Выводы и предложения

1. Строить изображение блика в процессе проектирования поверхности возможно с учетом параметров дифференциальной геометрии. Для этого необходимо иметь теоретический чертеж поверхности (3D-модель).

2. Форму и динамику блика задает главная кривизна поверхности. Положение источников света и точки зрения особого значения не имеют.

3. Расположение и форма блика не всегда совпадает с образующей поверхности. Все зависит от того, какая линия принята за образующую. Блик выбирает образующую с минимальной кривизной.

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MODELING OF TWILL-STRUCTURE OF REINFORCEMENT FOR PLAIN WOVEN GLASS FIBRE/EPOXY RESIN TEXTILE COMPOSITE

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МОДЕЛЮВАННЯ TWILL-СТРУКТУРИ АРМУВАННЯ ТКАНОГО ТЕКСТИЛЬНОГО ПОЛІМЕРНОГО КОМПОЗИЦІЙНОГО МАТЕРІАЛУ ЗІ СКЛОВОЛОКНАМИ

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МОДЕЛИРОВАНИЕ TWILL-СТРУКТУРЫ АРМИРОВАНИЯ ТКАНОГО ТЕКСТИЛЬНОГО ПОЛИМЕРНОГО КОМПОЗИЦИОННОГО МАТЕРИАЛА СО СТЕКЛОВОЛОКНАМИ

This paper presents results of investigations plain woven glass-fibre/epoxy resin textile composite material. The geometric characteristics of Twill-structure of reinforcement with MIMAS software were obtained. The structure of one layer of textile composite material was modeled with ANSYS software complex.

***Key words**: textile composite material, modeling, Twill-structure of reinforcement, glass-fibre, epoxy resin.*

Ця робота представляє результати досліджень полімерного текстильного композиційного матеріалу з тканим наповнювачем у вигляді скловолокна. Геометричні характеристики Twill-структури армування одержано за допомогою програмного забезпечення MIMAS. Структуру одного шару текстильного полімерного композиційного матеріалу змодельовано за допомогою комплексу ANSYS.

***Ключові слова**: текстильний композиційний матеріал, моделювання, Twill-структура армування, скловолокно, епоксидна смола.*

Данная работа представляет результаты исследований полимерного текстильного композиционного материала с тканым наполнителем в виде стекловолокна. Геометрические характеристики Twill-структуры армирования получены с помощью программного комплекса MIMAS. Структура одного слоя текстильного полимерного композиционного материала смоделирована с помощью комплекса ANSYS.

***Ключевые слова**: текстильный композиционный материал, моделирование, Twill-структура армирования, стекловолокно, эпоксидная смола.*

Introduction. Composite materials consist of at least two phases with different properties (elastic, plastic, elastic-plastic, viscoelastic, etc.). Variation of composition, form and content of components of composite materials in various combinations allows to create materials with significantly higher strength, stiffness, hardness, good damping properties in comparison to traditional materials with low thermal conductivity and high corrosion resistance. The properties of the composite material can be derived from the properties of the component or experimentally. Determination of effective characteristics of composite materials from the properties of components is the major objective of mechanics. Solution of this objective has two approaches. Deterministic approach – when the initial properties of the components, volume fraction and form of inclusions are adjustable parameters. Stochastic approach – when the properties of components and parameters of reinforcement are random parameters. There is problem of replacing the source material to a different, fictitious, usually homogeneous material with averaged characteristics for the deterministic approach. Substitution of materials are based on some criteria and assumptions and reduced to the equivalence of the fictitious and real materials in general [1].

There is no single model or method that allows to obtain the characteristics of composite materials with different components, form of structure and stress-strain conditions. Anisotropy and inhomogeneity of some composite materials make the problem of studying their characteristics more complex than for homogeneous materials. An important factor that influences the output characteristics of the material is the possibility to adjust the structure during development and design. Changing the structural parameters of individual components significantly influences the effective properties of material [2].

