loops skeleton. Therefore, these loops are turned in the same direction as the previous loops 5 and 6. That is the loops 7 and 8 (type III, Figure 2b) also placed obliquely in the knitted structure and form the diagonal ribs of cell.

Such positioning of loops in the mesh knitted fabric forms the vertical and diagonal ribs of hexagonal cell (Figure 2b). The cells size can be easily changed without changing its hexagonal shape by adding additional courses of tricot loops or/and chain loops into an interlooping repeat.

The Increasing the number of tricot courses in the repeat leads to cell extension in vertical direction. These tricot courses consist of closed loops with one-sided arrangement of junctures that positioned in knitted structure vertically. Addition chain courses in the repeat leads to extension of diagonal ribs of hexagonal cell. Consequently, the cell is extended: lengthened and widened. These open chain loops (type V and VI, Figure 3) are positioned obliquely in a structure similar to the tricot loops in previous course.

It should be noted the open chain loops are mirror positioned if there are two or more chain courses in the repeat. The outcoming junctures are placed in alternating left and right [11]. Next regularity in alternation of loop types have been revealed during investigating the fillet warp knitted structure. The followed tricot course is formed by the closed loops (type IV, Figure 3a) if interlooping repeat consists of odd number of chain courses and the followed tricot course is formed by the opened loop (type III, Figure 3b) if the interlooping repeat consists of an even number of chain courses.

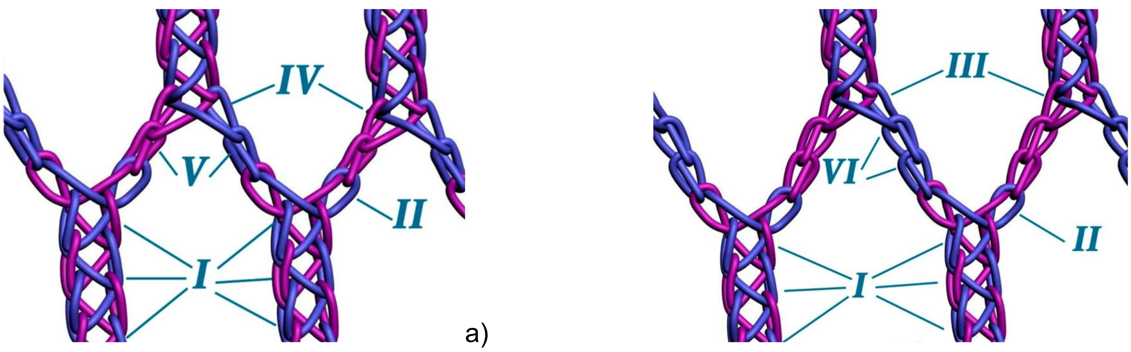


Figure 3 Extension of diagonal rib

The main principles of hexagonal cell formation in warp knitted fabric have been formulated as a result of geometrical modeling of mesh knitted structure:

1. Fillet interloping formed by alternating tricot and chain courses in the repeat and produced using two guide bars with partial drawing-in (1 in, 1 out) and symmetric movement is recommended to achieve the mesh with hexagonal cells.
2. The incoming and outcoming junctures are positioning beside on loop's arc, if next course is formed by closed loops, and the incoming juncture is positioning behind outcoming juncture on loop's arc, if next course is formed by closed loops.
3. Closed tricot loop with one-sided arrangement of junctures is positioned vertically and forms vertical rib of cell if the loop at the next course is the same tricot loop, which formed by yarn from other guide bar.
4. Closed tricot loop with one-sided arrangement of junctures is positioned obliquely and forms diagonal rib of cell if the loop at the next course is open tricot loop or chain loop. They are positioned obliquely too.
5. If interlooping repeat has consisted of odd number of chain courses, the next tricot course is formed by the closed loops, and if the interlooping repeat has consisted of an even number of chain courses, the next tricot course is formed by the opened loop.
6. The tricot loops (closed and open) followed chain loops in the repeat are positioned obliquely in relation to the wale.
7. The Increasing the number of tricot courses in the repeat leads to cell extension in vertical direction. Addition chain courses in the repeat leads to extension of hexagonal cell as in vertical as in horizontal direction.

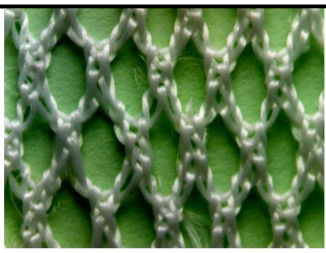
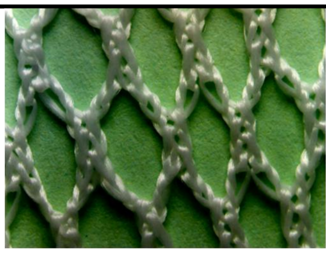
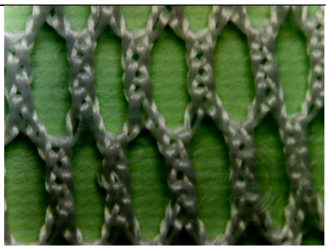
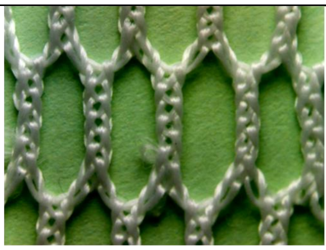
3 EXPERIMENTAL PART

Two-factors' experiment according Kono's plan have been planned and realized for investigation the cell's size in this research. As input factors were accepted: x_1 - the number of tricot courses n_t in the repeat 3, 5 or 7; x_2 - the number of the chain courses n_c in the repeat from 0 to 2. Nine variants of fillet warp knitted fabric with hexagonal cells were produced in accordance with this plan.

250 denier x 2 polyester yarns manufactured by Du Pont were used for fabric production on 10-gauge Muller Crochet Knitting machine (RD3MT3/630). This machine is equipped with latch needles and eight guide bars with electronic drive. Four bars can operate both with the "weft mode" and "knit mode" to obtain single-bed warp knitted fabrics.

Photos of fabric (Table 1) are shown that all variants of fillet warp knitted fabric have hexagonal cells. A boundary value of an angle between diagonal ribs is from 60' to 80'.

Table 1 Samples photos

Repeat	n_c = 0	n_c = 1	n_c = 2
n_t = 3			
n_t = 5			
n_t = 7			

The studies of cell sizes in the warp knit structure was performed by using a digital microscope Microsafe Shiny Vision MM-2288-5X-BN with minimum scale of 0.001 mm. 25 measurements for each of the studied parameters (width, height and square of cells) have been made.

The equations of regression (Table 2) have been established by the mathematical processing of experimental data. The equations are describing adequately the dependences between the cells sizes and the interlooping repeat.

The experimental results indicate that the width and height of the cell as well as its square depend on the repeat of interlooping, as showed at the corresponding diagrams (Figure 4). Thus, simultaneous extension and enlargement of the cell occur by increasing the number of courses as tricot as chain in the repeat that leads to an increasing of cell's square.

Another interesting point is the studying of the effect of cell size on its square. The analytical dependencies that have been established in this research (R^2 = 0.9) describes the influences of width and height of cell on the cell's square. Graphics dependencies are shown on Figure 5.

Table 2 Equations of regression

Sell's size	In code parameters	In natural parameters
Width ***C*** [mm]	$Y_C = 2{,}56 + 0{,}35x_1 + 0{,}62x_2 + 0{,}30{x_2}^2$	$C = 1{,}37 + 0{,}17n_t - 0{,}01n_c + 0{,}30{n_c}^2$
Height ***h*** [mm]	$Y_h = 7{,}11 + 1{,}55x_1 + 1{,}95x_2$	$h = 1{,}27 + 0{,}78n_t + 1{,}95n_c$
Square ***S*** [sq.mm]	$Y_s = 10{,}59 + 4{,}00x_1 + 4{,}47x_2 + 2{,}76{x_2}^2$	$S = -1{,}08 + 2{,}00n_t - 1{,}10n_c + 2{,}79{n_c}^2$

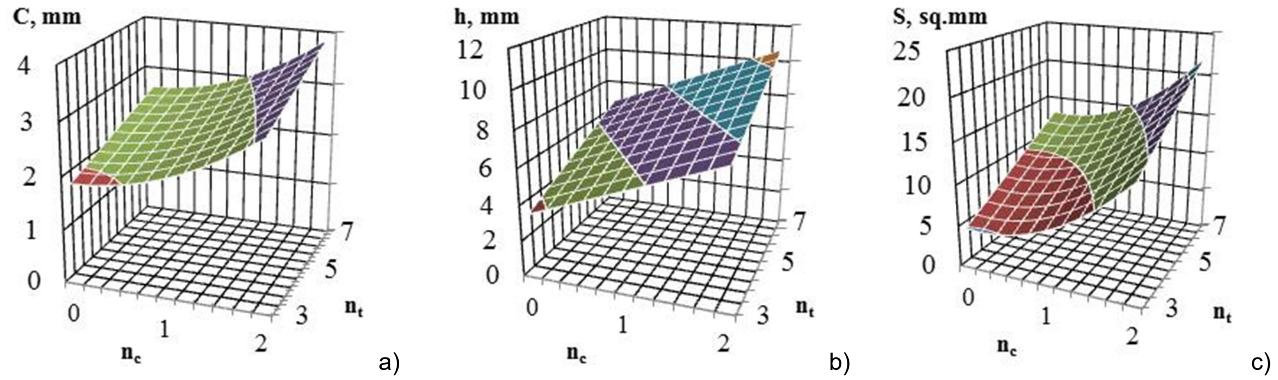


Figure 4 Dependences of cell's sizes on number of tricot and chain courses at repeat

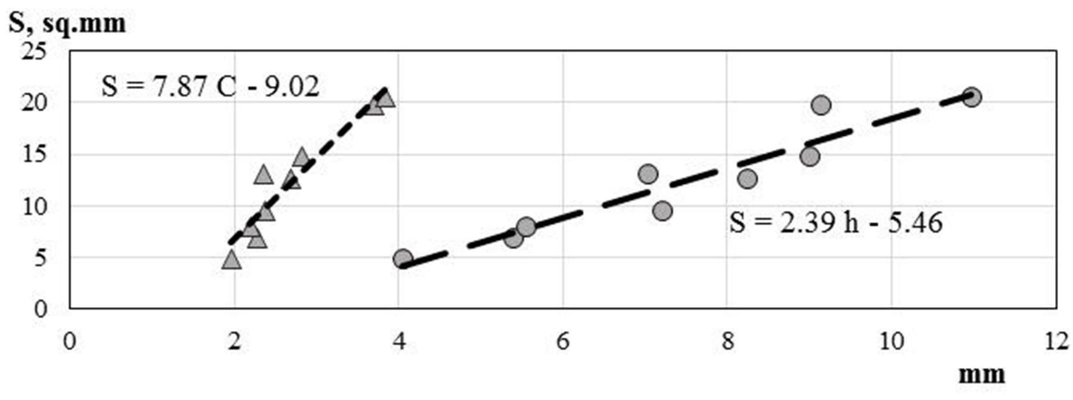


Figure 5 Dependences of cell's square on cell's size

4 CONCLUSION

The basic principles of formation of hexagonal cells in fillet warp knitted structures have been formulated as a result of the theoretical analysis. The analytical dependencies of the cell's size on the number of tricot and chain courses in the interlooping repeat and of the cell's square on the width and height have been defined based on experimental data. They confirm the theoretical positions of this research.

5 REFERENCES

1. Ermolenko I.V.: New aspect of end-using of warp knitted mesh fabrics, Bulletin of Khmelnitsky National University № 3, 2013, pp. 74-78, In Ukrainian
2. Rangasvamy Venkatraj: Net Fabrics, The Indian Textile Journal № 9, 1996, pp. 46-51
3. Shalov I.I., Dalidovich A.S., Kudryavin L.A.: Knitting technology, Moskow: Legprombytisdat, 1986, p. 376, In Russian
4. Ermolenko I.V., Kyzymchuk O.P.: Cells form and size of fillet warp knit fabric, Текстил и облекло (Textiles and Clothing) №1, 2014, pp. 2-8, In Russian
5. Morozova L.V., Zinovieva V.A.: About herringbone and fillet knitted structure, Izvestiya VUZov. Technology of textile industry № 4 (318), 2009, pp. 76-79, In Russian
6. Zavaruev V.A., Kudryavin L.A., Belyaev O.F.: Valuation of the Thread Efficiency Use for the Formation of the Cells with the Given Size in the Knitted Fabric Structure, Izvestiya VUZov. Technology of textile industry № 2 (323), 2010, pp. 93-94, In Russian
7. Moiseenko F.A.: Normalisation of knitting process on warp knitting machines, Moskow: Legkaya industry, 1978, p. 200, In Russian
8. David J. Spencer: Knitting technology: a comprehensive handbook and practical guide, UK: Woodhead publishing limited, 2001, p. 386
9. Ermolenko I.V., Kyzymchuk O.P.: The creation of hexagonal cells in fillet knitted fabric, Bulletin of Kyiv National University of Technologies and Design № 1, 2010, pp. 97-100, In Ukrainian
10. Ermolenko I.V., Kyzymchuk O.P.: Loop length of the fillet interlooping, Izvestiya VUZov. Technology of light industry №3, 2013, pp. 3-7, In Russian
11. Kyzymchuk O., Ermolenko I.: Loop length model of fillet structure, J Fashion Technol Textile Eng., 2015, S1: 004

RELATIONS BETWEEN DEVIATION RATE AND OTHER CHARACTERISTIC FUNCTIONS AND PARAMETERS OF YARN MASS IRREGULARITY

Eva Moučková, Petr Ursíny and Petra Jirásková

Technical University of Liberec, Faculty of Textile Engineering, Department of Textile Technologies
Studentská 2, 461 17 Liberec 1, Czech Republic
Telephone: +420 48 535 3274; Fax: +420 48 535 3542, eva.mouckova@tul.cz

Abstract: *The main aim of this article is to extend piece of knowledge about a deviation rate function (DR(±5%, L)) as one of characteristics of yarn mass irregularity. The relation of deviation rate to other characteristic functions of yarn mass irregularity (in particular to a variance-length curve and also a spectrogram) is analysed. Based on ascertained relations the possibilities of using the deviation rate function DR(±5%, L) in spinning technology and for a prediction of unevenness of textiles in a plane are presented.*

Key words: *Mass irregularity, DR function, yarn, variance-length function, spectrogram*

1 INTRODUCTION

Yarn mass irregularity, defined as the variation in mass between longitudinal sections of yarn, belongs to one of the important properties according to which yarn quality is evaluated. Yarn mass irregularity affects both the variability of some yarn properties (e.g. twist, tenacity, breaking elongation) as well as fluctuations of some properties of areal textiles made from yarn. Yarn mass irregularity can be expressed using both known, in a practice commonly used, parameters and characteristic functions of unevenness (*CV(L)*, the spectrogram, the variance-length curve) [1] as well as using parameters and functions, which have not found wide application in practice yet. The deviation rate (*DR*), more precisely the *DR* function, is one of such parameters. It is described and defined below. This parameter is one of outputs both recent apparatus for yarn mass irregularity measurements (for example Uster-Tester 4-SX and its higher versions, Keyssoki evenness tester) and other, in literature presented devices for yarn mass irregularity measurement (for example [2]) as well as a special software for evaluation of mass irregularity measurements results [3]. Wider technological interpretation of characteristic functions of yarn mass irregularity is a prerequisite for an application of these functions in practice. Regarding to the spectrogram and the variance-length curve, evaluation procedures enabling useful employment of these functions both in spinning technology itself and in defined cases for the prediction of unevenness in plane, are known [4, 5]. Contrary to this, applicable piece of knowledge concerning the *DR* functions appears in the literature in the limited extent.

