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The principles of ergodesign in products from composite materials

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Abstracts. The article is devoted to the possibilities of applying the principles of ergodesign in products made of composite materials. Composites with such characteristics as high strength and high quality, in addition to the use of various technological techniques in their manufacture, require solving problems of effective user interaction, that is, ergonomics and aesthetics (design). The general task of ergonomics and design (ergodesign) includes user and visual testing (VT or VI) and shirography (speckle interferometry) with direct adjustment to the user. The article also discusses the main methods of quality control of industrial and technical products made of composite materials. The advantages and disadvantages of quality control methods, the recorded parameters of CM products and their application areas are considered.

1 Introduction

Composite materials (CM) are widely used in many industries. They possess enhanced mechanical and operational characteristics, as well as high strength and quality. That's why they have successfully used in products of rocket and space technology, aviation, automotive, mechanical engineering, metallurgy, in the chemical and petrochemical industries, medicine, nuclear power, for the manufacture of sports equipment. With a minimum weight of the structure, CM products have high strength, are not subject to corrosion, and are durable.

Composite materials are multi-component materials consisting of a polymer, metal, carbon, ceramic or other base (matrix) reinforced with fillers made of fibers, filamentary crystals, fine particles, etc. According to the structure of the filler, CMs are divided into fibrous (reinforced with fibers and filamentary crystals), layered (reinforced with films, plates, layered fillers), dispersion-reinforced or dispersion-strengthened (with a filler in the form of fine particles). The matrix in the CM ensures the material solidity, stress transfer and distribution in the filler, determines the heat, moisture, fire and chemical resistance. According to the nature of the matrix material, polymer, metal, carbon, ceramic, and other composites are distinguished [1].

Step by step the composite materials CM have become widespread. CM products, which previously have been used exclusively as materials for strategic facilities, have moved into the rank of the most demanded. Today, the technologies for the production of elements and products from CM are developing at a faster pace in almost all industrialized countries [2].

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2 Ergonomics

Ensuring CM products high quality and reliability is impossible without effective modern control methods. CM products, developed, for example, for rocket and space technology, require careful verification, including user development and control. The possibility of applying the principles of ergodesign in products made of composite materials is quite high and predictable [6]. The combination of the basics of ergonomics and design in “ergodesign” happened quite a long time ago. The scientific foundations of ergonomics and practice-oriented design methods successfully complement each other, interpenetrating each other.

Ergonomics, as part of ergonomic design, studies products that are in direct contact with people, and design gives "shape" to the ideas of ergonomics [4,5].

In the aspect of composite materials, ergodesign plays an important role, and it is most in demand when the composite quality is being checked. Ergodesign states are a number of requirements, the observance of which is necessary to improve quality characteristics.

The quality control system of composite materials at the moment cannot do without the presence of a human operator (figure 1), and important parts of ergonomics are the sciences responsible for the optimal functioning of the human body, not only under its static position, but also under dynamics.

Fig. 1. Vacuum infusion production of wind blades [7].

The digitalization of the quality checking process for composites is not complete without computerization, so the tools and workplace must be designed for human body, habits and preferences. Nowadays, there are services for the personal design of the workplace, because different people have different preferences [3]. Ergodesign does not stand still, the design of the working environment, tools and equipment for composite research is increasingly meeting modern standards and user requirements [8]. Tools and systems for studying composites are becoming much more convenient for performing highly skilled work that requires attention, mathematical accuracy and a large amount of visually perceived and processed information.

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The workplace general background is important when research on composites is conducted. In this case, the workplace has a large number of different devices, equipment, as well as a computer system [9]. Therefore, the principles of ergodesign will help to ensure a balanced psychology of visual perception of large volumes of graphic information and interpret it correctly.

Ergodesign is applicable not only to a stationary workplace, but also plans possible transformations for temporary tasks or for changes in the situation, atmosphere [10,11].

The sphere of composites production and testing is in great need of ergodesign. Ergodesign is aimed at rationality, usefulness, correctness, effective and high-quality results of labor.

A huge number of different varieties of computers exists at the moment. But a careful, painstaking work of a designer, which is aimed not only at the visual environment, but also necessarily takes into account the principles of ergonomic design, is behind of each system unit. Different areas of use provide their own, special approach to design development. A transparent case, decorated with flashing multi-colored LEDs inside, is not suitable for performing tasks of visual examination and checking the quality of composites, since it will additionally introduce a video stream and become video noise for the researcher [12,13]. That is, the system unit located in the office differs sharply from the system unit located in the server room. In this study, the researcher, in addition to working with computers, performs many other functions using a number of professional equipment, as well as samples of composite material. Therefore, it is necessary to provide special places for this work and increase the working space, as well as the convenient access to them.