The simple method for determination of the properties of composite materials is the creation of models and calculation methods using mathematical tools and the properties of the components. This method allows take into account structural features and the type of stress-strain state. Using theoretical methods is justified when it is impossible to conduct experimental studies due to the complexity of the problem. Numerical simulations of the composites have many objectives, in particular determination of properties structure of material. The properties of the textile composite material depends of the properties of each phase, thickness of the fibres, their number in a single layer, layer thickness, their geometric distribution and other structural characteristics [3].

Literature review. The maximum approximation model to the real stuff is necessary factor for study the properties and the construction of the numerical or other model of textile composite materials of any structure of reinforcement. For this approximation is needed the most accurate approximation to the real structure of the material, i.e. the exact values of the geometric dimensions of the layer of material, thickness of the fibers, volume fraction and others. Such data can be obtained from a real composite material.

Mahmood, Wang and Zhou [5] presented methodology to predict the engineering elastic constants of 3D woven orthogonal composites based on a volume averaging method. The investigations were conducted with known structure features of one layer of composite: volume fraction, width of one bunch, distance between two bunches, properties of phases etc. The methodology has been proposing to use for other kinds of textile composites.

Khan [3] used for the prediction of mechanical characteristic of woven composites as a continuum on average at macroscopic scale. Numerical models of Plain-weave fabric, Twill-weave fabric, Satin weave fabric composite materials were obtained from properties of composite components. For investigations were used mechanical properties of fabrics and geometric features of material structure.

For prediction of mechanical properties of textile composites at the microscopic scale fibers were investigated as individual entities by Sherburn [6]. The interactions between these entities were modeled with software package named TexGen. The geometrical models created by TexGen were then used with finite-element method.

Kim and Swan [7] presented geometry description of woven yarn and its cross section. Variants of finite-element cell models of plane-weave textile with orthogonal inserts were obtained.

Principle of modeling and investigation of textile structures was obtained by Lomov and Belov [8]. The model of textile geometry served as a base for meso-mechanical structures of composites, which provided simulation tools for analysis of properties.

Nakai, Kurashiki and Zako [9] presented finite-element modeling of textile composites with using of built finite-element model for unidirectional fiber-reinforcement composites. The representative elements for two kinds of textile woven fabric structures were obtained. For prediction of mechanical properties of material were used geometric dimensions of the layer of material, volume fraction, thickness of the fibers and others. Such data can be obtained from a real composite material.

However, in many cases, the precise measurement of geometric dimensions of the material by conventional contact methods is impossible due to the small size of the components of the material. In such cases, the use of non-destructive methods, along with special software system is justified substantially, because it is not affected to the real structure of the material [4].

Unsolved aspects of the problem. One of the software systems, which allows to make prediction of geometric properties for any type of material without altering of structure is MIMAS (Mikrooptik IMage Analysis Software). After conducting such research in any finite-element software product it can build models of textile composites, selecting representative volume element of the whole material. There are several models For textile composites [2, 10]. The constructed finite-element model will determine initial mechanical and other properties of composite materials.

Objective of the paper. The objective of present paper is conduction of investigations for textile composites with Twill-structure reinforcement with glass fibers and reproduction and construction models of such materials with using of MIMAS software system.

Investigation of Twill-structure of reinforcement. There are many textile composite materials with different kinds of structure reinforcement and fibers [2]. In the present paper woven textile glass-fibre Twill-structure of reinforcement is investigated (fig. 1).

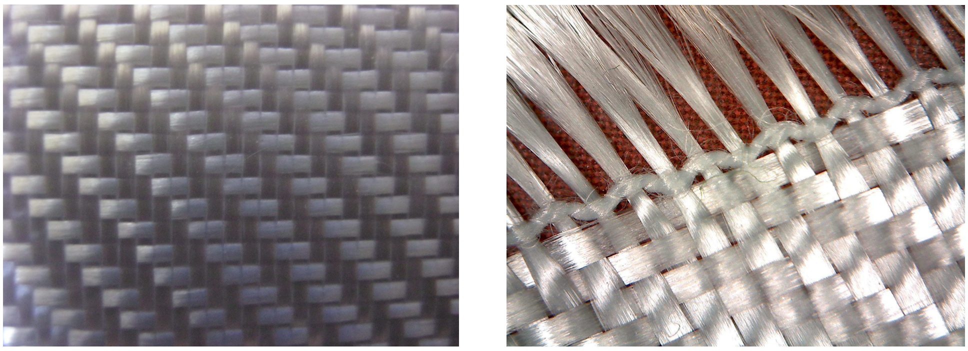

Fig. 1. Plain woven glass-fibre Twill-structure of reinforcement

In the textile composite material like this fibres with diameter in the range cross-section shape (~5-10 μm micron) (fig. 2, *a*, digital microscope) are connected into the bunch which are then woven into the structure (fig. 2, *b*).