Marshal, et al. [6] studied a correlation between yarn mass deviation rate *DR* value and appearance of knitted fabrics produced from tested yarns. They used four various samples of worsted yarns. Authors found out that there is a significant Spearmann correlation coefficient between the yarn mass deviation rate *DR* and subjectively evaluated appearance of knitted fabrics. Chellamani, et al. [7] observed connection between the deviation rate in yarn mass and the variation in yarn strength, the variation in yarn elongation and the number of weak spots and constructed formulas for predicting *DR* from these yarn mechanical parameters. In works [8] and [9], authors presented dependence of the *DR(5%; 1.5 m)* values on values of *CV(1 m)* of ring spun yarns.

The aim of this work is to summarize results of previous authors´ works [8-11] and mainly extend piece of knowledge of *DR* values (more precisely the *DR* function) and its possibilities in the relation to spinning technology and the prediction of areal unevenness. The explanation of the relation to other characteristic functions (the variance-length curve, the spectrogram) can open possibilities for wider application of the *DR* function in practice. Thus, the scope of overall evaluation of mass irregularity also extends. It has positive impact on quality assurance in a spinning mill and consequently during manufacture of areal fabrics. The work determines intensity of correlation between values of variation-length curve *CV(L)* and corresponding values of deviation rate *DR(±5%, L)* on the set of cotton carded and combed yarns as well as polyester rotor yarns of various yarn count. The course of spectrograms, variation length curves of even and uneven yarns with various kinds of irregularity are compared with the course of *DR* functions and *DR(±5%, L)* values.

2 DEFINITION OF SELECTED CHARACTERISTICS OF YARN MASS IRREGULARITY

2.1 Deviation rate DR(x, L)

The value of *DR(x, L)* determines what percentage of the total yarn length exceeds a pre-set limit $\pm x$ of yarn mass deviation [12], see Figure 1. It is calculated for a certain yarn length sections *L*.

The deviation rate can be calculated by formula (1) [12]:

$$DR(x,y)\ [\%] = \frac{\sum_{i=1}^{k} l_i}{L_T} \cdot 100 \qquad (1)$$

where: *DR(x,y)* is the deviation rate, a sum of parts length l_i [m] of all mass deviation, which are the same or out of the limit $\pm x$ [%], relative to the total length L_T [m]; x is the set limit of mass deviation [%]; y is the length section of fibrous product (yarn), which is used, i.e. so-called "cut length" [m]; l_i is the length of "i^th^ part" of fibrous product (yarn), which surpass limits $\pm x$ [%]; L_T is the total length of fibrous product (yarn), k is number of parts (i = 1, 2, ..., k).

Graphical presentation of *DR(x,y)* values in dependence on the limit mass deviation $\pm x$ [%] is called a *DR* curve.

2.2 Spectrogram

The spectrogram shows a distribution of amplitudes of harmonic component (resp. the variation coefficient of harmonic component) of mass fluctuation of linear fibrous product depending on the wavelength. It serves for the analysis of periodic defects [12]. The spectrogram enables retrospectively identify causes of possible characteristic or cumulous spectrum. Next, it makes possible to predict negative areal effects in the flat textile (moiré effect, stripiness, cloudiness) [4]. The effects of harmonic components of mass irregularity on the course of *DR* function were studied using the simulated course of spectrogram of yarn mass irregularity with very increased characteristic spectrum on various wavelengths [10, 11]. Authors found out that the harmonic components with short wavelengths do not influence the outer *DR* curve (corresponding to mass irregularity at small length section *L*=0.01 m) whereas harmonic components with the middle and long wavelengths increasing the *DR* values.

During the spectrogram application we can evaluate structure of mass irregularity wrong in the same courses of spectrogram curves due to limited range of wavelengths of harmonic component of mass irregularity. Possible latent presence of very long-term mass irregularity components can be detected by simultaneous determination of *DR* functions. By this more comprehensive approach to mass irregularity the results about structure of yarn mass irregularity, presented by means of the spectrogram, can be confirmed or corrected.

2.3 Variance-length curve

The variance-length function expresses dependence of outer mass variability on cut length. Outer mass variability is a fluctuation of mass among yarn length sections. Although the variation-length function is relatively easily determinable and its theoretically elaborated evaluating processes are known for a long time [13-16], it is used in the textile technological practice in a relatively small extent. This function enables wider analytic view on both spinning technology in terms of yarn mass irregularity and prediction of surface unevenness (cloudiness) [5].

The variation-length curve and the *DR* function present a deviation rate of mass in certain range of yarn cut lengths by various ways. So, it can be supposed that some correlation exists between correspondent values of both functions. As noted previously, the basic task is to determine intensity of correlation between values of the variance-length curve *CV(L)* and correspondent values of the deviation rate *DR(±5%, L)*.

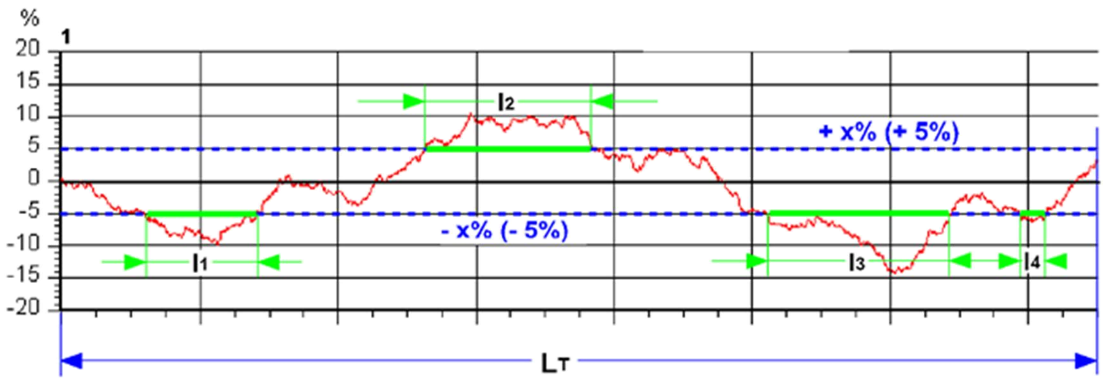


Figure 1 Definition of deviation rate *DR* [12]

3 EXPERIMENT, RESULTS AND DISCUSSION

The experiment is divided into two parts:

1) Relation between the course of *DR* curve and other characteristic functions (spectrogram and variance-length curve) using normal and irregular yarns.
2) Intensity of correlation between values of the deviation rate *DR(±5%, L)* and correspondent values of the variance-length curve *CV(L)* and yarn count.

3.1 Experiment No. 1

Materials and methods

100% cotton yarns purposely produced with different level and source of irregularity were used for the experiment. Yarn count was in the range 20 - 30 tex.

Yarn mass irregularity was measured using the apparatus Uster Tester 4-SX. The course of spectrogram as well as variance–length curve, CV_m values and simulated appearance of yarn wound on the board were compared with *DR(±5%, 1.5 m)* values and the course of *DR* curve. Appearance of yarn boards were generated by Uster Tester 4-SX apparatus based on measurements of yarn mass irregularity and evaluated visually.

Results and discussion

Table 1a and Table 1b show results of measurement of yarn irregularity.

It is evident from the experimental results that *DR(±5%, 1.5 m)* value is affected more by irregularity at long sections. The comparison of *DR* curves and spectrogram confirms results of previous work [10], where authors analysed that increased simulated characteristic spectrums of mass irregularity on very short wavelengths did not reflect on the outer *DR* curve. Regarding periodic unevenness in combination with increased *CV(L)* values, the outer *DR* curve corresponds to the level of CV_m value and the cumulous spectrum on short wavelengths. The shape of the *DR* curve is then markedly convex. Harmonic components of mass irregularity with middle and long wavelengths express themselves in certain changes of shape of *DR* curves with cut lengths *L*=1.5 m to 10 m. Parts of the curves belonging to positive mass deviations are deflected noticeably and show a staircase course.

It is visible from Table 1a, that *DR(±5%, 1.5m)* values do not correlate with CV_m values, i.e. with irregularity at very short cut lengths (*L*=0.01 m). Thus, experiment No. 2 was suggested to determine correlation coefficients between values of *CV(L)* and *DR(±5%, L)*. Usual ring and OE-rotor spun yarns were used for this.

3.2 Experiment No. 2

Materials and methods

We used for the experiment: 100% cotton combed and carded ring spun yarns produced from medium-stapled cotton A1 and 100% polyester OE-rotor spun yarns. Their specification is mentioned in Table 2.

Yarn mass irregularity was measured using the apparatus Uster Tester 4-SX. Values of *CV(L)* at selected cut lengths *L* (0.01; 1 ; 1.5; 3 and 10 m), from which the variance-length curve is also constructed as well as *DR(±5%, L)* values were read from measurement results.

Results and discussion

The example of measurements results are mentioned in Table 2, where mean values of *DR(±5%, 1.5m)* and their 95% confidence limits are presented.

Table 1a Selected results of yarn mass measurements – parameters of yarn mass irregularity

Yarn No.	Yarn count T [tex]	CV_m [%]	CV(1 m) [%]	CV(3 m) [%]	CV(10 m) [%]	DR(±5%, 1.5 m) [%]	Thin place-50% [1/km]	Thick place+50% [1/km]	Neps+200% [1/km]
1	30	18.29	5.2	4.42	3.98	28.7	350	510	0
2	30	17.54	7.5	6.98	6.28	50.9	47.5	277.5	35
3	25	15.76	4.6	3.54	2.68	24.9	111	300	191
4	20	14.3	6.62	5.96	4.42	37	2.5	77.5	47.5
5	29.5	11.73	3.17	3.12	1.36	6.8	0	10	45

Table 1b Spectrogram, variance-length curve, *DR* curve and simulated yarn board

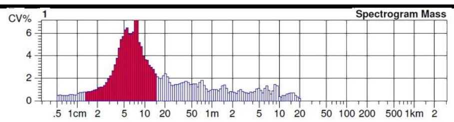
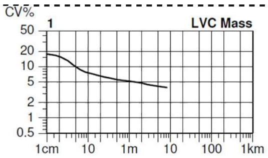
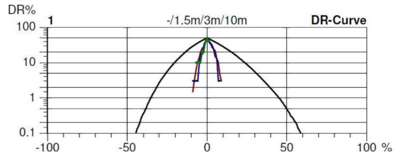
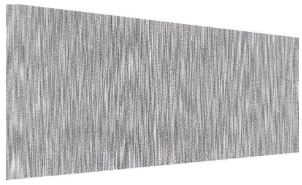
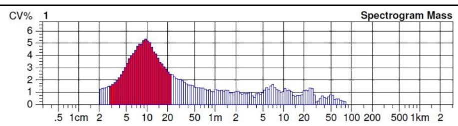
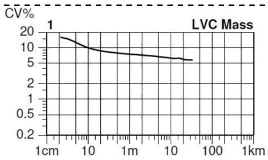
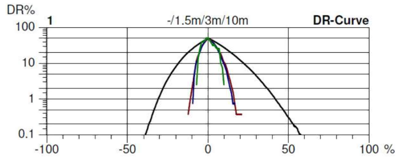
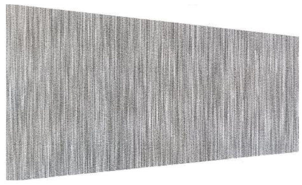
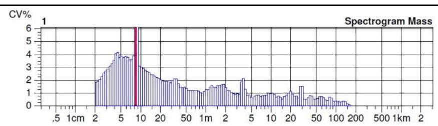
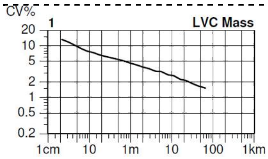
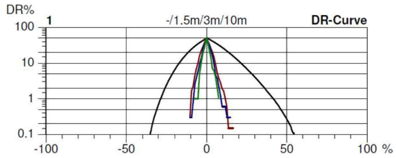
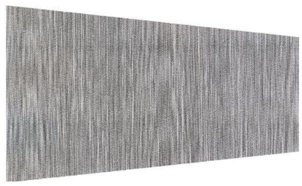
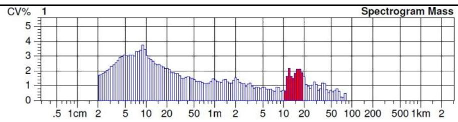
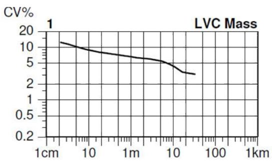
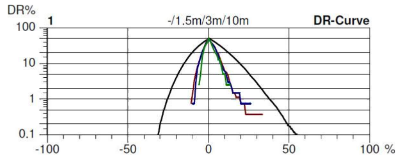
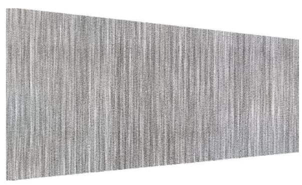
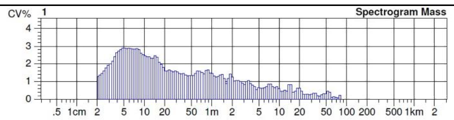
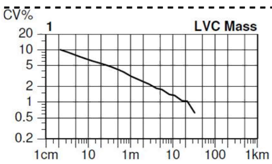
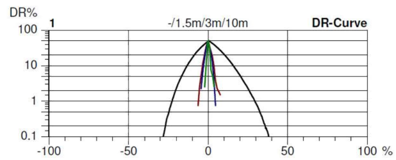
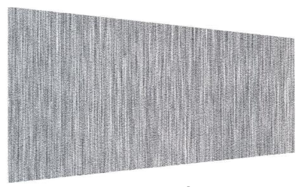
Yarn No.	Spectrogram and variance-length curve	DR curves	Yarn board and its subjective evaluation
1	 Combination of cumulous spectrum and characteristics spectrum (“a chimney”) on short wavelength 		 Moiré effect and short-term stripiness
2	 Typical cumulous spectrum on short wavelengths 		 Cloudiness and short-term stripiness
3	 Characteristic spectrum on short wavelength 		 Clear moiré effect
4	 Cumulous spectrum on long wavelengths 		 Cloudiness and middle-term stripiness
5	 Spectrum without fault 		 Without big faults

Table 2 Yarns used for experiment No. 2 and results of deviation rate *DR(±5%, 1.5 m)*

Material	Technology	Nominal yarn count T [tex]	Nominal yarn twist [m^{-1}]	Mean value of *DR(±5%, 1.5 m)* [%]	95% confidence intervals *DR(±5%, 1.5 m)* [%]
100% CO	Ring - combed	15.6	1000	19.12	(17.08 ; 21.16)
		20	780	16.26	(14.82 ; 17.70)
		25	650	13.06	(10.64 ; 15.48)
		35.5	600	10.47	(9.25 ; 11.69)
100% CO	Ring - carded	25	800	24.90	(23.24 ; 26.56)
		29.5	730	19.01	(17.44; 20.58)
		42	650	16.88	(14.97; 18.79)
		60	520	14.14	(13.01;15.27)
100% PES	OE rotor	29.5	723	17.76	(15.96 ; 19.55)
		35.7	670	30.38	(23.97; 36.79)
		50	590	11.76	(8.80 ; 14.72)
		100	436	11.74	(7.93 ; 15.56)

The effect of yarn count *T* on the quantity *DR(±5%, L)* is presented in Table 3 in the form of correlation coefficients. The example of course of this dependence is shown in Figure 2a. Correlation coefficients between yarn count and square mass irregularity *CV(L)* were calculated for the comparison too – see Table 4 and Figure 2b. Correlation coefficients resulted from the determination of a linear function by the least square methods, which approximate the given dependence. Correlation coefficients highlighted with red colour in tables are statistically significant at 5% significance level. The statistical significance was tested according to literature [17].

