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The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

The journal is published 4 times a year and contains publications in the following main areas:

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- Automotive Engineering;
- Civil and Structural Engineering;
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Investigation of impregnation speed depending on fillers during the manufacturing of parts by the vacuum infusion method

U.D. Kosimov[1][a], I.A. Yudin[2], V.A. Eliseev[2], A.D. Novikov[2]
[1]Tashkent state transport university, Tashkent, Uzbekistan
[2]Bauman Moscow State Technical University, Moscow, Russia

Abstract: In the article examines the process of manufacturing three-layer carbon-fiber-reinforced plastic (CFRP) panels using the vacuum infusion method. A comparative analysis is conducted to assess the impact of various fillers on the manufacturability of the three-layer panel. Specifically, the study compares the impregnation speed of the part depending on the type of filler used.
For the research, the layers of carbon fabric and filler were laid simultaneously before sealing with vacuum film. A comparison was made between the manufacturability of using a non-woven reinforcing material (Soric) and polystyrene foam (Airex).
Keywords: polymer composite materials, carbon-fiber-reinforced polymer, vacuum infusion, filler, non-woven reinforcing material, polystyrene foam

1. Introduction

Polymer fiber composites have become indispensable in the aviation industry due to their unique combination of structural and special properties. Composite materials are an excellent alternative to traditional materials, as they offer significant advantages in terms of specific strength and stiffness. However, composite material products have significant anisotropy of properties. The three-layer design of the panels allows to adjust their stiffness anisotropy within wide limits, significantly increasing the stiffness of the structure with a slight increase in mass.[1]

The principles of operation of I-beam and three-layer structures are identical. In a three-layer structure, the role of the wall is played by the filler, due to which the load-bearing layers are separated, which gives the package of layers high characteristics of stiffness and strength at a relatively low weight. By combining materials of bearing layers and filler, it is possible to achieve the desired physical and mechanical properties of three-layer structures. The outer layers are called bearing layers and the inner layer is called filler. The outer layers are made of stronger materials (carbon fiber reinforced plastic). The inner layer (filler) is made of relatively low-strength materials with low density (nonwoven materials, plastic, polymer foam, lightweight methane.[2]

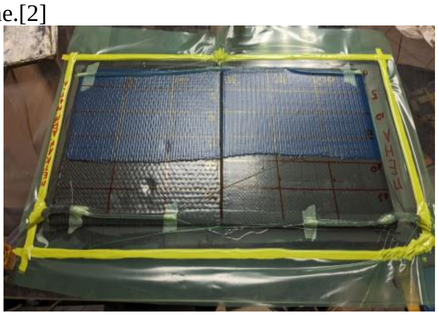

Figure 1. Test specimen

For products with small wall thicknesses, the most suitable is the technology of three-layer plate production, the carbon fiber cladding that is produced directly during panel forming by vacuum infusion. This production technology does not require expensive equipment and a large-sized production room, but makes it impossible to use honeycombs and corrugations as filler.

2. Research methodology

Degassed binder is fed into the prepared samples under pressure P=0.9 atm through the drainage system and distributed over the surface of the sample using a distribution grid. Then the binder is distributed on the package.

The package surface is marked in the Cartesian coordinate system to simplify the tracking of the binder front movement. During the experiment, time-synchronized photographic recording of the test was performed. During the test, the movement of the binder front was tracked from the top and bottom sides of the plates. Figure 2 is labeled: 1 - specimen with nonwoven reinforcing filler, 2 - specimen with foam, 3 - sacrificial fabric layer, 4 - conductive mesh, 5 - spiral tube, 6 - binder supply tube, 7 - tubes of connection to vacuumization unit.