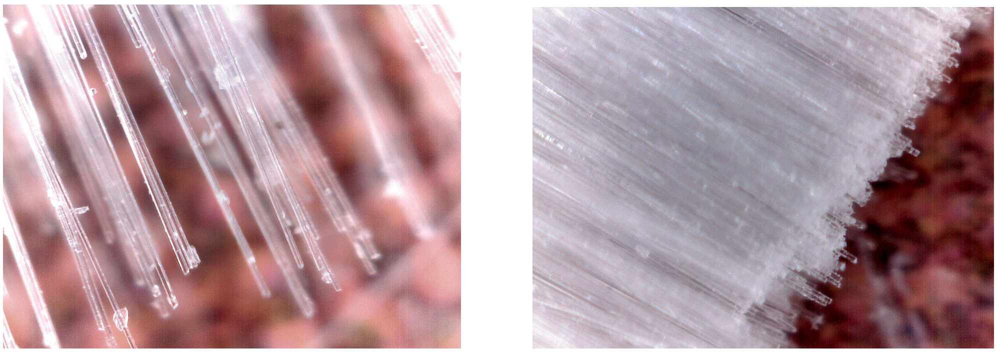

Fig. 2. Structure of glass fibres (a) and bunch (b) of textile composites

For building of finite-element model of composite materials exact values of width of bunch and distance between two bunches are needed. Software complex MIMAS, v.4.2.0 was used for definition of geometrical sizes (fig. 3).

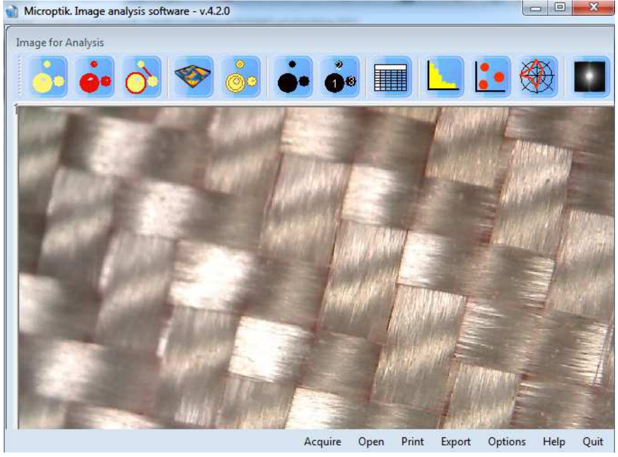

Fig. 3. View of working window of MIMAS software

Digital microscopes were used for obtaining of high magnified images of textile structure. For designation of sizes for one layer of plain woven glass-fiber structure was conducted ruler with millimeters scale of measurements (fig. 4).

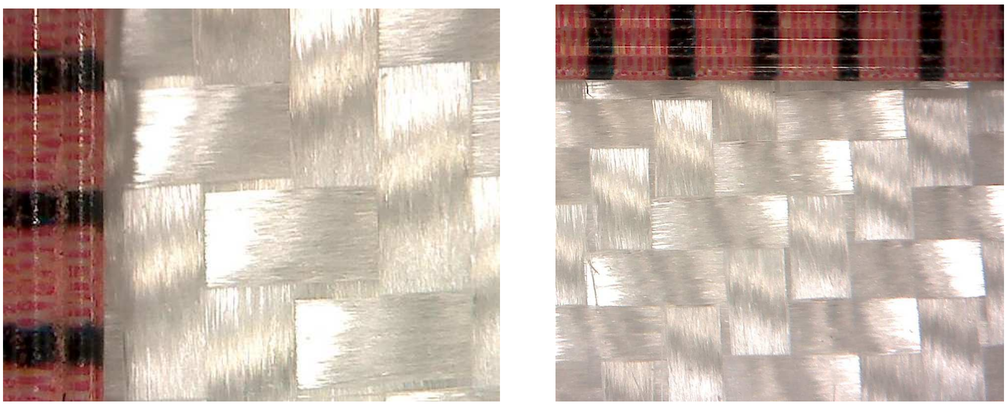

Fig.4. Samples of textile glass-fiber structure of reinforcement with different degrees of approximation and vertical (a) and horizontal (b) location of ruler