Table 3 Correlation coefficients between yarn count *T* and *DR(±5%, L)*

L [m]	Correlation coefficient *R*		
	Ring combed yarn	Ring carded yarn	OE rotor yarn
0.01	-0.937	-0.914	-0.781
1.5	-0.768	-0.779	-0.436
3	-0.731	-0.754	-0.374
10	-0.473	-0.517	-0.185

Table 4 Correlation coefficients between yarn count *T* and *CV(L)*

L [m]	Correlation coefficient *R*		
	Ring combed yarn	Ring carded yarn	OE rotor yarn
0.01	-0.968	-0.958	-0.853
1.5	-0.769	-0.847	-0.436
3	-0.669	-0.800	-0.347
10	-0.552	-0.545	-0.261

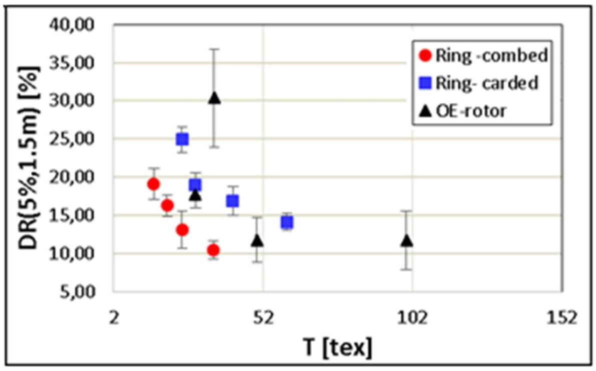


Figure 2a Dependency of deviation rate *DR(±5%, 1.5 m)* on yarn count *T*

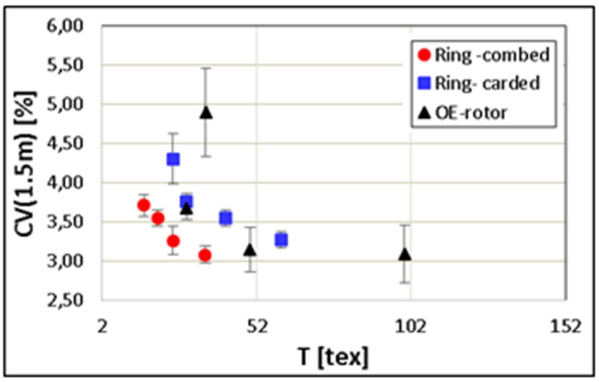
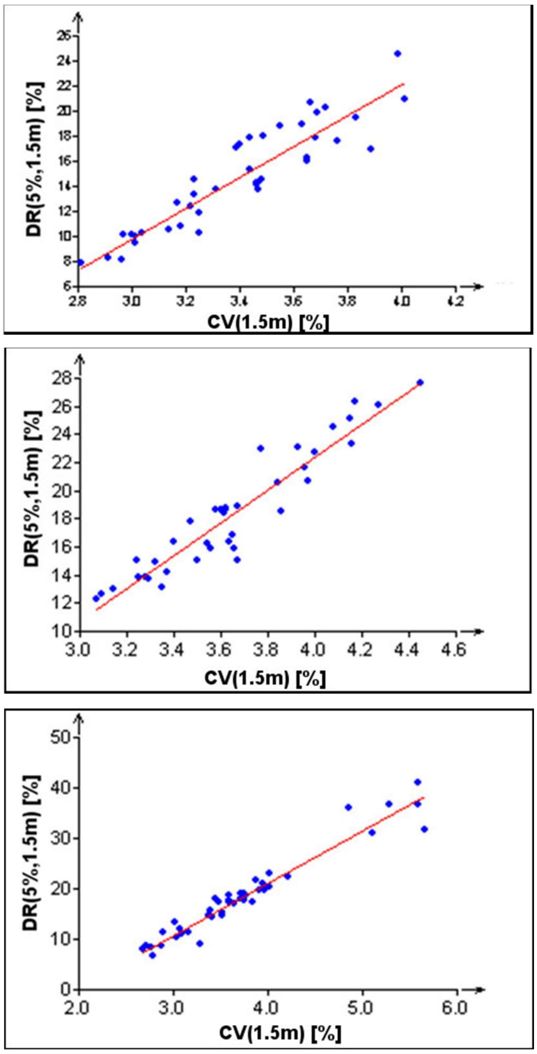


Figure 2b Dependency of yarn mass irregularity *CV(1.5 m)* on yarn count *T*

It is evident that deviation rates, as a parameter of yarn mass irregularity, are influenced by yarn fineness according to the general theory - the value of *DR(±5%, L)* decreases with increasing value of linear density of yarn and thus with growing number of fibers.

But the dependence is weaker with growing length section *L*. One of the reasons can be a number of measurements which decreases with increasing length section on the given total tested length of yarn because during irregularity measurement the respective values at the length section *L* = 0.01; 1.5; 3; 10 m are investigated within yarn tested length. Relatively low correlation coefficients in the case of rotor yarn are caused by high irregularity of 35.5 tex rotor yarn. Combed yarns reach the lowest *DR* values. It corresponds to generally known findings about assumptions of combed yarns compared to carded yarns in the term of mass unevenness.

Correlation coefficients describing the degree of linear dependence between square mass irregularity *CV(L)* and the deviation rate *DR(±5%, L)* at various cut lengths *L* are mentioned in Table 5 and in Figure 3. Results include measurements of experimental yarns of all linear densities.



a)

b)

c)

Figure 3 Dependence of deviation rate *DR (±5%; 1.5 m)* on mass irregularity *CV(1.5 m)*; a) ring combed yarns; b) ring carded yarns; c) OE - rotor yarns

Table 5 Correlation coefficients between *CV(L)* and *DR(±5%, L)*

***L* [m]**	**Correlation coefficient *R***		
	Ring combed yarn	**Ring carded yarn**	**OE rotor yarn**
0.01	0.960	0.955	0.897
1.5	0.920	0.946	0.970
3	0.903	0.908	0.967
10	0.726	0.811	0.952

It is obvious from experimental results that strong linear dependency is between the deviation rate *DR(±5%, L)* and square mass irregularity *CV(L)* at the same section lengths *L*. However, the influence of linear density reflects into it. Decreasing value of correlation coefficient with growing section length can be also observed there.

This effect is probably caused by decreasing number of measurements within total test length. Subsequent observed relations between *DR(±5%, L)* and *CV(L)* calculated for yarns with individual linear density (see Table 6) have a lower level of correlation coefficients in many cases. Yarn linear density, which is a major influential factor affecting both monitored quantities, does not affect there. It is obvious from results that it is possible to use the *DR*-function for the prediction of unevenness in plane with utilization of hitherto known piece of knowledge about the variance-length curve and unevenness in plane.

Table 6 Correlation coefficients between *CV(L)* and *DR(±5%, L)*

		Correlation coefficient *R*			
	***T* [tex]**	***L*=0.01 m**	***L*=1.5 m**	***L*=3 m**	***L*=10 m**
Ring combed yarn	15.6	0.716	0.784	0.752	0.646
	20	0.447	0.896	0.818	0.728
	25	0.615	0.899	0.875	0.821
	35.5	0.422	0.935	0.822	0.451
Ring carded yarn	25	0.469	0.949	0.763	0.907
	29.5	0.399	0.762	0.873	0.741
	42	0.715	0.811	0.709	0.564
	60	0.277	0.845	0.763	0.907
OE-rotor yarn	29.5	0.473	0.932	0.872	0.773
	35.7	0.59	0.905	0.879	0.934
	50	0.832	0.892	0.966	0.894
	100	0.632	0.933	0.974	0.967

4 CONCLUSION

The relation between course of *DR* curves and other characteristic functions (the spectrogram and the variance-length curve) of normal and irregular yarns were observed. Correlation coefficients between *DR(±5%, L)* values and yarn count as well as values of variance-length curve, i.e. square mass irregularity *CV(L),* at corresponding cut lengths *L* were calculated. The strong linear dependency is between the deviation rate *DR(±5%, L)* and square mass irregularity *CV(L)* at the same length section *L*, excluding *L*=0.01 m. Values of deviation rates are also influenced by yarn fineness, deviation rates decreases with increasing yarn linear density. It was found out that a potential cumulous spectrum of mass irregularity on short wavelengths in the combination with increased *CV(L)* values is reflected negatively in the course of outer *DR* curve. Thus considerably convex shape of outer *DR* curve can predict disturbed appearance of fabric (i.e. cloudiness). The cumulous spectrum with middle and long wavelengths affects shape of *DR* curve with cut lengths *L*=1.5 m to 10 m. Deflected and from the point of view of course staircase parts of *DR* curves corresponding to positive mass deviations can predict disturbed appearance and partially a certain stripiness. Yarn linear density also influences values of deviation rates – deviation rates decrease with increasing yarn linear density.

Originally, the *DR* function was developed and applied in Japan. However, low amount of relevant research piece of knowledge has not allowed its application in wider industrial basis yet. Selected results, mentioned in this paper, should contribute to filling-in this gap. They should make possible their extended application in the area of evaluation of yarn mass irregularity and its relation to unevenness in plane of both woven and knitted fabrics.

5 REFERENCES

1. Slater K.: Yarn evenness, The Textile Institute, (Manchester), 1986
2. Carvalho V., Monteiro J.L., Soares F.O. and Vasconcelos R.M.: Yarn evenness parameters evaluation: A new approach, Textile Research Journal 78(2), 2008, pp. 119-127
3. Militký J., Ibrahim S.: Complex Characterization of Yarn Mass Unevenness in Selected Topic of Textile and Material Science, Technical University of Liberec, Faculty of Textile Engineering and West Bohemia University in Pilsen, New Technology Research Center (Liberec and Pilsen), 2011
4. Zellweger Uster: Zusammenhänge zwischen den Ergebnissen der Gleichmässigkeitsprüfung und den Aussehen der fertigen Gewebe und Gewirke, Uster News Bulletin, No. 15, (January 1971), pp.3-36
5. Zellweger Uster: Neue Möglichkeiten der Analyse von Masseschwankungen an Garnen, Vorgarnen und Bändern, Uster News Bulletin, No. 35. (August 1988), 6-18
6. Marsal F., Palet D., Indrie L., Ratiu M.: Aspect prediction of the knitted fabrics from the yarn properties, International Scientific Conference "Innovative solutions for sustainable development of textile industry", Oradea 2009
7. Chellamin K.P., Veerasubramanian D. and Vittopa M.K.: Inter-relationships Between Deviation Rate (%) in Yarn Mass and Variations in Tensile Characteristics and Fabric Appearance, Journal of the Textile Association, March-April 2014, pp. 353-359
8. Moučková E., Jirásková P. and Ursíny P.: Surface Unevenness of Fabric in Woven Fabric Engineering, Edited by Polonia Dobnik Dubrovski, 2010, pp. 195-217, Sciyo
9. Ursíny P.; Moučková E. and Jirásková P.: New knowledge about relation between yarn mass irregularity and surface unevenness, Book of Proceedings of 4nd International Textile, Clothing & Design Conference - Magic World of Textile, Dubrovnik, Croatia, 2008, pp. 915-92 (Zagreb)
10. Ursíny P., Janoušek J., Hedánek O. and Drozdová I.: Interrelation between applied mass irregularity characteristic function of yarn. 37th International Symposium on Novelties in Textiles - Book of proceedings, CD-ROM edition (Ljubljana), 2006
11. Ursíny P., Moučková E. and Hedánek O.: Analysis of mass irregularity by means of new parameter and ascertained relation, Proceedings of 13th International Conference Strutex - Structure and Structural Mechanics of Textile Fabrics, Technical University of Liberec, Faculty of Textile Engineering (Liberec), 2006, pp. 75-80
12. Zellweger Uster: Uster Tester IV Application Handbook, V1.0/400 106-04010, 2001
13. Grosberg P.: The Medium and Long-Term Variations of a Yarn – I, The Journal of the Textile Institute, 1955, T303
14. Malatinsky P. and Grosberg P.: The Medium and Long-Term Variations of a Yarn – II, The Journal of the Textile Institute, 1955, T310
15. Grosberg P.: The Medium and Long-Term Variations of a Yarn – III, The Journal of the Textile Institute, 1955, T317
16. Grosberg P. and Palmer, R.C.: Comparison of the Variance-Length Curves given by the Zellweger Instrument and by Cutting and Weighing, The Journal of the Textile Institute, 1954, 45, T303
17. Meloun M. and Militký J.: Statistické zpracování experimentálních dat (in Czech), PULS, Prague 1994

VZTAH MEZI MÍROU ODCHYLEK A DALŠÍMI CHARAKTERISTICKÝMI FUNKCEMI A PARAMETRY HMOTOVÉ NESTEJNOMĚRNOSTI PŘÍZE

Translation of the article

Relations between deviation rate and other characteristic functions and parameters of yarn mass irregularity

Hlavním cílem příspěvku je rozšířit stávající poznatky o míře odchylek (*DR(±5%, L*) jako jedné z charakteristických funkcí hmotové nestejnoměrnosti. K tomu je analyzován a vyhodnocen vztah (*DR(±5%, L*) k dalším charakteristickým funkcím, zejména k délkové variační funkci ale i ke spektrogramu. Na základě zjištěných závislostí jsou uvedeny možnosti využití *DR(±5%, L)* funkce v oblasti technologie předení a predikce nestejnoměrnosti v ploše.

CAM SYSTEMS FOR CLOTHING PRODUCTION AND TRANSFER OF DATA FROM CAD SYSTEM

Márie Nejedlá

Technical University of Liberec, Faculty of Textile Engineering, Department of Clothing Technology
Studentská 2, 461 17 Liberec, Czech Republic
marie.nejedla@tul.cz

Abstract: *The article focuses on analysis of automated cutting systems with regard to used unconventional and conventional cutting tools, types of desks and their usage for clothing production, for technical ready-to-wear clothes and when cutting leather for car industry. It analyses the procedure of data transfer between CAD and data transformation for CAM systems and the method of creating machine codes for the cutting automaton – cutter. The aim of the article is to support implementation or distribution of such cutting systems in all production spheres of ready-to-wear and small series clothing products and technical ready-to-wear products by provision of up-to-date useful information.*

Key words*: computer-aided manufacturing, conventional cutting tools, unconventional cutting tools, leather cut-out, CNC machine codes*

1 INTRODUCTION

One of the main directions of current scientific and technical progress is automation. Automation represents the highest form of modern mechanical large-scale production when operating of machines and production processes is transferred to automated systems. It consists in using the technical means, economic a mathematical methods and controlling systems that partially or fully free persons from direct involvement in processing, transfer and utilization of energies, materials and information.

CAD – (computer-aided design) is a mean for automation of the works of production technical preparation that is connected with a change of algorithm of works.

CAM – (computer-aided manufacturing) is an indication for computer supported production. In the clothing industry, these are the systems ensuring automated cut-out of clothing parts from a material layer.

Automation in the clothing industry and application of CAD/CAM systems is primarily used in the process of design, modelling, gradation, adjusting and when cutting-out positions of layered materials.

By mutual interconnection of these activities based on precisely defined steps and procedures, the program is processed by computer and the results of work are displayed on screen or sent to output equipment, i.e. to printer, plotter or cutter.

Automated systems replace time-consuming manual works in separation process, i.e. in cutting-out the parts of cut positions from the material. These systems use computing and digital technologies.

Optimize of cutting of clothing products by using of a CAM systems and using an automatic systems in the splitting process allows to the design of more complex structured products that better cover the surface of the body of human being and also enable to achieving better sensorial comfort of functional clothing [1].

Cutting systems – cutters are used not only in the clothing production but also in other industries such as e.g. footwear, aeronautical, car, furniture, engineering and other industries [2].

2 BASIC ELEMENTS OF CUTTING AUTOMATONS - CUTTERS

All cutters consist of working, motion, stable, control and auxiliary elements.