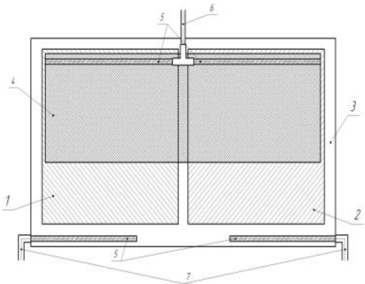

Figure 2. Schematic of the test specimen

3. Materials

2 laminates with dimensions of 300 x 300 mm were prepared as samples: 1st of 5 layers of carbon fabric, non-woven reinforcing material, 5 layers of carbon fabric; 2nd of 5 layers of carbon fabric, layer of perforated foam, 5 layers of carbon fabric. The detailed characteristics are summarized

[a] https://orcid.org/0009-0000-5681-524X

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in Table 1 and Table 2. A glass plate was chosen as the tooling. On top of the carbon fabric, 1 layer of sacrificial fabric and a layer of conductive mesh were placed over the entire area.

Table 1

Characteristics of carbon fabric

Carbon fabric	
Weave type	Twill
Fiber	UMT45
Surface density, g/m²	240
Reinforcement directions, °	+45/-45

Table 2

Characteristics of fillers

Fillers	
Material type	Non-woven reinforcing material
Material grade	Lantor Soric XF
Density, g/m²	180
Impregnated density, kg/m³	600
Thickness, mm	3
Material type	Structural foam
Material grade	AIREX C70
Density, g/m²	200
Impregnated density, kg/m³	70
Thickness, mm	5

Table 3

Characteristics of consumables

Material type	Peel ply
Density, g/m²	80
Material type	Resin-conducting mesh
Surface density, g/m²	160

Table 4

Technological characteristics of epoxy resin

Wide processing window	2 hours
Initial viscosity, mPa*s	300
Binder temperature, °C	17-30

The first advantage of nonwoven reinforcing material - flexibility - is revealed at the stage of package molding; in order to bend the foam, it is necessary to heat it up to 70°C. It is also necessary to perforate the foam to improve the impregnation of the lower crust. However, the impregnated density of the foam is much lower.

4. Results and discussion

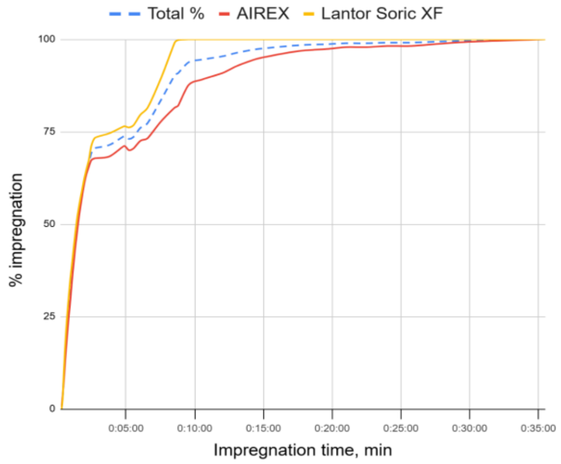

Figure 3. Graph of time dependence of percentage of binder impregnation on the top part of the plate

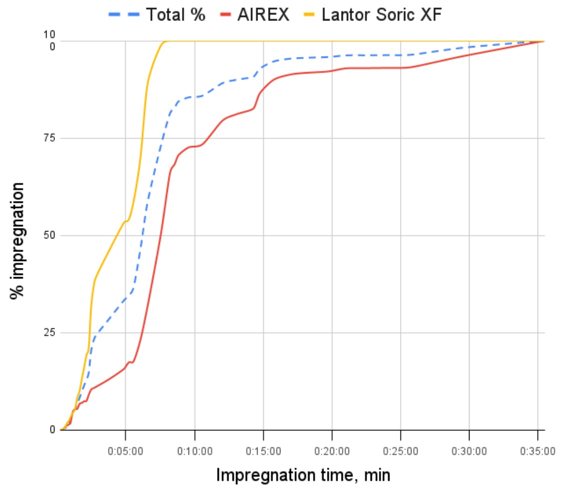

Figure 4. Graph of time dependence of the percentage of binder impregnation of the bottom part of the plate