For improvement the accuracy of measurements sixteen images with different degrees of approximation and location of ruler were obtained with microscopes. Sizes (distances) for each image were measured in average four times (fig. 5).

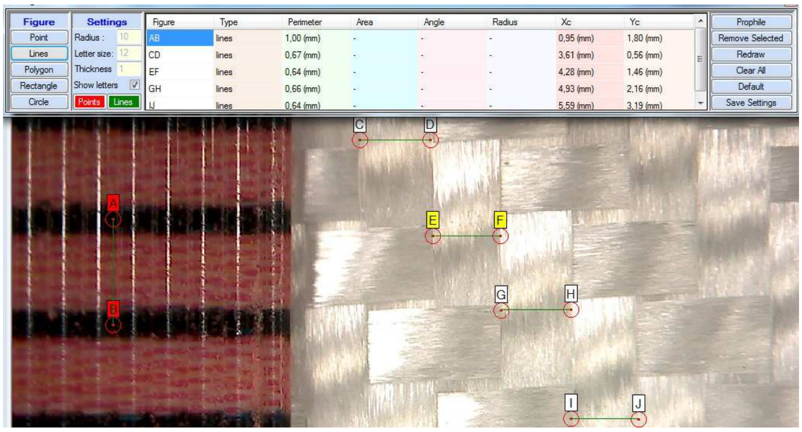

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Figure	Type	Perimeter	Area	Angle	Radius	Xc	Yc
AB	lines	1,00 (mm)	-	-	-	0,95 (mm)	1,80 (mm)
CD	lines	0,67 (mm)	-	-	-	3,61 (mm)	0,56 (mm)
EF	lines	0,64 (mm)	-	-	-	4,28 (mm)	1,46 (mm)
GH	lines	0,66 (mm)	-	-	-	4,93 (mm)	2,16 (mm)
IJ	lines	0,64 (mm)	-	-	-	5,59 (mm)	3,19 (mm)

Fig. 5. The sample of textile glass-fiber structure of reinforcement with the calibration scale and measurement of the distances using the MIMAS software

For the building of the finite-element models of plain woven glass fibre textile composite material representative element was obtained. This periodic repetition reproduces the actual structure of the composite material (fig. 6).

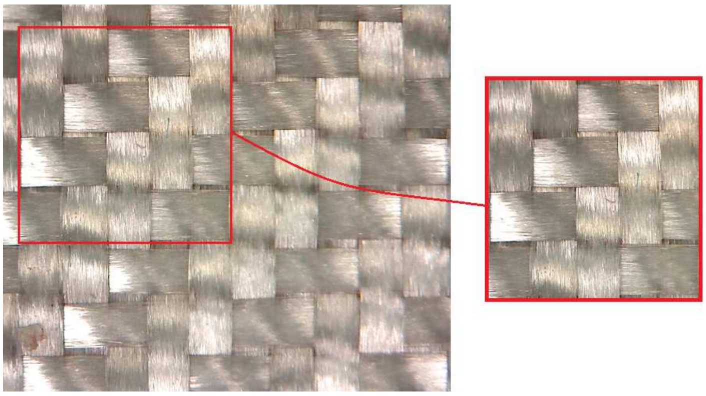
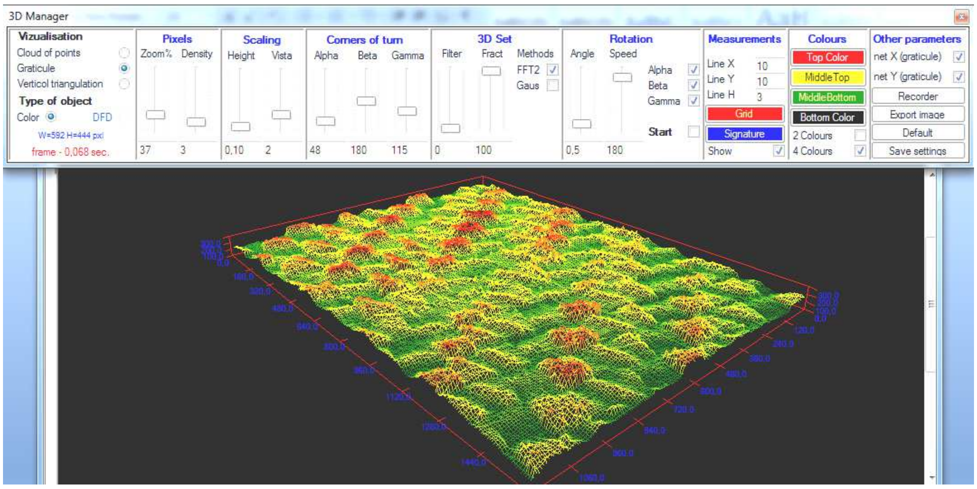