Working elements consist of:

Cutting tool – conventional or unconventional material separating part (in the direction of Z axes);

Auxiliary tools – drills, punches.

Motion elements consist of:

Automaton head - working elements carrier and transport element of the cutter moving along bridge shoulder in the direction of X axis (desk width);

Supporting bridge shoulder – cutter head carrier and transport element of the cutter moving only in the direction of Y axis (desk length).

Stable element consists of:

Cutting desk, work surface where the material is separated (surface is treated according to the type of used cutting tool).

Control and auxiliary elements consist of:

Technical accessories – conductors of propelling media (electric power, compressed air) or conductors of cutting media (knife, water, laser beam), automaton control computer, communication portal, communication network, other hardware accessories;

Program accessories – software accessories, system programs for controlling the automaton [3].

3 THE KINDS OF CUTTING TOOLS APPLIED IN CUTTING AUTOMATONS

In cutting automatons where the motion of cutting tool is fully automated, conventional (knife) and unconventional (non-knife) tools can be used, however, each of them has its advantages and disadvantages in parting certain kind of material. Conventional tools have been applied more frequently in classic clothing production so far because they are less expensive and they can be used for almost all kinds of clothing materials. Nonconventional tools are divided into thermal (plasma arc, laser) and cold (water jet).

As for nonconventional methods of separation, laser cutting, which applied in parting technical ready-to-wear clothing, is used most frequently in the sphere of ready-to-wear clothing.

Cutting automatons used in the clothing production can then be divided by:

Height of cut material in compressed condition

- one-layer loads (1-3 sheets)
- low layer loads (10-25 mm)
- medium layer loads (25-55 mm)
- high layer loads (55-75 mm)

Constructions and kinds of cutting desks

- static desk
- desk with conveyor
    - with brush surface
    - with special surface

3.1 Laser beam cutting

Laser beam cutting is used in the sphere of parting technical materials most often. The principle is based on optic concentration of the ray of light into one point (Figure 1).

In the point of impacting on material, the ray of light is transformed into thermal energy and a material layer is separated [2].

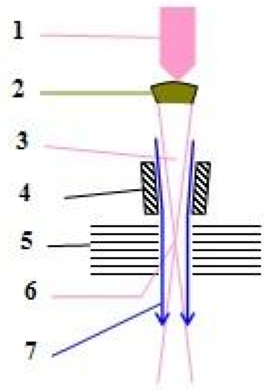


Figure 1 Laser beam cut: 1 - laser beam, 2 - focusing lens, 3 - laser beam in cutting quality, 4 - jet, 5 - material layer, 6 - beam outbreak, 7 - air flow [3]

The basic element of laser cutters is so called resonator (the source of laser beam). The beam is led from resonator through the system of mirrors to cutting head (Figure 2).

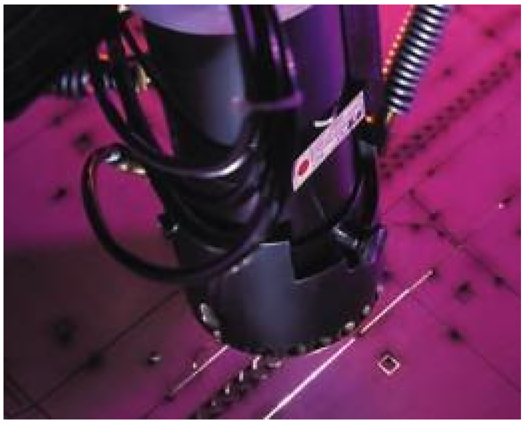


Figure 2 Cutting head of laser cutter [4]

In cutting head, the beam is focused into technologically accurately defined focus, which depends on the type and thickness of cut material. Cutting head moves.

Fuse cutting is the most frequently used method of laser beam separation for textiles; however, it cannot be applied for all kinds of materials. That is why it is used rather in the sphere of technical ready-to-wear clothing or in other industry fields such as car, furniture, engineering and other industries.

As material fuses while separated by laser beam, thin foil or paper, which prevent from shrinking individual layers of separated material together, need to be inserted between individual material layers. The cut is also cooled down, when the flow of shielding gas, which prevents from development of undesirable burn, passes coaxially with the laser beam. Gas pressure influences quality of the cut [2].

Laser beam cutting becomes more accurate and of higher quality thanks to developing technology.

Cutting tool is not blunt as a result of cutting. Purchase costs of cutting systems – cutters are, however, significantly higher than those of conventional cutters.

Among all possible methods of thermal cutting, lasers are the best in terms of cutting speed of up to 9 m/min, very small width of cut space of 0.1-1 mm; lasers can cut wider scope of clothing materials and cleanness of the cut is better than in case of cutting by knife.

The disadvantage is high development of temperature, which in combination with limited focusing distance do not allow cutting of bigger loads of clothing material (only fewer sheets), sintering of material layers can occur in the cut space (beam rather burns than cuts). Edges of the part are sealed and sharp after the cut-out; this cutting method is not suitable for all kinds of clothing materials, particularly the materials of natural fibres. Purchase and operation costs of the equipment are high.

Cutting desk surface is special. The upper part is usually in the form of a grating. The grating is made of special alloy, can be formed as honeycomb or classic grating. Most often, the surface consists of parallel vertically built steel laths with up to 60 mm high tips on the top side (Figure 3).

Figure 3 View of the laser cutter desk [4]

The tips form continuous surface, on which the parted material is placed, the tips are resistant to the beam action due to small surface of the top points.

3.2 Water jet cutting

Water jet (Figure 4) develops by chemically treated (softened) pressure water at 300-500 MPa passing through a special jet.

Jet is made of resistant material (sapphire) with the diameter of 0.2 mm. Emulsion of water and clean solid particles (garnet, olivine powder) is used to increase the cutting effect of water jet. Powder is supplied in special containers and using pressure air it is transported to the mixing chamber of special abrasive cutting jet. Water jet cutting can certainly be done without adding the powder. Powder is added in case of separation of hard metals. Water jet without added powder is used to separate plastics and softer material.

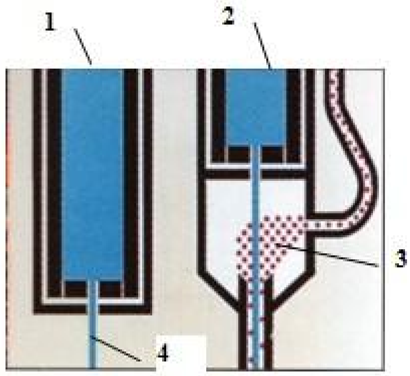


Figure 4 Sectional view of the special jet: 1 - sapphire cutting jet, 2 - abrasive cutting jet, 3 - powder added to water jet, 4 - water jet [3]

The system forms a closed circuit with regard to consumption of water and abrasive material. Water pressure is achieved by special high-pressure pump. First, water is pressurised to the first level of 4 kPa and by pressure hoses it is transported to the high-pressure pump, where water is pressurised to the second level of 300-500 MPa and transported to the jet by high-pressure hoses. In the form of a beam it passes through the jet and parted material, falls into water surface under the desk surface. From here it is pumped over to filtering equipment and used again. Part of abrasive material is gained back for reuse by filtration and cleaning [5].

The speed of water and beam is three times higher than the speed of sound, so it is about 1000 m/s. Cutting speed ranges depending on the kind of cut material. When cutting 5 mm thick PE foil, the speed is 250 mm/s. The distance of the jet from cut material is 13-25 mm. Diameter of water jet is 0.2 mm. Detail of the cutter head is in Figure 5.

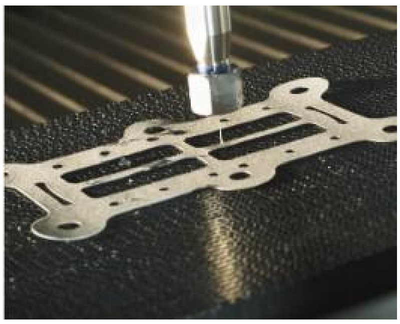


Figure 5 Cutter head with water beam [6]

Desk surface is formed of parallel vertically built narrow laths (Figure 5) made of high quality steel, the upper part of the laths is sharp, when the beam falls onto the edges, it splits up. Under the laths there is a 100mm layer of water because when material passes, water beam still has high kinetic energy and can be sprayed; when it falls onto the water surface, it is reduced.

Water jet cut is very clean and accurate - 10 m/min. Purchase and operation costs are lower than those of cutting by laser or plasma.

Water jet cutting can be used in production of technical ready-to-wear products, separation of foils, resilient technical textiles. Water jet is commonly used for parting metallurgical, ceramic, plastic materials.

As it is a wet process of cutting, this method cannot be applied in parting classic clothing materials. There is a problem with conducting water away and suitable surface of the desk under the cut-out textile material [5].

3.3 Knife cutting systems - cutters

Nowadays the cutting automatons are numerically controlled by computers. There are GGT, Investronica, Lectra, Kuris/Wastema, Bullmerwerk and others among the top producers.

The cutting tools of knife cutters are steel knives that differ in their types, shapes and their application. To carry out parting the knife must move (oscillate), which causes cutting, or must be push with certain power against the cutting desk surface, which causes parting by cutting-out.

3.3.1 Straight knife

Straight knife (Figure 6) oscillates straightforward returnable in the direction of Z axis.

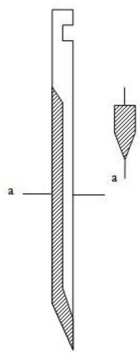


Figure 6 Straight knife

The speed of knife oscillation is determined by the engine speed, which is automatically regulated by the cutter or can be regulated by the cutter operator in accordance with the height of cut material. Knife construction type and parameters are influenced by the type of cutter. It is very important for **what material height the knife is designated**. Longer knives are used for higher loads; short knives are used for low loads. Knife construction is also influenced by the cutting head parameters, characteristics of engine and transmission that ensures oscillatory motion of the knife. Shapes of the knives are invariable; only dimensions and power of the knife, or shapes of knife shank for anchoring to crank shaft, change (Figure 7).

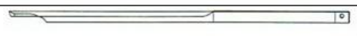
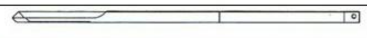
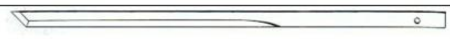
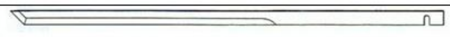
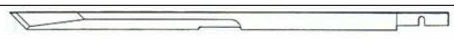
Species and illustrations of direct and oscillating knives ***Gerber Technology*** Companies	Dimensions in [mm] (length x thickness x width)
	175 x1,5 x 6,3
	195 x 2,0 x 7,9
	200 x 2,15 x 6,3
	202 x 2,1 x 6,3
	206 x 1,9 x 7,9/6,4
	206 x 1,9 x 7,9
	254 x 2,35 x 8
	254 x 2,35 x 8
	254 x 3,13 x 9,7

Figure 7 Examples of straight knives produced by Gerber Technology [2]

While cutting the knife leans with its sides and back part against the roller guide beds guiding the **contact beads**, which press material directly in the place of cut. There is also knife sharpening equipment on the bead. The most significant loading of the knife occurs when it passes through the material top layer when cutting-out the curves. Applied resistance forces of the material are so significant that automatons intended for cutting high loads have special equipment of knife balancing (knife intelligence).

Knife intelligence is a device that balances resistance forces of material applied onto the knife. In lower parts of the bead, there are rollers of knife guide beds adjusted as sensors. In case of knife deflection in certain direction, relevant sensor responses and based on the impulse, the cutter control unit regulates engine speed optimally. Besides it turns the knife edge more vertically to the cut material. In no case the knife is allowed to tilt because lower sheets in the load would be damaged. All cutters intended for medium and high loads are equipped with this device [3].

The material of the knives is high-quality carbon steel with suitable properties – firmness and sufficient flexibility.

Sharpening of knives is ensured by grinding wheels that are designed for the knife construction. Material of the sharpeners is special CBN – cubic boron nitride. Diamond or other sharpeners cannot be used for knives made of carbon steel. Regularity and frequency of sharpening is set by the program. When setting the sharpening program and when setting the sharpeners the parameter of **top ankle** of the knife edge is very important [3].

Surfaces of the cutting desks (Figure 8) for this kind of knives are brush and consist of bristles, into which the knife point penetrates (Figure 9). This ensures good separation even of the lowest layer of material without blunting the knife or damaging the desk surface.

General view of the detail of knife cutter is in Figure 10.

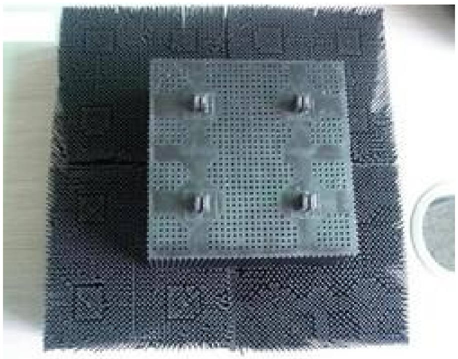


Figure 8 Part of brush surface of cutting desk

Figure 9 Penetration of straight knife into brush surface of cutting desk [7]

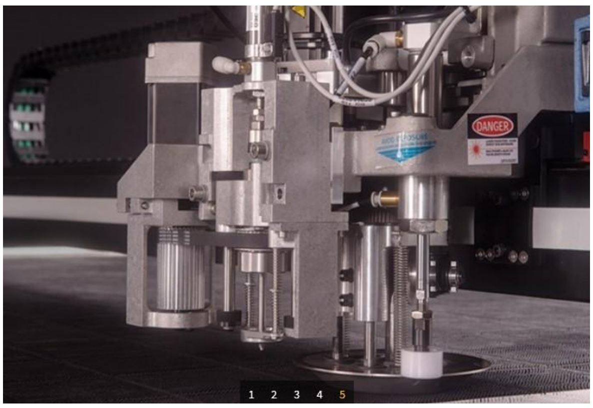


Figure 10 Cutter head – knife, with contact bead, grinding wheels and drill [8]

3.3.2 Disc knife

Disc knife is the latest tool applied in cutting automatons. It is made of carbon steel and it rather cuts the material out. Disc knife is not sharpened at cut-out, the knife is resistant; moreover, the price of the knife is very low. If worn out the knife is replaced. The knife (Figure 11) is manufactured in two basic sizes – 28 and 45 mm for one-layer and deeper cut.

Tool parameters limit the maximum height of the cut layer of material. Detail of the cutter head with disc knife is in Figure 12.

Figure 11 Disc knife

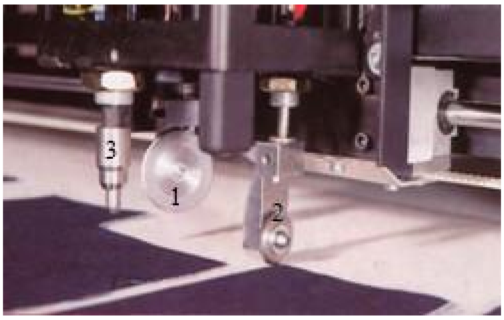


Figure 12 Cutter head with disc knives: 1 - disc knife for higher layer of the material; 2 - disc knife for lower layer of the material; 3 - punch

3.3.3 High-frequency oscillatory knife

The knife is small, its width is 5 mm and length 20 mm, its point is sharp (Figure 13).

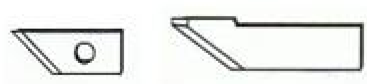


Figure 13 High-frequency oscillatory knife produced by GERBER TECHNOLOGY (length of 20 mm x width of 5 mm x thickness of 1 mm) and by Topcut-Bullmer (length of 25 mm x width of 6.3 mm x thickness of 0.6 mm)

Knife is fastened in a holder. The holder connects to the core of special electromagnetic coil. The coil carries adjusted electric current of high frequency. The current causes amplitude of the coil and this oscillatory motion is transmitted to the knife that cuts the material. The height of knife amplitude is c.1.5 mm and its frequency is 1-2 kHz.

