Experimental and analytical study of the distribution of fiber volume fraction in the threads' cross-section of layered fabric composite

К.О. Коваленко, С.О. Давыдова

Самарский национальный исследовательский университет им. С.П. Королева, Самара, Россия

Background. Layered fabric composites are widely used in modern industry, as they allow for the creation of complex structures [1–3]. The strength of a composite largely depends on the manufacturing process and proportions of its components [4]. The volume content of fibers is an important factor, as it affects technical characteristics of the material [5]. A higher fiber content results in increased strength, stiffness, and improved molding capabilities for products with complex geometries.

Aim. The determination of the regularity of fiber volume fraction distribution over the cross-sectional area of the threads in a layered fabric composite, using graphoanalytic and programming methods.

Methods. A material based on alternating layers of carbon and glass structural fabrics, combined with a two-component epoxy binder, is considered. The internal structure of this material was examined using a Nicon Eclipse MA 200c microscope. A quantitative analysis of the volumetric fiber content in the strands of the layered composite material was performed in the Compass-3D CAD system by calculating the areas of both the fiber and the binder. After that, a statistical (graphical) analysis of the data was conducted. A computer program was developed to calculate the volume of fiber content. Its developer is Gennady Kovalenko, a ninth-grade student of School No. 102. "FiberCalc", his web application, provides cross-platform compatibility. The user interface is built using HTML and CSS, while the logic for working with files and processing images is written in JavaScript. Using Canvas and the ImageData API, an image is divided into an array containing information about the color components of each pixel. The data are then processed in a loop to recognize the individual components of the fiber. This approach provides greater accuracy and allows for quick processing of multiple sections resulting in an average value for the volumetric fiber content across the entire sample.

Results. In the first method, it was found that the maximum number of fibers is located at approximately 40–45 % of the total length of the thread's cross-section. At the same time, the average volumetric content is approximately 48 %. Based on the results of calculations using the "FiberCalc" software, the average value for the volumetric fiber content in 10 randomly selected thread sections from the composite plate under investigation was 43.98 %.

Conclusions. These two methods of calculating the reinforcement component allow for a reliable modeling of the elastic-strength characteristics of laminated fabric composites.

Keywords: layered fabric composite; cross section; microscopic image; thread; fiber volume fraction; Web application.

Список литературы

1. Каблов Е.Н. России нужны материалы нового поколения // Редкие земли. 2014. № 3. С. 8–13. EDN: UJSELR
2. Савин С.П. Применение современных полимерных композиционных материалов в конструкции планера самолетов семейства МС-21 // Известия Самарского научного центра Российской академии наук. 2012. Т. 14, № 4(2). С. 686–693. EDN: PYZDUR
3. Smurov M.Y., Gubenko A.V., Ksenofontova T.Y., et al. Comparative analysis of innofative materials application in aircraft building of different countries // International Journal of Applied Engineering Research. 2017. Vol. 12, N 3. P. 394–401.
4. Комаров В.А., Павлов А.А., Павлова С.А. Экспериментально-аналитическое определение упругих характеристик слоистого тканевого композита // Вестник Самарского университета. Аэрокосмическая техника, технологии и машиностроение. 2022. Т. 21, № 2. С. 65–79. EDN: ZAZJXP DOI: 10.18287/2541-7533-2022-21-2-65-79
5. Pavlov A.A., Komarov V.A. Determination of fibers volume fraction in layered composite materials by optical methods // Computer Optics. 2022. Vol. 46, N 3. P. 473–478. doi: 10.18287/2412-6179-CO-1068

Сведения об авторах:

Ксения Олеговна Коваленко — студентка, группа 1202-240507D; кафедра конструкции и проектирования летательных аппаратов, Самарский национальный исследовательский университет им. академика С.П. Королева, Самара, Россия. E-mail: ksushko05@mail.ru

Светлана Олеговна Давыдова — старший преподаватель; кафедра иностранных языков и русского как иностранного, Самарский национальный исследовательский университет им. академика С.П. Королева, Самара, Россия. E-mail: davidova.so@ssau.ru

Сведения о научном руководителе:

Светлана Александровна Павлова — доцент; кафедра конструкции и проектирования летательных аппаратов, Самарский национальный исследовательский университет им. академика С.П. Королева, Самара, Россия. E-mail: pavlova.sa@ssau.ru