The results of the composite materials study seem to be a large amount of graphic material, that's why not all "paper" printers will cope with this task. Therefore, there is a large front for work on ergodesign. It is necessary to take into account the its location, and not only in relation to the harmonics and lack of conflict with other objects, but also in terms of how convenient their location is for use [17].

All the techniques that are used in the study of the composites quality necessarily require a certain intervention of ergodesign in order to achieve the most comfortable use.

Ergodesign problems in this aspect are very relevant, especially in the age of rapid technological development. Researchers need both the ergonomic design of the composite product itself and the convenience of its design and quality control. Ergodesign, as a fusion of two sciences, is in demand when checking the quality of CM - modern materials, which once again emphasizes its role in modern society [15].

When considering CM products, effective application of ergodesign principles occurs at the product design stages in user and visual testing (VT or VI) and shearography (speckle interferometry).

Speckle interferometry is a measurement and testing method (similar to interferometry) with direct adjustment to the user.

The processing of speckle interferograms can be conditionally divided into two stages: primary reduction associated with the removal of artifacts introduced by the radiation receiver, and direct extraction of information from interference patterns.

When studying the surface, the speckle structure contains information about the microrelief and the shape of the object, about the near-surface layer, about the distribution and movement of scatters in it. From the statistical processing of speckles, one can obtain information about such parameters as displacement, movement speed, including scatters in the near-surface layer, amplitude and frequency of vibrations, etc. induced deformations, displacements and internal mass transfer, and due to the occurrence of random processes, such as chemical transformations and phase transitions, abrasion due to friction, deposition, condensation or evaporation of particles on the surface, heating, etc.

The method is based on the use of digital image processing systems for correlation comparison of specklograms of the original and deformed surface. Research in the field of speckle interferometry is currently gaining a new impulse due to the advent of high-resolution image detectors, as well as small-sized solid-state lasers. The new elemental base makes it possible to create small-sized speckle interference systems capable of operating under harsh industrial conditions.

The combination of speckle-grams television registration with computer processing makes it possible to obtain information about the field of displacements or deformations almost instantly from the pattern of correlation bands. With the right choice of loading, the surface defects of the studied object will appear as local distortions of the correlation bands. Thus, it is possible to establish defects and determine the areas of their localization already by the anomalies of the bands. However, in the most cases quantitative information is needed. To obtain it, it is necessary to decipher the correlation bands, i.e., determine the phase shift caused by the deformation of the surface and associated with the components of the displacement vector or their derivatives.

The stress-strain state studies by speckle interferometry are successfully developing [16]. The main issues that need to be addressed are increasing the visibility of correlation bands to expand the measurement range, as well as finding ways to use the information contained in the speckle pattern.

The disadvantages of the method include the following: it is impossible to determine the sign of the phase increment for interferograms of complex shape without the participation of the operator. So, the principles of ergodesign should be taken into account.

One of the most important elements of a universal holographic system is optical information input devices. Input devices are systems designed to convert an optical signal into an analog electrical signal, digitize it, and input it into computer systems. Usually, they include: a photodetector, i.e., an optical (analogue) signal converter into a corresponding electrical signal, devices for amplifying and correcting this signal, an analog-to-digital converter, a communication and coordination interface with a computer. It can be imagined with some assumptions that in electronic speckle interference systems, photodetectors matched with the display devices are, in some way, input devices.

The experimental speckle interference system consists of a fairly large number of instruments.

The use of interferometers designed specifically for speckle interferometry methods allows solving these tasks.

The considered technical devices and systems are necessary for conducting CM studies using speckle interferometry methods.

Visual testing (VT or VI), visual inspection is one of the methods of non-destructive inspection of the optical type. It is based on obtaining information about the tested (controlled) object through its visual assessment or assessment using optical instruments and measuring instruments. The visual inspection method makes it possible to detect defects (discontinuities, deviations in size and shape from the specified ones) with a size of more than 0.1 mm using instruments with a magnification of up to 10x.

Visual control is performed either with the naked eye or with the use of magnifying loupes with magnification up to 7x. In case of doubt, as well as during technical diagnostics, it is allowed to use magnifiers with magnification up to 20x [13]. Before visual inspection, the surface in the inspection area must be cleaned of rust, scale, dirt, paint, oil, metal spatter, and other contaminants that prevent inspection.

The kit (set) for visual-optical testing is used for non-destructive testing by the visual-optical method in laboratory, workshop, field conditions. The kit contains all the necessary tools and tools for it.

The kits can be used in workshops, laboratories, field conditions, at high-rise facilities and in conditions where power supply is difficult or unacceptable according to safety regulations.

The kit is intended for visual and measuring quality control in order to detect deformations, surface cracks, delaminations, backfins, nicks, scratches, abscesses and other discontinuities; checking the geometric dimensions of the product; verification of the admissibility of the identified deformations and surface discontinuities.