While cutting by this knife, the whole material layer is cut perfectly, so the knife cutting the lowest layer of the material slightly hits backing of the cutting desk. That is why the desk backing needs to be replaced after certain period.

The cutting desk surface consists of a special solid and slightly elastic backing made of significantly hardened non-woven textile, which is used also in desks when cutting by circle knives. Maximum depth of the cut is ensured by a depth limiting device. Contact pressure of the knife is ensured by a pneumatic mechanism and is regulated according to the conditions of the cut-out. The pneumatic mechanism presses not only the knife but also the holder and magnetic coil.

Cut-out by high-frequency knife is more accurate than by disc knife.

Oscillatory knife can be applied for cut-out individually or can be used as an auxiliary tool in combination with disc knife. That is why disc knives are used for cutting long cuts and oscillatory knives for cutting-out curves or grooves.

3.3.4 Pivex® knife

The Pivex technology knives (Figure 14) are intended for cutting complicated shapes of leather using Taurus™ II cutter.

Figure14 Cutter head with oscillating Pivex® knife for cutting leather [9]

Above the cutting desk, there is a digital camera installed (Figure 15). It records leather even with defect marks. Reversible motion of the Pivex knife connected with the desk surface with high friction minimises motion of the leather and ensures accurate cut-out.

The cutter allows cutting with zero buffers between the parts, even more shape actions with extreme accuracy without reducing the cutting speed, which reduces waste generated at application of cut-out (Figure 16).

Figure 15 Taurus™ II cutter with recording camera

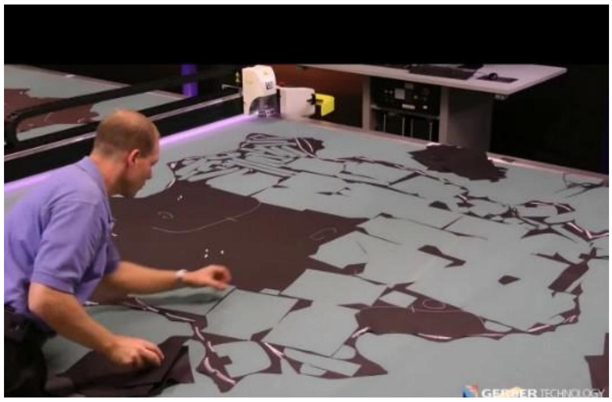


Figure 16 Cut-out of leather on Taurus™ II cutter

The controlling persons use symbols to define four levels of leather defects, so less critical parts can be placed in the areas with minor defects for maximum utilisation of the leather.

The cutter can digitally record information about surface, shape and defects of all leathers.

Using CutWorks automatic positioning, it can process the quality of cut parts and ensures that critical parts are cut-out only from the best quality parts of the leather. It allows positioning onto leathers with holes or onto leathers with multiple directions of strain [9].

4 TRANSFER OF DATA FROM CAD SYSTEM TO CAM SYSTEM

This step can be characterised as transfer of the values of the set position of parts to the coordinates of cut-out using *parametric chart*.

4.1 Transformation of the coordinates of position parts to coordinates of cut-out

Principle of the transformation consists in transferring the coordinates of the points that make contour of the parts from CAD system to machine codes, which they transform to the program language that the cutting automaton can process.

Machine code is a sentence consisting of individual machine words made by alphanumeric signs. The machine word always determines one step (action) that has to be executed by the cutting automaton, e.g. stick the knife, go from X0Y0 point to X0Y25 point, lift the knife, and others.

A part of CAM system software equipment is the *parametric chart* called *POWER PROCESOR* that forms a supporting system program, using which the transformation is executed [10].

Using the parametric chart, the following actions are executed:

A. *Automatic transformation of the values of the point:*

a) Transformation of coordinates' values of parts' construction points in the position;
b) Setting the machine sentence in accordance with the order of parts' cut-out;
c) Determination of the direction and order of parts' cut-out, (go from X0Y0 point to X0Y25 point);
d) Determination of the location of trims and other marks.

B. *Automatic entry of preparatory and auxiliary functions:*

a) Type and parameters of cutting automaton, desk length, desk width;
b) Definition of the starting point – zero point;
c) Type of trims and "T", "V", "U" marks;
d) Instructions for work with knife - stick, lift the knife;
e) Speed of the knife;
f) Other supporting commands
   - automatic start and control of sharpening cycle,
   - starting knife intelligence,
   - automatic control of load height.

C. *Manual modification or correction of commands and functions:*

a) Correction of tool dimensions – grinding, etc.;
b) Other control and optimization functions [10].

4.2 Analysis of machine code for CAM systems

Transfer of values and entering operating commands is executed automatically using the program and parametric chart [9]. Manual interference into these procedures is exceptional. Correction of the position machine code modification can be done only by the CAM system administrator.

In Figure 17, there is an example for identification of coordinates of the points of a cut-out rectangular part [3].

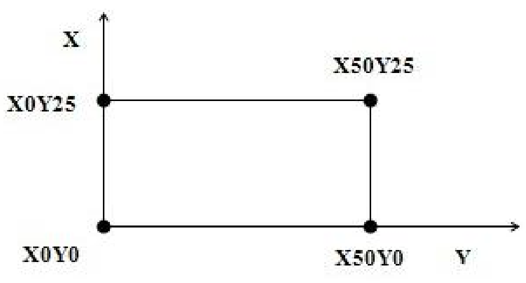


Figure 17 Depiction of coordinates of the points of a cut-out rectangular part

Simplified record of the machine sentence for cut-out of rectangular is:

X0Y0/M14/X0Y25/M15/C/M14/X50Y25/M15/C/M14/X50Y0/M15/C/M14/X0Y0/M15

Sentence code legend:

M15 – supporting function – lift the knife
M14 – supporting function – stick the knife
C – turn the knife (degrees of turning from the basic position must be stated here)
* - demarcation of block
/ - separation of block
X50 – measurement of shift in X axis in mm
(x = desk width)
Y25 – measurement of shift in Y axis in mm
(Y = desk length)

There can be a problem with data transfer from one CAD system to another producer' CAD system. Each system works in certain modes, difference of these modes can cause incorrect transfer or even unrealized transfer. That is why all current producers of CAD and CAM systems endeavour to use software. Another problem during numeric values transfer can occur if the system works with more value systems, metric or inch system, it needs to be taken into account.

4.3 Cutter output

Practically the cutter output is as follows. Operator enters command from the cutter controlling computer to start transfer of data from CAD database, data is loaded into computer memory. Operator activates the program, transfers cutter to the zero point of the position using manual control and confirms the zero point. The operator confirms activation and data is loaded to CPU processor. The CPU processor starts to communicate with controllers and cutter starts working. After reading the whole of the machine sentence (cutting the entire position out) cutter returns to the zero point or is set into different starting position.

5 CONCLUSION

Cutteries count among the machines known as "CNC" - (Computerized Numerical Control). The CNC machines are used wherever it is possible to produce more pieces using the same prearranged technology. The technological NC program consists of a string of characters, i.e. commands that begin with a letter followed by a numeric code. These represent the shift of the tool - knife, the nearest way from the original place to the place of destination, which is entered in absolute coordinates as relative to the zero point on the part. A prerequisite for proper function and operation of CNC machines is the correct setting of lengths and diameters of the tools.

Thanks to new technologies, the production has improved substantially, becoming more efficient, and even its price has been reduced. That's why today´s CNC machines are being installed not only in all workplaces focusing on machine production, but also those within the clothing industry.

The essential advantage of cutting automatons – cutters, compared to other cutting machines, is high quality of the cut-out even in case of cutting higher load of material with accurate cut-out of acute angles and curves. There are a lot of routine tasks that are processed automatically.

As for the purchase costs, conventional cutters are less expensive than unconventional cutters. Moreover, when parting using conventional tools, the edges of the cut material are not burnt or wetted.

The cutter knives are made of universal steel of high quality and they can be used for separation of all kinds of textile materials. So knife has been and always will be the most suitable cutting tool, with regard to the kind of separated material for clothing production.

Implementation of cutting automatons – cutters in clothing production leads to better accuracy of outputs, easier control, increase of social labour productivity. Changes in economic structure occur, division of labour develops, specialization deepens, which relates to higher percentage of qualified employees. Finally, also company image is improved.

6 REFERENCES

1. Nagy L., Havelka A., Kůs Z., Jandová S.: Testing Physiologic Comfort of Functional Clothing, ACC Journal: Natural Science and Technology, Liberec, 2013, XIX(1/A), pp. 85-92
2. Čentéšová P.: Specifikace nožů pro cuttery podle řezaného materiálu v oděvní výrobě, Technická univerzita v Liberci, Liberec, 2011
3. Parák Z.: Studie typů cutterů z hlediska jejich konstrukce, funkce a využití v podmínkách hromadné a zakázkové výroby, Technická univerzita v Liberci, Liberec, 2002
4. Laserový cutter: http://www.gerberinnovations.com/pdf/GI_ML_brochure.pdf
5. Prospektové materiály a internetové adresy firem Assyst/Bullmer, Gerber, Investronica, Kuris/Wastema, Lectra, Bystronic.
6. Řezání vodním paprskem: http://www.gerberinnovations.com/pdf/GI_WJ_brochure.pdf
7. http://www.oblibene.com/userdata/shopimg/zadas/File/XLc7000ApparelE%20%28CZ%29.pdf
8. http://www.gerbertechnology.com/fashion-apparel/sourcing-production/paragon-cutting-system/
9. http://www.gerbertechnology.com/fashion-apparel/sourcing-production/taurus-ii-leather-cutter/
10. Seznam ovládacích strojových kódů pro GERBERcutter

CAM SYSTÉMY PRO ODĚVNÍ VÝROBU A PŘENOS DAT Z CAD SYSTÉMU

Translation of the article

CAM systems for clothing production and transfer of data from CAD system

Článek je zaměřen na analýzu řezacích automatizovaných systémů z hlediska používaných nekonvenčních a konvenčních řezných nástrojů, typů stolů a jejich použití pro oděvní výrobu, dále pro technickou konfekci a při řezání usní pro automobilový průmysl. Analyzuje postup přenosu dat mezi CAD a transformaci dat pro CAM systémy a způsob tvorby strojových kódů pro řezací automat – cutter. Záměrem článku je podpořit zavádění, popřípadě rozšíření těchto řezacích systémů ve všech oblastech výroby, jak konfekčně, tak malosériově zpracovávaných oděvních výrobků a výrobků technické konfekce, podáním aktuálních užitečných informací.

DISCRETE THREE-DIMENSIONAL MODEL OF MOISTURE SPREADING IN TEXTILE MATERIALS

A. Schutskaya and N. Suprun

Kyiv National University of Technologies and Design, Nemyrovycha-Danchenka 2, 01011, Kyiv, Ukraine
polischuka@mail.ru

Abstract: *In this paper were developed methods of determining the period of passing the liquid through textile materials by modelling its discrete structure. The work is based on experimental data of the structure of materials and experiments on the passing of fluid through elementary samples. These data were obtained on the basis of a brightness of colour liquid that passes through the sample of material. Dependence to determine the concentration of the liquid in the volume model of the textile material was proposed. Discrete distributions are obtained, which show the presence of fluid in the various points of the material in the longitudinal, transverse direction and depth. It revealed the border, which reaches the fluid at different times. Discrete points have been replaced by a continuous curve. An analytical function of changing of wetted zone was built. The results allow predicting the term of full wetting of materials and forecasting the term of comfort use of products, to define the parameters of the material for a certain period of work.*

Key words*: textile materials, discrete model, moisture spreading, pore structure.*

1 INTRODUCTION

Textile fabrics play an important role in everyday life and their applicability for many end uses is determined by their appropriate transport properties. Mass exchange between the underwear space and environment through textile material is carried out due to the presence of a great number of through pores in it. In order to study moisture transfer processes in such systems, as a rule, this or that model of a porous medium is set. Different techniques and also some theoretical models have been developed and used to characterize and compare the transport of a fluid (gas, liquid or their mix). Although studies of fluid transport have been carried out on different fabrics, the influence of three dimensional fabric structural features on this process has not been fully explored.

Textile as a fractal material [1, 2] has expressed discontinuous structure, which consists of individual components - cells with specific properties. When using these materials in hygienic purposes the question about the prediction of the term of fluid passing through products that are made from this material arises. Existing methods do not answer this question.

2 PROBLEM STATEMENT

The purpose of the work is to develop a discrete calculated model for woven fabrics on the basis of the analysis of their structure and use of discrete mathematical programming. Despite the large number of publications about spreading of moisture in textile materials the peculiarities of their structure are not widely used in the development of mathematical models of this process. In [3] was noted the importance of determining the parameters of the fluid passing through the material. Authors of [4-5] attempted to develop a model of textile material as a continuous body, but the complexity of the results makes it difficult for use in practice.

To receive space distribution of liquid concentration in a general case it is necessary to solve a diffusion equation, which in a three-dimensional case is represented [6] as:

$$\frac{\partial u}{\partial t} = \sum_{i=1}^{3} \sum_{j=1}^{3} \frac{\partial}{\partial x_i} \left[D_{ij}(u) \frac{\partial u}{\partial x_j} \right] \tag{1}$$

where u is moisture concentration in the point with coordinates ($x_1 = x$, $x_2 = y$, $x_3 = z$), D_{ij} (u) is a diffusion coefficient that depends on concentration and direction of liquid distribution, t is time.

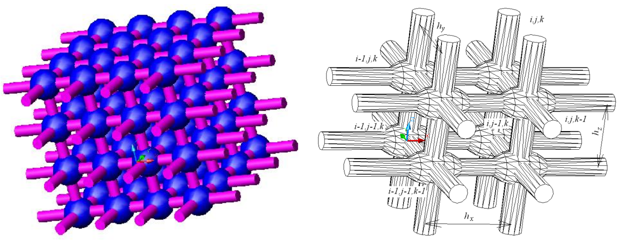
Considering that a diffusion coefficient depends on liquid concentration, we draw a conclusion about the nonlinearity of the equations, general methods of solution of which do not exist.

It is known that textile materials have a clearly expressed structure that includes longitudinal and cross elements. Experimental data on moisture penetration in such systems is published widely enough (for example, [7-10]). Unfortunately, they cannot be used directly for modeling because the obtained continual models are very complex;

however they can be a basis for development of discrete models. In our previous publication [11] was done an attempt to use peculiarities of calculations for flat structures. Similar tasks can be used for the analysis of processes of spreading of the liquid in the volume material.

3 RESULTS AND DISCUSSION

The woven fabrics can be ideally represented as a system of pores and connections between them. However it does not simplify, but complicates development of model. We offer to represent such a structure as a system of containers for storage of liquid with the system of elements which transfer liquid between them (Figure 1a). The system can be isotropic or anisotropic. A discrete cell of such a structure for calculations can be represented as shown in Figure 1b.



a) b)

Figure 1 Ordered structure of textile material (a) and its low-level discrete cell (b)

A set of experiments was carried out in the samples of woven fabrics to determine the dynamics of change of the concentration and parameters of fluid distribution. It should be noted that the concentration in a direct way is difficult to determine. Therefore we used the method of changing the brightness of spreading liquid. One of the boundaries of the test material was set in contact with colored liquid. Due to the diffusion properties of the material the liquid spread along the sample, changing its brightness. The brightness of the liquid determines its concentration in the material.

