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Reinforcement of aerospace structural elements made of layered composite materials

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Abstract

The paper investigates the possibility to apply some reinforcing techniques to enhance the interlaminar strength of layered composite materials. Experimental study of the efficiency of these methods was performed using curve-beam structural elements loaded by bending moment. Tests were carried out using a specially designed and produced testing tool with the maximum approximation to the requirements of ASTM D6415 standard. The obtained results provide a means to estimate the influence of strengthening techniques on the interlaminar strength of composite materials in a transverse direction. The article observes the following reinforcing methods: needling of carbon preform with aramid filament and introduction of special particles into the interlaminar voids. Experimental study of both needled and fiber-reinforced samples demonstrated that needling is more efficient (by 13-15%) for improving the interlaminar characteristics of layered composite material in transverse direction.

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Keywords: layered polymer composite material; interlaminar strength; experimental study; curved-beam element; needling; reinforcing particles.

1. Introduction

The strength of composite materials along planes parallel to the principal fiber orientation could significantly exceed the tensile strength. The low interlaminar strength leads to such type of failure as delamination in transverse direction. This may cause a loss of the load-carrying capacity of aerospace structures normal to laminate loaded planes. Consequently, there is a need to investigate possible ways to improve the interlaminar tensile strength of layered composite materials.

Nowadays an active study of such a reinforcing techniques, as an additional reinforcement of composite material are carried out. Stitching, tufting, previous work with needling, fiber-flocking, needling refer to this method [1]. The objective of this paper is to consider two ways of three-dimensional reinforcement, namely needling and short-fiber reinforcement.

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Needling is the procedure of connecting several layers by means of continuous filaments. This method improves strengthening a fracture toughness and prevents the spread of cracka or delamination couples with the action of percussive loads. In this case, the needling technology can be used to reinforce unit areas or regions of detail connection. At the same time, the method has a negative impact. Needling material violates the integrity of the structure of the fibres in the needling area, which significantly affects the strength properties of the final product.

Another approach is the introduction of special reinforcing particles into the interlaminar voids. This article discusses the reinforcement of composite material by thin, short (less than 2 mm) carbon fibers. These particles were obtained by cutting the individual fibers of a thin layer of polymerized unidirectional composite. [2]. Short fibers exhibit high stiffness which allow them to penetrate into the woven structure of laminate during its stacking. An important feature of this method is that the application of special reinforcing particles on each layer preserves the integrity of the filament structure for the fabric itself. In addition, it prevents loss of strength in-plane of stacking composite material. Fig. 1 shows the considered reinforcing particles:

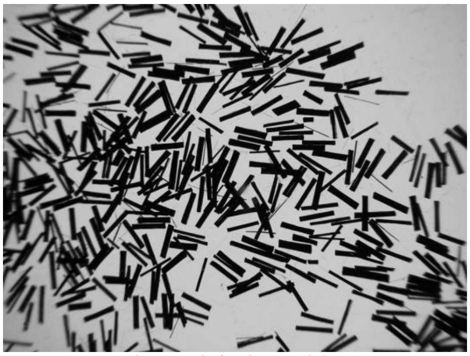

Fig. 1. Reinforcing particles

Each of these methods has its advantages and disadvantages. The purpose of this paper is to investigate the efficiency of needling and fiber-reinforcement for enhancing interlaminate tensile strength.

2. Curved-beam structural elements

Determination of the material's ultimate stress in transverse direction is an important challenge from the viewpoint of structural design. For this purpose, the experimental and analytical analyses of radial stresses and destructive forces was carried out in the area of a bending curved-beam element. The curved-beam element is a sample consisting of two straight legs connected by a 900 bend with a 10 mm inner radius [3]. The samples were made on the basis of a composition including 16 layers of carbon fabric CC201 and epoxy system SR8100/SD8824 using the vacuum infusion method. The vacuum system can be schematically represented as follows (Fig.2.):

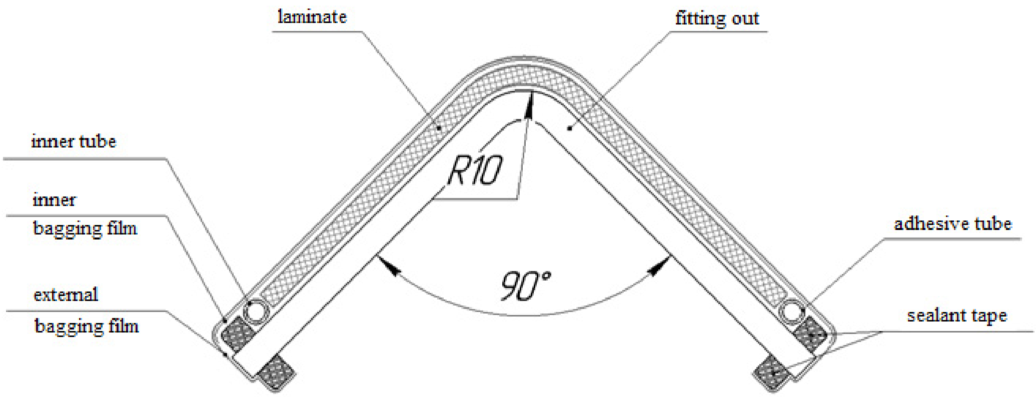

Fig.2. Vacuum system for curved-beam element