Fig. 6. Representative element of plain woven glass-fibre/epoxy resin textile composite material

After measuring the required geometrical dimensions using a number of images of layers 3D (three-dimensional) image was constructed (fig. 7). This image was used for determining the bending angle of the bunches and thickness of one layer.



Cloud of points ○
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Zoom% 37 Density 3
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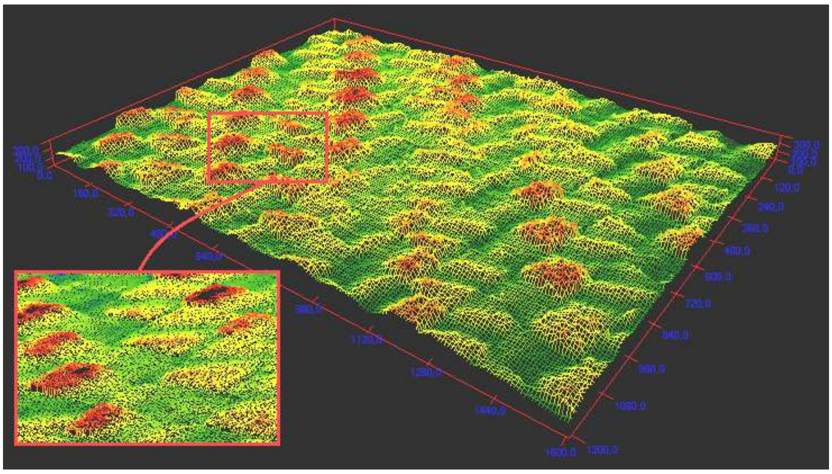

Fig. 7. 3D-model of the one layer of woven glass-fibre Twill-structure of reinforcement

The average width of one bunch of glass fibers and distance between two bunches of fibers were obtained from 64 measurements. Dependences width of one bunch of fibres (in mm) and distance between two bunches of fibers (in mm) from number of measurements are shown on fig. 8-9.