To receive the changes in brightness on the length at time with the help of camera the photos of the wetted zones of samples were made. Then images were transferred to the computer and divided into uniform sections. The brightness of each such section J in the additive RGB system is defining as:

$$J=0,222 * R + 0,707 * G + 0,071 * B \qquad (2)$$

where R – is the percentage of red color in the point (is changing from 0 to 255), G and B - of green and blue, respectively. Ten points was allocated on a linear pattern for the experiment. The point number is represented by symbol n. The brightness of each was determined by the digital image on the computer. For different points of time the change of the brightness of the sample is described by the relation, which is shown in Figure 2.

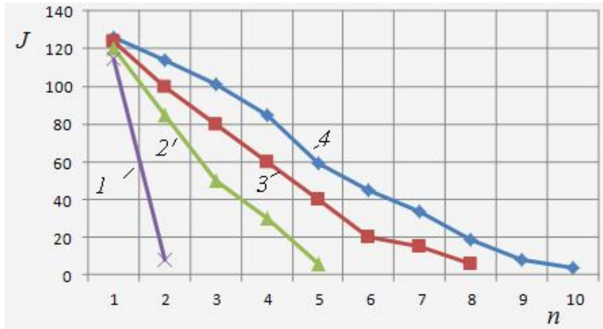


Figure 2 Changing of the brightness on the length of sample in time (here n – the plot number for measuring of the brightness, J – brightness) (1,2,3,4 – different moments of time t, $t_4>t_3>t_2>t_1$)

The value of concentration of liquid on the left border close to unity, on the right boundary - asymptotically approach zero. Mathematically this dependence can be described by the exponential function of the form:

$$U = e^{-A \cdot x} \qquad (3)$$

where the coefficient A depends on time.

Experimental changes of dependence of concentrations of liquid in samples were analysed and with the use of linear least-squares method were received functions as:

$$u = e^{-a_x \frac{x}{t}} \qquad (4)$$

The results of the experiments on one-dimensional samples can be used for the modelling of distribution of liquid in the space of material. The element that accumulates moisture has i number in the direction of x-axis, j - in the direction of y-axis, k - in the direction of z-axis. Supply elements come to it from three directions, in its turn this element distributes liquid in three directions. Moisture amount that enters into the element let's designate as 0 index, moisture amount that goes out of the element – as 1 index. Each supply element has a transfer function which determines a difference between liquid concentration at the beginning and at the end of the element. In the general case this function depends on coordinate and time. For example, for elements placed along x-axis we can write:

$$u_i^{x,0} = u_{i-1}^{x,1} \cdot f(x,t) \qquad (5)$$

Let's assume that the average cell size of the coordinate axes is stable. Let's designate it for three axes h_x, h_y, h_z.

Then for three axes it is possible to write:

$$\begin{cases} u^{x,0}_{i,j,k} = u^{x,1}_{i-1,j,k} \cdot f(h_x, t) \\ u^{y,0}_{i,j,k} = u^{y,1}_{i,j-1,k} \cdot f(h_y, t) \\ u^{z,0}_{i,j,k} = u^{z,1}_{i,j,k-1} \cdot f(h_z, t) \end{cases} \tag{6}$$

A peculiarity of the process can be a change of values in time at an initial section of the supply element. In this case it is necessary to say not about of change of full concentration, but about change of concentration in differentials when it is considered that a record made in formula (6) remains true in increments obtained under the methods of differential calculus. In such a case for a time point τ we shall obtain:

$$\begin{cases} du^{x,0,\tau}_{i,j,k} = du^{x,1,\tau-1}_{i-1,j,k} \cdot f(h_x, t) + u^{x,1,\tau-1}_{i-1,j,k} \cdot df(h_x, t) \\ du^{y,0,\tau}_{i,j,k} = du^{y,1,\tau-1}_{i1,j-1,k} \cdot f(h_y, t) + u^{y,1,\tau-1}_{i,j-1,k} \cdot df(h_y, t) \\ du^{z,0,\tau}_{i,j,k} = du^{z,1,\tau-1}_{i1,j,k-1} \cdot f(h_z, t) + u^{z,1,\tau-1}_{i,j,k-1} \cdot df(h_z, t) \end{cases} \tag{7}$$

The liquid that has arrived to the unit, accumulates that mathematically means a sum of separate concentrations:

$$du^{\tau}_{i,j,k} = du^{x,0,\tau}_{i,j,k} + du^{y,0,\tau}_{i,j,k} + du^{z,0,\tau}_{i,j,k} \tag{8}$$

After arrival to the unit the liquid is distributed by liquid diverting elements, and liquid amount diverted to each direction is determined by properties of the unit. Let's note that a real structure of material determines properties of liquid transfer from one direction to each of three initial ones. It can be written mathematically as:

$$\begin{cases} du^{x,1,\tau}_{i,j,k} = k_{xx} \cdot du^{x,0,\tau}_{i,j,k} + k_{yx} \cdot du^{y,0,\tau}_{i,j,k} + k_{zx} \cdot du^{z,0,\tau}_{i,j,k} \\ du^{y,1,\tau}_{i,j,k} = k_{xy} \cdot du^{x,0,\tau}_{i,j,k} + k_{yy} \cdot du^{y,0,\tau}_{i,j,k} + k_{zy} \cdot du^{z,0,\tau}_{i,j,k} \\ du^{z,1,\tau}_{i,j,k} = k_{xz} \cdot du^{x,0,\tau}_{i,j,k} + k_{yz} \cdot du^{y,0,\tau}_{i,j,k} + k_{zz} \cdot du^{z,0,\tau}_{i,j,k} \end{cases} \tag{9}$$

where k_{xx}, k_{xy}, k_{xz}, *and others* - liquid distribution node indicators textile material in other directions. The first character indicates the coefficient of the initial motion of the fluid, and the second - the direction in which the fluid moves after the assembly. For example k_{xy} coefficient shows the relative amount of liquid that initially moved in x direction, after a meeting with discrete element – in y direction.

The condition (8) requires observance of conditions:

$$\begin{cases} k_{xx} + k_{xy} + k_{xz} = 1 \\ k_{yx} + k_{yy} + k_{yz} = 1 \\ k_{zx} + k_{zy} + k_{zz} = 1 \end{cases} \tag{10}$$

In case of finding of all intermediate increments, liquid concentrations in different directions can be determined as integrals:

$$u_{i,j,k} = \int_0^t du^{\tau}_{i,j,k}, u^{x,0}_{i,j,k} = \int_0^t du^{x,0,\tau}_{i,j,k}; u^{y,0}_{i,j,k} = \int_0^t du^{y,0,\tau}_{i,j,k}; u^{z,0}_{i,j,k} = \int_0^t du^{z,0,\tau}_{i,j,k} \tag{11}$$

Although the given method simplifies a solution of the differential diffusion equation, all the same it remains too difficult for a solution. In fact it replaces a solution of one equation in partial derivatives with the system of usual differential equations, the number of which is three times more.

A real calculated model can be built if to replace a continuous system with final increments:

$$\begin{cases} \Delta u^{x,0,\tau}_{i,j,k} = \Delta u^{x,1,\tau-1}_{i-1,j,k} \cdot f(h_x, t) + u^{x,1,\tau-1}_{i-1,j,k} \cdot \Delta f(h_x, t) \\ \Delta u^{y,0,\tau}_{i,j,k} = \Delta u^{y,1,\tau-1}_{i1,j-1,k} \cdot f(h_y, t) + u^{y,1,\tau-1}_{i,j-1,k} \cdot \Delta f(h_y, t) \\ \Delta u^{z,0,\tau}_{i,j,k} = \Delta u^{z,1,\tau-1}_{i1,j,k-1} \cdot f(h_z, t) + u^{z,1,\tau-1}_{i,j,k-1} \cdot \Delta f(h_z, t) \end{cases} \tag{12}$$

In this case real concentration in the certain point (cell) of the structure can be written as:

$$u_{i,j,k} = \sum_{\tau=0}^{t} du^{\tau}_{i,j,k}; u^{x,0}_{i,j,k} = \sum_{\tau=0}^{t} du^{x,0,\tau}_{i,j,k}; u^{y,0}_{i,j,k} = \sum_{\tau=0}^{t} du^{y,0,\tau}_{i,j,k}; u^{z,0}_{i,j,k} = \sum_{\tau=0}^{t} du^{z,0,\tau}_{i,j,k} \tag{13}$$

The specified algorithm has been used for modelling of liquid spreading in the rectangular structure. Zero concentration has been taken as initial values by all cells. Liquid has been constantly supplied to the cell under number 0,0,0. The results of modelling of liquid spreading are shown in Figure 3. Different figures show the change in the liquid concentration in the individual elements of the material for different points in time.

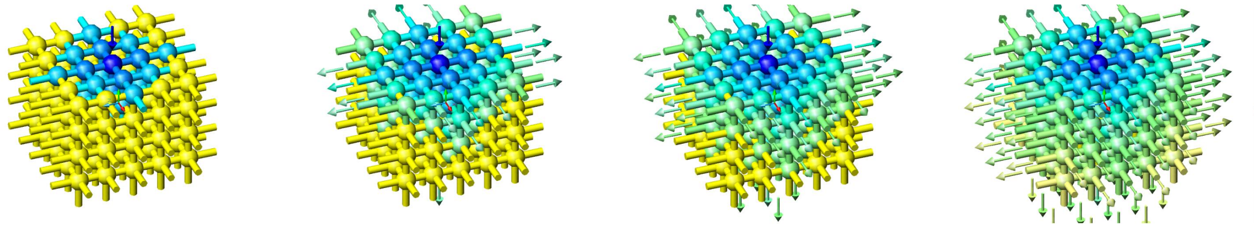
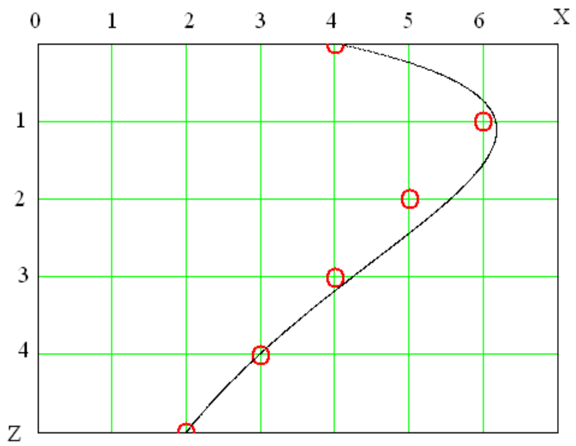


Figure 3 Liquid spreading within a discrete model



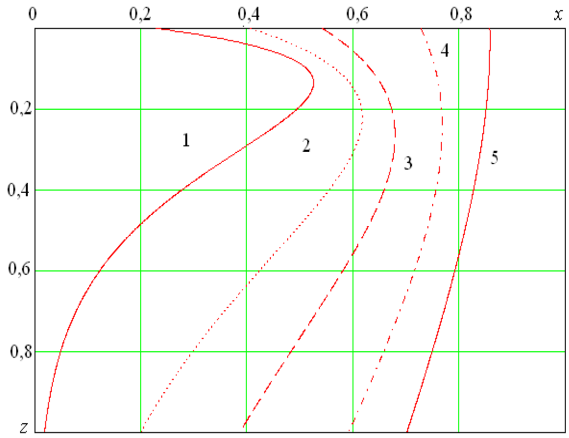


Figure 4 a) Discrete results of fluid distribution (X- longitudinal coordinate, Z - coordinate to the depth of the material), b) Changing the border of moistened areas for different moments of time, (1,2,3,4,5 – different moments of time t, $t_5>t_4>t_3>t_2>t_1$)

The discrete model of distribution of fluid at a time gives the results which allow determining the actual concentration of the liquid at a certain point, and also the shape of the borders of wetted zone which liquid reached in its distribution. Figure 4a shows the shape of wetted surface in a single period. This figure indicates the discovered effect of increasing the penetration of liquid inside the material. Something similar was obtained by the authors [12] at study of liquid spreading in spacer fabrics. For the description of the process of fluid distribution was carried out the approximation of discrete distribution of fluid by continuum model.

Figure 4a) shows the points to which the liquid has reached on the basis of discrete modeling. Figure 4b) shows continuous curves that simulate the process of fluid distribution in the material. These curves were also obtained on the basis of the discrete model (Figure 3). However, it shows its smooth images.

We will present a function as a combination of direct and exponent:

$$X = (A + B \cdot Z) \cdot e^{-C \cdot Z} \tag{14}$$

Further we will work with dimensionless coordinates.

The dimensionless coordinates obtained as follows:

$$x = \frac{X}{X_{\max}}, \; z = \frac{Z}{H} \tag{15}$$

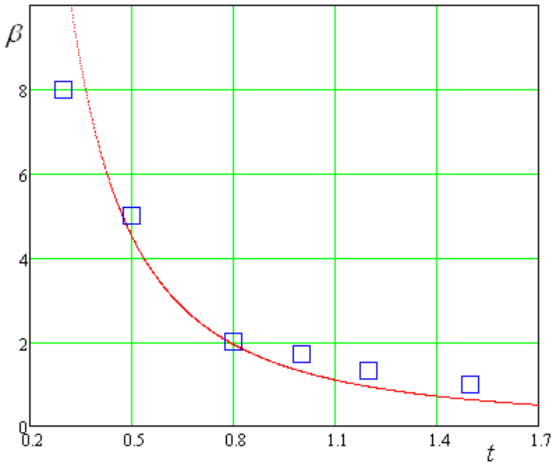
where X_{max}- the maximum wetting zone, H - the thickness of the material.

$$x = \alpha(1 + \beta \cdot z) \cdot e^{-\gamma \cdot z} \tag{16}$$

where α, β, γ – coefficients depending on material and liquid.

Unknown coefficients may act as functions of time. Taking into account received discrete results can be obtained the dependences for different moments of time. The investigations of penetration of the liquid into depth make it possible to build a number of discrete dependencies which was done at the approximation by continuous lines on Figure 4b.

The study of functions of change of the moistened border makes it possible to determine the dependence of coefficients on time. Figure 5a shows a discrete function of dependence of coefficient β on time.



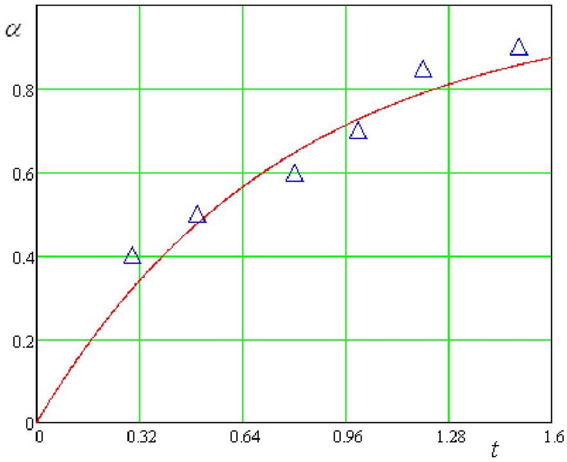


Figure 5 Dependence on time a) of the coefficient β, b) of the coefficient *α*

Try to approximate this dependence by inverse power function. Determination of the regression coefficients by least squares for this function gives expression:

$$\beta = \frac{1.7}{t^{1,8}} \tag{17}$$

Similarly we determine coefficient γ:

$$\gamma = \frac{1,2}{t^{1,04}} \approx \frac{1,2}{t} \tag{18}$$

Another relationship can be obtained in the study of discrete values of change of coefficient *α* of time (Figure 5b). Unlike previous cases, this relationship looks as a continuous increase in the expectation of entering the asymptotic value. Approximation of this dependence is best by using the exponential function with saturation. After holding regression procedures we determine the best possible coefficients for this function:

$$\alpha = 1 - 0,97 \cdot e^{-1,3 \cdot t} \approx 1 - e^{-1,3 \cdot t} \tag{19}$$

These calculations allowed building a continuous function for a particular case:

$$x = \left(1 + \frac{1,7 \cdot z}{t^{1,8}}\right) e^{-1,2 \cdot \frac{z}{t}} \cdot \left(1 - e^{-1,3 \cdot t}\right) \tag{20}$$

This function takes into account the specific indicators of liquid penetration into the material. For arbitrary case the function for the boundary of wetted zone we'll be write as:

$$x = \left(1 + \frac{A_3 \cdot z}{t^{A_4}}\right) \cdot e^{-A_1 \frac{z}{t}} \cdot \left(1 - e^{-A_2 \cdot t}\right) \tag{21}$$

This function is universal. The coefficients which enter into it are constants that determine the interaction of material and fluid at the elementary level.