There is a set of tools designed to work with products made of composite materials. Easy-to-use layout and layering tools allow to create finite element models for composite structures quickly. It helps to create, optimize, and validate composite products using NX Nastran, LMS Samcef, MSC Nastran, Ansys, Abaqus, or LS-Dyna as a solver. Post-processing tools and advanced reporting capabilities allow to effectively identify problem areas from simulation results. Zone modeling allows to apply composite properties directly to 2D or 3D meshes. Composite stack modeling tool with an interactive graphical interface helps to create and organize stack layers efficiently. To reduce labor costs when creating and modifying complex multi-layer properties.

The standard predefined stacking sequences and/or layer groups can be used. The staking may be also imported from Microsoft Excel. NX Laminate Composites layering modeling can be used to create global layers by assigning them to polygon faces and/or 2D features and specifying the layer orientation, projecting the material orientation, or using one of the drape algorithms. The layers orientation takes into account both the direction set for draping and the offset angle set for each layer. NX automatically calculates feature zones with unique material properties for export to the solver. An offset can be set for each polygonal face, thus controlling the shape of the rig. The fiber orientation for each layer can be displayed on 2D meshes.

The composite may be visually checked by displaying the thickness and offset based on the data of FE mesh and by setting the location of the reference plane specified for the physical properties of the composite or layout. Displaying the field of the elements thickness value helps to estimate the correctness of the constructed model quickly.[18]

The user can view sets of elements with equivalent properties and the stackings assigned to them, as well as to create groups of elements based on these sets, which will simplify further changes to the FE model. The composite stiffness matrices (A, B, D, and S) are available in both Microsoft Excel and text formats. Equivalent engineering constants are available in the same formats. They will help to evaluate the bearing capacity of the composite before launching the simulation. Also, it is possible to obtain the values of stresses, failure indexes and factor of safety for layers, after setting the expected loads: forces, moments and temperatures. NX Laminate Composites strength criteria supports the following criteria: • maximum stress, maximum strain.

Results postprocessing. The NX CAE postprocessor allows to view the resulting shell stresses and the results by layers: stresses, strains, failure indexes (layer and interlayer connection), strength factors (layer and interlayer connection).

References

1. F. Matthews, R. Rawlings, Mechanics and technology Technosphere **406** (2004)
2. A.A. Barzov, A.L. Galinovsky, I.E. Kuznetsov, Bulletin of USATU **4**, 121-126 (2009)
3. A.A. Barzov, A.L. Galinovsky, *Patent support for research on diagnostic quality assurance of composites. Collection of reports of the III International Youth Conference "New approaches and technologies for design, production, testing and*

industrial design of products of rocket and space technology" (Spektr Publishing House, M., 2019)
4. D. Berman, *How designers can change the world* (M., Symbol-Plus**,** 2011)
5. V.G. Brekalov, N.Yu. Terekhova, D.Yu. Safin, Design and Technologies **29(71)**, 118-123 (2012)
6. M. Gladwell*, Illumination. The power of instant decisions* (Williams "Alpina Business Books"**,** M., 2009)
7. https://www.hedrich.com/ru/industries/wind-energy
8. R. Jones, K. Wikes, *Holographic and speckle interferometry* (Peace, M., 1986)
9. R. Cooper, M. Press, *Design power: The key to the consumer's heart* (Grevtsov Publisher, Moscow, 2008)
10. W. Leadwell, K. Holden, D. Butler, *Universal principles of design. 125 ways to make any product more convenient and attractive with the help of original design concepts* (Piter, St. Petersburg, 2014)
11. V.V. Bushueva, S.A. Vlasov, A.N. Volkov et al, *Methodology of scientific knowledge: textbook M.: Publishing house of* (MSTU im. N. E. Bauman, Moscow, 2015)
12. M.M. Mikheeva, *Design methodology: guidelines* (MSTU im. N.E. Bauman, Moscow, 2015)
13. R. Morris, *Fundamentals of product design: textbook. allowance* (*Tride Cooking*, M., 2012)
14. J. Panero, *Fundamentals of Ergonomics. Man, space, interior* (M., Astrel, 2008)
15. V.F. Runge, *Ergonomics in environment design* (Architecture, M., 2009)
16. K. Ulrich, *Eppinger St. Industrial Design. Creation and production of a product* (Vershina, M., 2007)
17. N.Yu. Terekhova, *Guidelines for the implementation of research work forstudents under the master's program "Industrial Design" direction training "Design": textbook* (MSTU im. N.E. Bauman, Moscow, 2020)
18. N.Yu. Terekhova, *Computer technologies in design. Guidelines for laboratory work on the course "Computer technologyin design"* (2018)