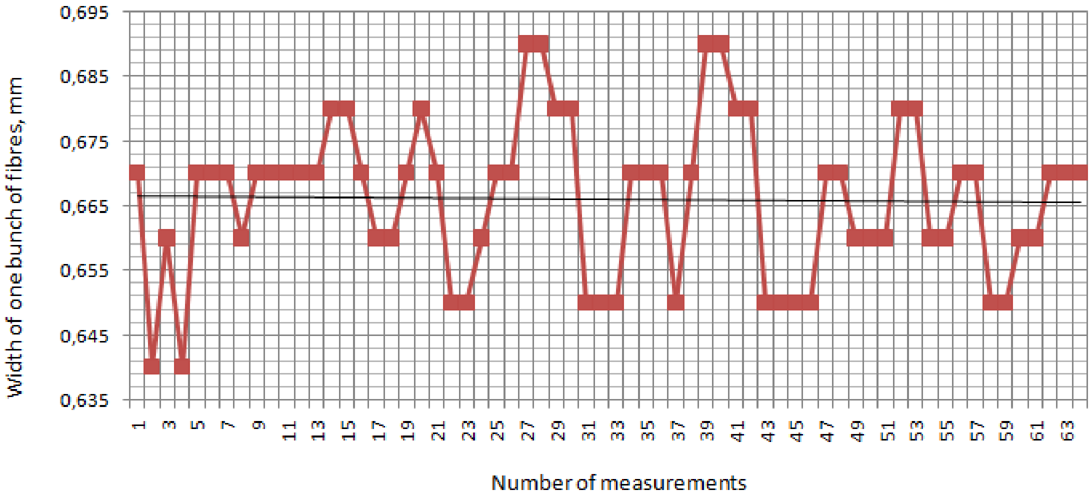

Fig. 8. Dependence width of one bunch of fibres (in mm) from number of measurements

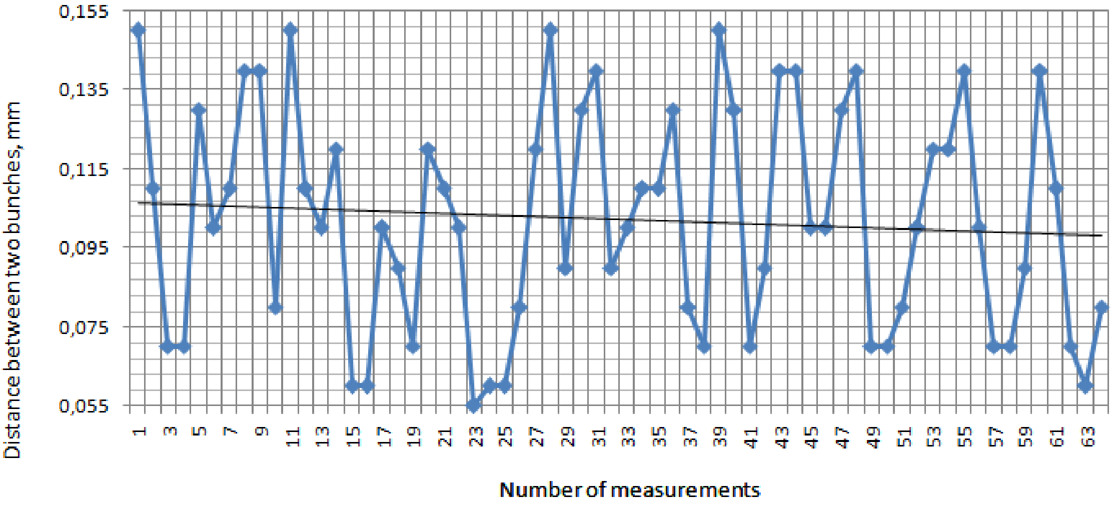

Fig. 9. Dependence distance between two bunches of fibers (in mm) from number of measurements

The properties of the glass fibre layers, derived from the images, are shown in Table 1.

Table 1

Properties of the layers of glass fibers in the textile composite material

Property	Quantity
Density	280-300 g/m^2
Average width of one tow of fibers	0,667 mm
Average distance between two tows of fibers	0,102 mm

The properties of the components of plain woven glass-fibre/epoxy resin textile composite material are given in Table 2.

Table 2

The properties of the components of plain woven glass-fibre/epoxy resin textile composite material

Material	Young's modulus E, GPa	Poisson's ratio, ν
Fibers - E-glass	72	0,2
Matrix - Epoxy (Aradur 5052)	3,35	0,35

Conclusions. The investigations for plain woven textile composites with Twill-structure reinforcement with glass fibers were conducted. The MIMAS software was used for prediction of geometrical properties of a plain woven glass fibre Twill-structure of reinforcement, including the estimated average width of a single bunch of material in horizontal and vertical directions and the average vertical and horizontal distances between two bunches of fibers. The thickness of one layer of material and bending angles were determined. Necessary geometric properties for building of finite-element model of textile composite with Twill-structure of reinforcement were obtained.

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