4 CONCLUSIONS

In this paper a discrete calculated model of textile materials based on the analysis of their structure and use of discrete mathematical programming has been developed. This model uses data of elementary components of material for forecasting of its overall properties. On the basis of the model the algorithm of calculation of liquid spreading in material has been developed. The results allow predicting the full term of wetting of materials and products from them, what can be used for prognostication of comfort application.

5 REFERENCES

1. Suprun N.P.: Use of fractal dimension at description of porosity of textile materials, Visnuk of Kiev National University of Technology and Design 1(5), 2005, pp. 51-53
2. Boming Yu ,L. James Lee, Hanqiang Cao: Fractal Characters of Pore Microstructures of Textile Fabrics. Fractals 9(2), 2011, pp. 155-163
3. Crow R.M., Osczevski R.J.: The Interaction of water with Fabric Textile Res. J. 68(4), 1998, pp. 280-288
4. Riabchykov N., Vlasenko V., Arabuli S.: Linear mathematical model of water uptake perpendicular to fabric plane, Vlakna a textil (Fibres and Textiles) 18(2), 2011, pp. 24-29
5. Suprun N.P.: Modeling of masstransfere processes in textiles, Vlakna a textil (Fibres and Textiles) 8(2), 2001, pp. 125
6. Gorbis Z.R.: Heat transfer and hydromechanics of disperse through streams, Moscow Energy Ed., 1970, p. 124
7. Yoneda M., Mizuno Y., Yoneda J.: Measurement of water absorption perpendicular to fabric plane in two- and multi-layered fabric systems, Textile Res. J. 29(12), 1993, pp. 940–949

8. Sousa Fangueiro R.M, Cunha Soutinho H.F.: Moisture Management Performance of Multifunctional Yarns Based on Wool Fibers, Advanced Materials Research 123-125, 2010, pp. 1247-1250
9. Mhetre S.K.: Effect of fabric structure on liquid transport, inkjet drop spreading and printing quality, A thesis presented to the academic faculty Georgia Institute of Technology. May, 2009, p. 152
10. De Gennes P.G., Brochard-Wyart F., Quere D.: Capillarity and wetting phenomena: drops, bubbles, pearls, waves, New York: Springer-Verlag New York, Inc., 2004, p. 287
11. Schutskaya A., Suprun N.: Discrete two-dimensional model of moisture spreading in textile materials. Vlakna a textil (Fibres and Textiles) 22(3-4), 2015, pp. 12-18
12. Davies A, Williams J.: The Use of Spacer Fabrics for Absorbent Medical Applications, Journal of Fiber Bioengineering and Informatics 1(4), 2009, pp. 321-329

GRAPHIC MODELING OF CONDUCTIVE FILLER SPATIAL DISTRIBUTION IN POLYMER MATRIX

Dmitriy Novak, Yuriy Budash and Natalia Bereznenko

Kyiv National University of Technologies and Design, Nemyrovycha-Danchenka 2, 01011, Kyiv, Ukraine
novak.knutd@gmail.com

Abstract: *The method of graphic modeling of current conductive filler particles distribution in the polymer matrix was suggested. Maps of particle line levels density distribution in composite films based on high-pressure polyethylene containing 5% of metal fillers of various nature were made. It was demonstrated that under the same production conditions probability of forming continuous structures of conductive filler and thereafter filler concentration that reflects percolation threshold depends on filler nature.*

Key words: *polyethylene, composite film, conductive filler, percolation threshold*

1 INTRODUCTION

Adding fine-dispersed metal fillers to polymer matrix is one of the methods of creating conductive polymer materials [1-3]. Simultaneously, sharp increase in the electrical conductivity of the composition (percolation transformation) is observed after the certain marginal concentration of filler is reached. [3].

Percolation threshold is reached when endless connected structures (clusters) of separate elements have particle concentration higher than film in total. Higher particle concentration in cluster causes particles to contact, eventually leading to increase in electrical conductivity of the composition.

Concentration of the metal filler corresponding to the percolation threshold depends on the following factors:

1. Geometrical characteristics of the filler (its size and shape) and distribution of these indicators;
2. Conditions under which polymer and filler are mixed (method of mixing, temperature, duration, shear force);
3. Possibility of aggregation and/or destruction of the filler particles in composition by mechanical impact during mixing;
4. The value of filler-polymer interfacial tension;
5. Conditions of composition cooling and effect the filler has on the structure forming in the polymer matrix.

All of the abovementioned factors will determine spatial distribution of the filler particles in polymer matrix composition.

2 OBJECTS AND METHODS OF THE STUDY

The objects of the study are composite high-pressure polyethylene films containing conductive metallic fillers of various nature.

Currently, to describe percolation matrix structure several geometric models based on depicting cluster as a lattice of interconnected nodes or a fractal of specified dimension were used [3]. At the same time, these models do not consider polydispersity of particle size and shape, as well as particularities of composition preparation.

Previously, it was shown [4] that the same volumes of different conductive fillers form structures with noticeable differences in the distribution of the filler in the polymer matrix.

Existing dependency of percolation threshold on the shape of the particles and their spatial distribution type (random or regular) is shown in the study [5]. This indicates the relevance of studying and modeling structures of concrete compositions obtained in conditions close to industrial.

Study objective

Objective of this study was to model and analyze polymer structures containing conductive filler in order to optimize filler concentration in terms of percolation threshold and its presumably concentration nature.

3 RESULTS AND DISCUSSION

As initial samples, for models described in this paper, microphotographs of aluminum (Al), copper (Cu), and bronze (Br) (5 vol.%) particles distribution in polyethylene matrix were used (low density polyethylene stamp 16803-070 (PE). Characteristics of particles and production method of compositions are described in [4]. Difficulty in obtaining of polymer compositions based on PE, that can conduct electric current, is a high level of homogeneity with mixture components. This is achieved using disk mixer. After mixing the composition mixture is placed in a heated mould.

Mould with compositional mixture was placed in heat chamber for heating and transition to highly plastic state, in which the presswork can be made. After staying of materials in heat chamber for 12-15 min at 160°C, it was compressed at a pressure of 22 MPa using laboratory press.

In Figure 1 are presented microphotographs of composite films based on PE, containing 5% of conductive fillers. From the presented figures was shown that the nature of the filler influences on the structure of composite films.

Building of models was based on the method of image analysis [6], a two-dimensional spline interpolation of the data and subsequent creation of maps of particle line levels density distribution in a plane. In Figure 2 is presented procedure for construction of models (PE-Cu films).

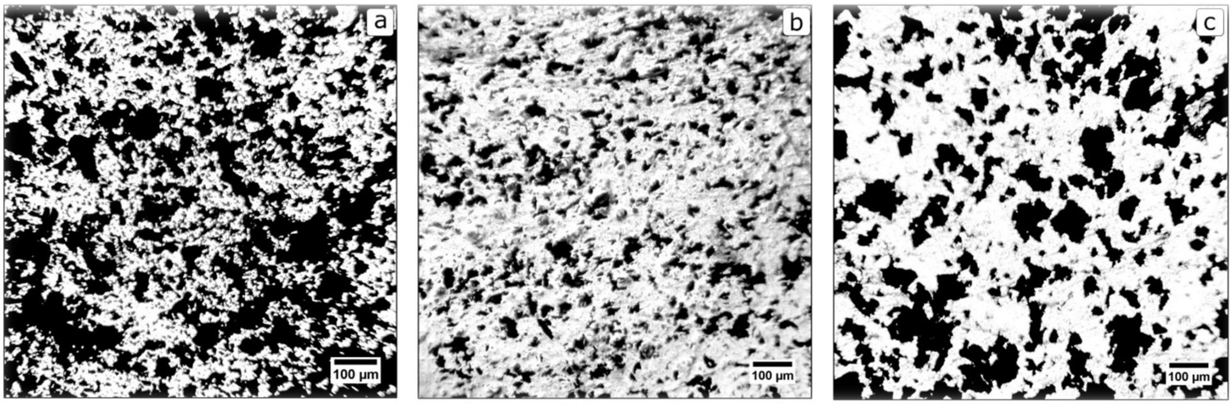


Figure 1 Polarized light microscopy (PLM) images of composite films based on PE, containing 5 vol.%. of conductive fillers: a) aluminum; b) copper; c) bronze

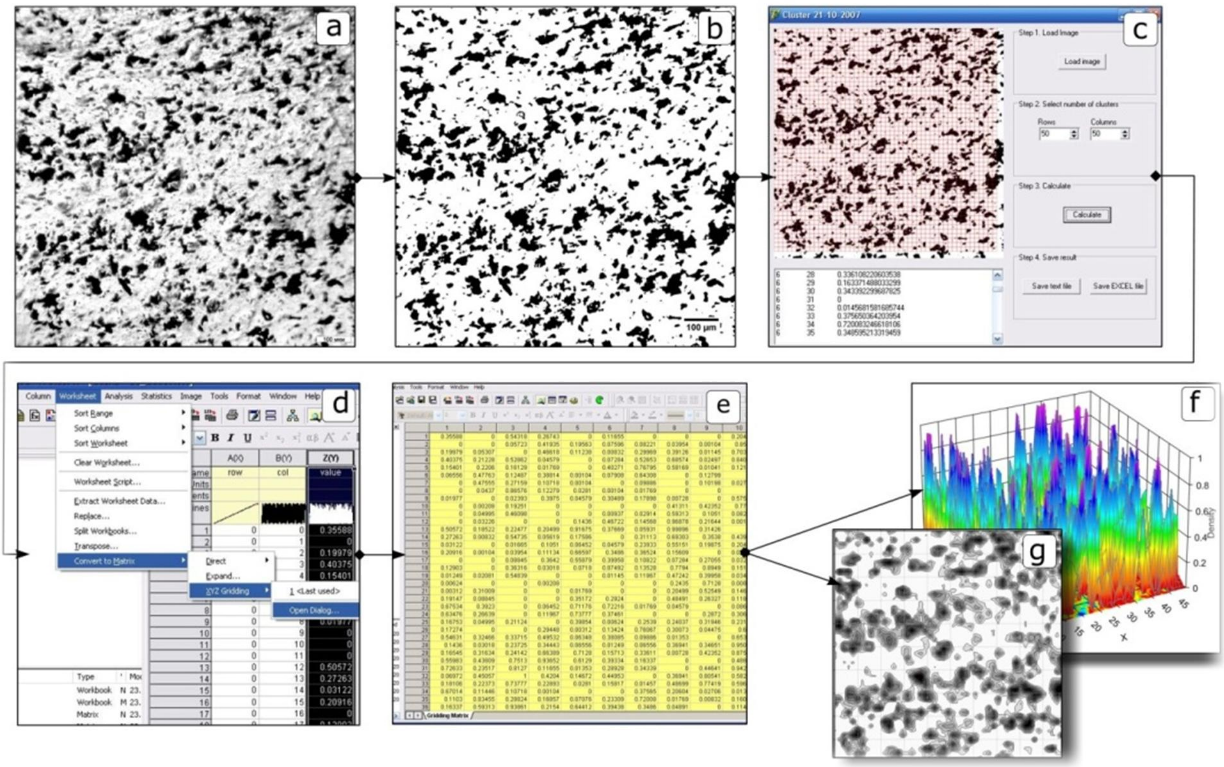


Figure 2 Step-by-step procedure for construction of models: a) original image; b) binary image after threshold; c) cluster analysis; d) conversion results in a matrix; e) final matrix; f, g) graphic representation of results

The methodology consists of the following steps:

1. *Obtaining digital microscopy images of composite film structure in transmitted light* (Figure 2a)
2. *Processing of digital images*
At this stage objects for the following analysis were selected by comparing color intensity of each pixel on the image with specified range of values for this indicator. As a result, binary images (Figure 2b) of composite films structure were created. At these images bit 1 corresponds to element of the structure while 0 corresponds to element of background.
3. *Cluster analysis of the binary images* (Figure 2c)
In this analysis an image was geometrically split using orthogonal grid (50 parts in height and width) into separate clusters. Thereby, overall number of analysed clusters amounted to 2500 [7]. Relative filler concentration in each particular cluster was calculated as a ratio of number of pixels with bit 1 to the general cluster area. Moreover, the obtained values can be interpreted as probability of presence of filler particles in analysed area.
4. *Generating a two-dimensional matrix* (Figure 2d)
Obtained values of concentration were converted into two-dimensional matrix (50x50) of a size corresponding to geometrical division of a cluster analysis image (Figure 2e). Each matrix value matched relative filler concentration in corresponding cluster of analysed image.
5. *Surface diagram construction* (Figure 2f)
To construct a surface diagram, element values obtained for two-dimensional matrix were used. An algorithm of two-dimensional interpolation of fifth order polynomials for Z values irregularly distributed on an X-Y plane, also known as Akima interpolation [8], was used in this study. Two-dimensional spline interpolation constructs a surface z(x, y) that passes through a set of points describing lattice on a two-dimensional coordinate's plane (x, y). A surface is composed of parts of two-dimensional splines which are functions (x, y) and which have continuous first and second derivatives at both coordinates [8]. Figure 3 exhibits an example of filler density distribution in composite film (95% PE + 5% Al) diagram obtained using Akima [8] algorithm.
6. *Construction of a contour plot levels density distribution of filler in the composition* (Figure 2g)
A contour plot is the projection of a three-dimensional surface onto a two-dimensional plane. The values of the fitted surface in terms of the Z variable are depicted either by variously colored lines or by shades of color (areas) on an X-Y scatterplot [9].

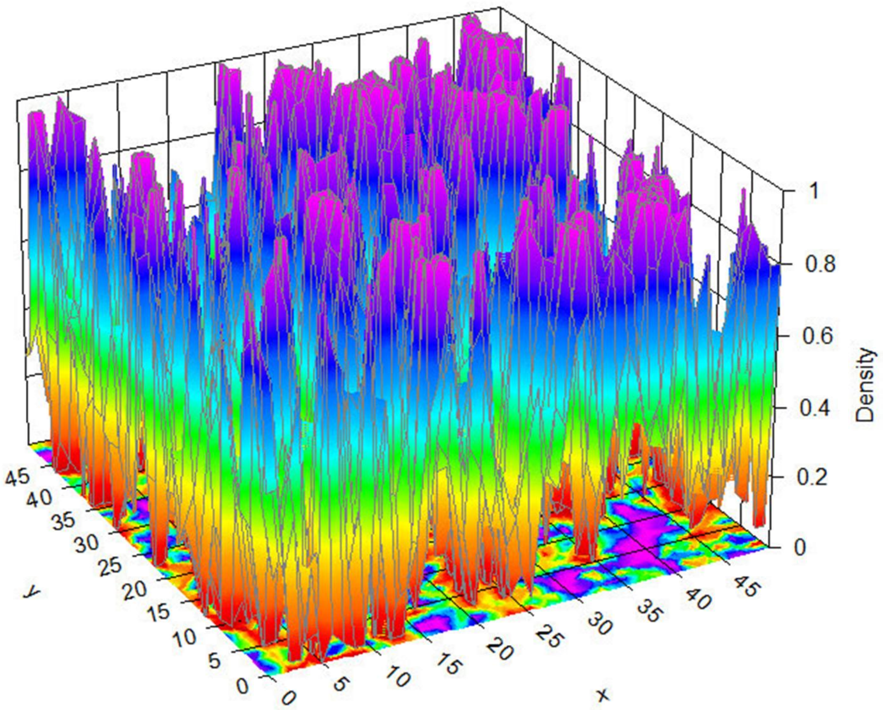


Figure 3 3D-chart of filler density distribution in composite film 95% PE + 5% Al obtained by interpolation of surface concentration output values using Akima algorithm

Obtained contour plot levels (probabilistic concentration of the filler in composition) for systems researched in this study are exhibited in Figures 4-6. Analysis of these maps shows that filler density is characterized by sufficiently wide distribution in the range of 0 (no filler area) to 1 (areas completely filled by filler).