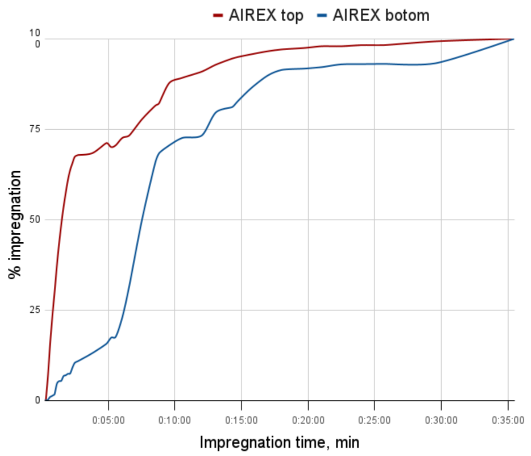

Figure 5. Graph of time dependence of the percentage of binder impregnation of the top and bottom part of the AIREX plate

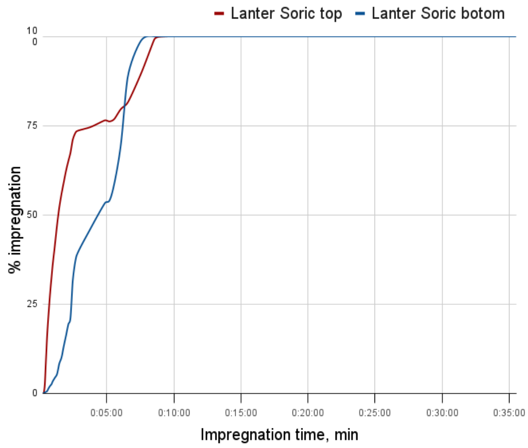

Figure 6. Graph of time dependence of the percentage of binder impregnation of the top and bottom part of the SORIC plate

Based on the processed results (fig. 3-6), the impregnation of the bag can be divided into 3 stages: 1 all inlets and outlets were open, until the binder passed through the entire distribution grid; 2 blocking the exit on the foam side; 3 Opening the exit on the foam side and blocking the exit on the SORIC side. The plate with SORIC soaked 3.7 times faster (9:20) than the similar plate with Airex(35:15). The lower crusts of both plates soaked much slower than the upper crusts, this is due to the presence of a distributing grid on the top. However, as soon as the binder front has reached the end of the distribution grid, the lower crust of the plate with SORIC starts to soak much faster than the upper crust due to the good conductivity of the non-woven filler. In the case of foam, this does not happen due to its lack of any conductivity.

5. Conclusion

Technological properties of non-woven reinforcing material are much better than similar properties of foam filler. Soric is easier to lay out, it is much better impregnated (3.7 times faster than foam).

When using non-woven reinforcing materials, it is necessary to leave a much larger retaining strip because of their good conductivity.

The structural properties are much better for composite parts with foam filler. While the Airex is about 1.5 times thicker, it is 4 times lighter than impregnated non-woven reinforcement material.

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Information about the author

Kosimov Umidbek Dilshod ugli	Assistant of the “Aviation Engineering” Department of Tashkent state transport university E-mail: umidbek.k@yandex.ru Tel.: +99897 761 99 16 https://orcid.org/0009-0000-5681-524X
Yudin Ivan Alekseevich	Student of the " Rocket and space composite structures" Department of Bauman Moscow State Technical University, Russia, Moscow E-mail: ivan.a.yudin@gmail.com
Eliseev Vasiliy Andreevich	Student of the " Rocket and space composite structures" Department of Bauman Moscow State Technical University, Russia, Moscow E-mail: 13VasilyEliseev@gmail.com
Novikov Andrey Dmitrievch	Ph.D. of Engineering Sciences, associate professor of the Department "Rocket and space composite structures" of Bauman Moscow State Technical University, Russia, Moscow E-mail: novikov.andrey.sm13@gmail.com

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