Changing lower thresholds of levels shown on the map enables to assess probability of formation of continuous (within the observed area) cluster with filler concentration above certain value. Increasing the lower threshold allows to identify areas with the highest probabilistic concentration of the filler.

Analysis of contour diagrams shown in Figures 4-6 (b-d) concluded that in PE-Al system concentration field continuity takes effect with lower margin not greater than 0.3 while in PE-Cu and PE-Br systems lower margin should not be greater than 0.1. When increasing lower levels margin above these values, the concentration field continuity for studied systems is not observed.

The proposed method enables to visually determine probability level of continuous cluster formation for each specific case of conductive filler distribution in polymer matrix.

Conducted analysis demonstrates that under the same mixing conditions probability of forming continuous conductive structures depends on filler type and is significantly higher for PE-Al system while lower for PE-Cu and PE-Br systems. It is expected that similar patterns will be observed in analysed composites with filler concentration above percolation threshold.

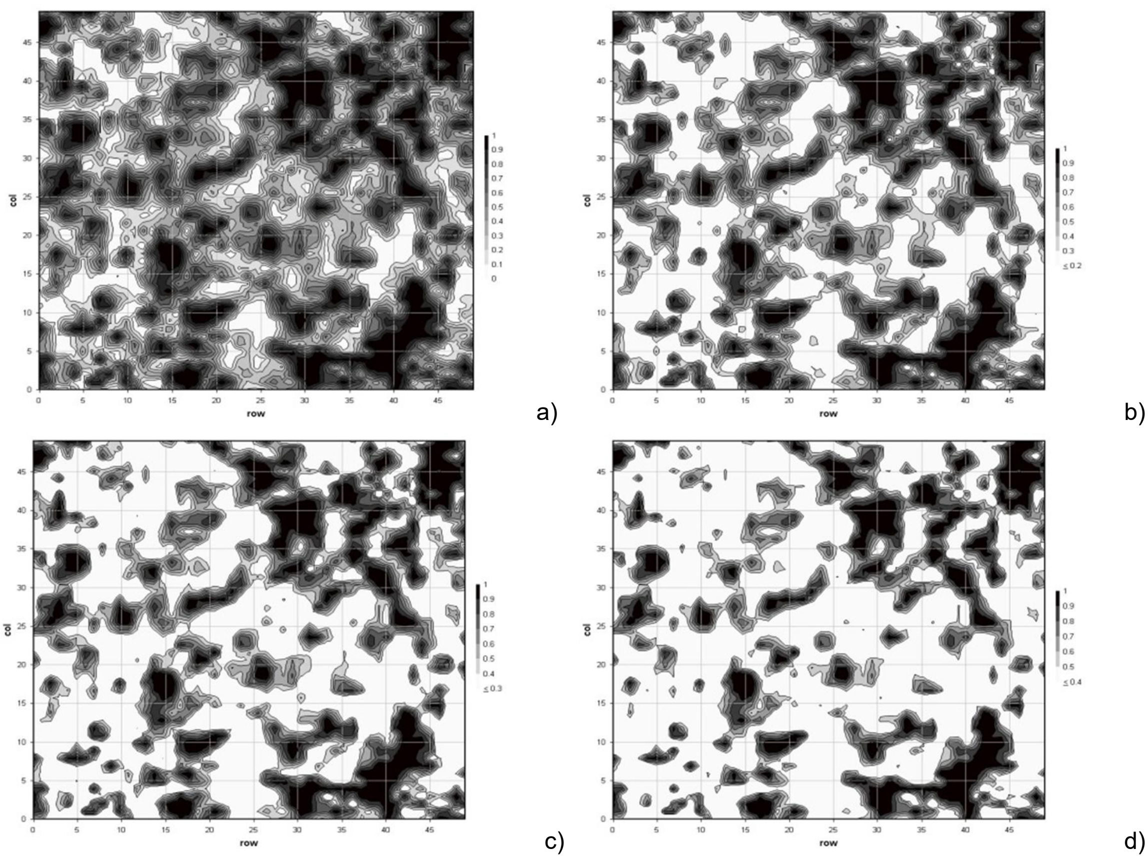


Figure 4 Contour plot levels concentration of filler for model systems corresponding to composite film 95% PE + 5% Al with different lower marginal concentrations, specifically: a) 0; b) 0.2; c) 0.3; d) 0.4

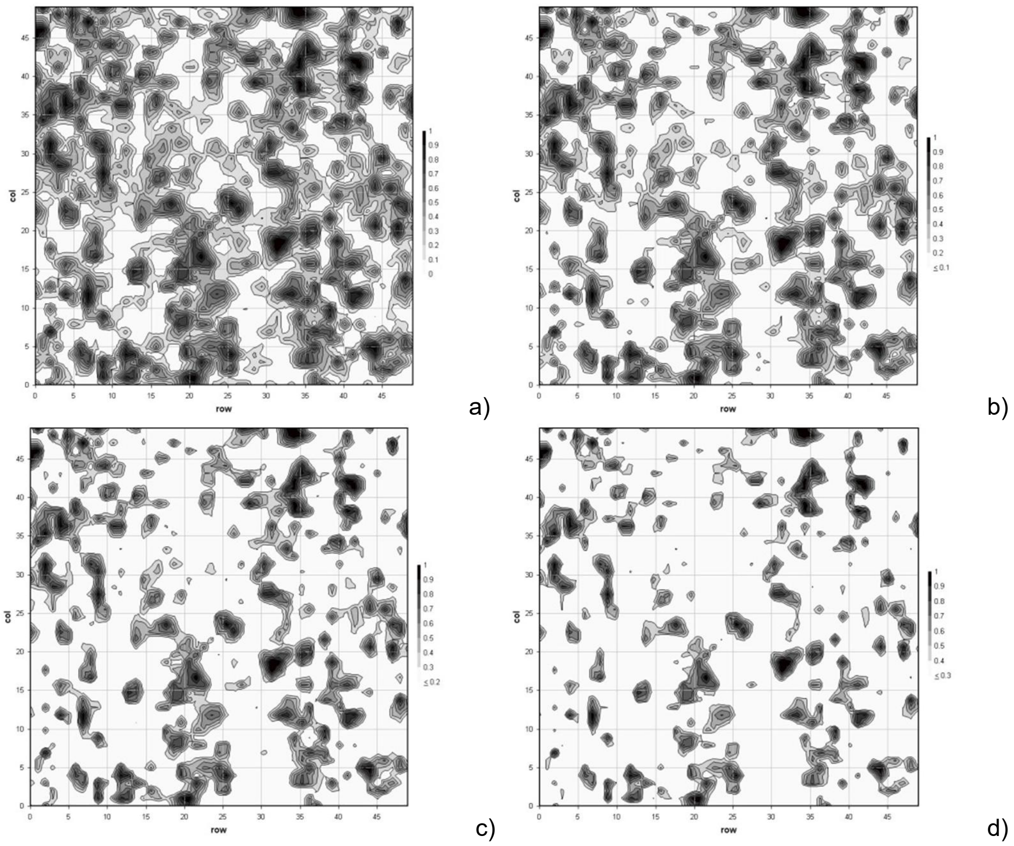


Figure 5 Contour plot levels concentration of filler for model systems corresponding to composite film 95% PE + 5% Cu with different lower marginal concentrations, specifically: a) 0; b) 0.1 c) 0.2 d) 0.3

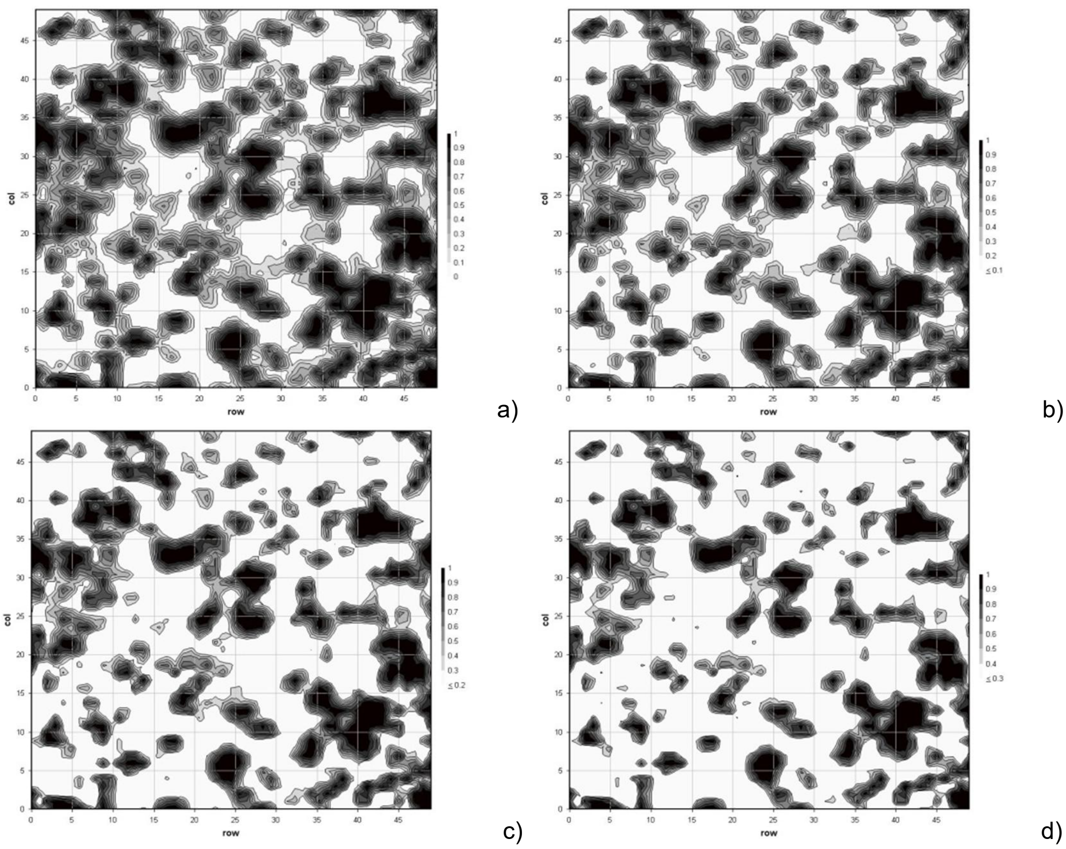


Figure 6 Contour plot levels concentration of filler for model systems corresponding to composite film 95% PE + 5% Br with different lower marginal concentrations, specifically: a) 0; b) 0.1 c) 0.2 d) 0.3

4 CONCLUSIONS

1. The method of object-oriented, graphic modeling of conductive filler particles distribution in the polymer matrix was suggested.
2. Using this method, maps of line levels density distribution of different conductive fillers in composite films based on high-pressure polyethylene were made.
3. It was demonstrated, that under the same production conditions, probability of forming continuous structures of conductive filler and concentration that reflects percolation threshold depends on filler nature.

5 REFERENCES

1. Xanthos M.: Functional Fillers for Plastics, John Wiley & Sons, 2010, p. 531
2. Bhattacharya S.K.: Metal-Filled Polymers: Properties and Applications, CRC Press, 1986, p. 376
3. Tarasevich Y.Y.: Perkolyatsyya: theory, applications, algorithms, 2002, p. 112
4. Novak D.S., Budash Y.O., Pakharenko V.V., Pakharenko V.A.: Polyethylene compositions containing conductive filler. Structural and morphological properties, Chemical industry of Ukraine, Vol. 5, 2011, pp. 35-44
5. Mamunya Ye.P.: Electrical and thermal conductivity of polymers filled with metal powders, European Polymer Journal, Vol. 38, 2002, pp. 1887-1897
6. Frank Y. Shih: Image Processing and Pattern Recognition: Fundamentals and Techniques, John Wiley & Sons, 2010, p. 537
7. Malutin D.: Cluster analysis (Image Segmentation) program 21-10-2007 (Personal Communication), Available from http://xaraxtv.at.tut.by/
8. Akima H.: Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Points, Journal ACM Transactions on Mathematical Software, Vol. 4 №2, 1978, pp. 148-159
9. Hill T., Lewicki P.: Statistics: methods and applications : a comprehensive reference for science, industry, and data mining, StatSoft Inc., 2006, p. 832

INSTRUCTIONS FOR AUTHORS

The journal ,,**Vlákna a textil**" (**Fibres and Textiles**) is the scientific and professional journal with a view to technology of fibres and textiles, with emphasis to chemical and natural fibres, processes of fibre spinning, finishing and dyeing, to fibrous and textile engineering and oriented polymer films. The original contributions and works of background researches, new physical-analytical methods and papers concerning the development of fibres, textiles and the marketing of these materials as well as review papers are published in the journal.

Manuscript

The original research papers are required to be written in English language with summary. Main results and conclusion of contribution from Slovak and Czech Republic may be in Slovak or Czech language as well. The advertisements will be published in a language according to the mutual agreement.

The first page of the manuscript has to contain:

The title of the article (16 pt bold, capital letters, centred)

The full *first name* (s) and also *surnames* of all authors (11 pt, bold, centred).

The complete address of the working place of the authors, e-mail of authors (9 pt, italic, centred)

Abstract (9 pt, italic)

Key words (9 pt, italic)

The manuscript has to be written in A4 standard form, in **Arial, 10 pt**.

The text should be in ***double-column format** (width 8.1 cm)* ***in single line spacing***.

Page margins: up and down 2.5 cm; left and right 2.0 cm.

Do not number the pages and do not use footnotes. Do not use business letterhead.

Figures, tables, schemes and photos (centered) should be numbered by Arabic numerals and titled over the table and under the figure or picture.

Photos and schemes have to be sufficiently contrastive and insert in text as pictures.

Figures, tables, schemes and photos, please, send in separate file.

Mathematical formulae should be centred on line and numbered consecutively on the right margin.

Physical and technical properties have to be quantified in SI units, names and abbreviations of the chemical materials have to be stated according to the IUPAC standards.

References in the text have to be in square brackets and literature cited at the end of the text.

References (9 pt), have to contain names of all authors.

[1] Surname N., Surname N.: Name of paper or Chapter, In Name of Book, Publisher, Place of Publication, YYYY, pp. xxx-yyy

[2] Surname N., Surname N.: Name of paper, Name of Journal Vol. (No.), YYYY, pp. xxx-yyy

[3] Surname N., Surname, N.: Title of conference paper, Proceedings of xxx xxx, conference location, Month and Year, Publisher, City, Surname N. (Ed.), YYYY, pp. xxx-yyy

[4] Surname N., Surname N.: Name of Paper, Available from http://www.exact-address-of-site, Accessed: YYYY-MM-DD

The final template of manuscript is available on **http://www.ft.tul.cz/mini/Vlakna_a_textil**

Authors are kindly requested to deliver the paper (in Word form) to be published by e-mail: marcela.hricova@stuba.sk

Address of the Editor Office:

Marcela Hricová

Faculty of Chemical and Food Technology,

Slovak University of Technology in Bratislava

Radlinskeho 9

812 37 Bratislava,

Slovakia