THE EFFECT OF SURFACE FINISHING OPTIONS FOR CORE MATERIALS ON THE MECHANICAL PROPERTIES OF SANDWICH STRUCTURES

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Abstract
Polymeric sandwich composite structures are widely used as lightweight and durable materials for naval, aviation and energy applications. The increasing use of polymer foams in composite structures has encouraged the polymer industry to improve the mechanical properties of the core materials by applying different types of surface finishing. In this study, sandwich composites consisting of PVC polymer foams with various surface finishing options (plain, flexi cut, knife cut, saw cut and mini cut) have been investigated, by performing four-point bend tests and digital image correlation. The strain maps and equivalent shear stresses in the core have been examined, and the influence of the different foam finishing options was determined.

1.Introduction

Polymer foams have been widely used as the core in composite sandwich structures over the past decades. They have a great importance within materials in weight sensitive applications due to their high strength and stiffness, as well as adjustable mechanical properties depending on the requirements. Polymer-foam cored composite sandwiches are commonly used in naval, aerospace and wind turbine industries [1-5].

The increasing demand for polymer foams in composite sandwiches encouraged the polymer foam industry to improve and produce novel foam structures with various densities, types, surface finishing options and configurations. The evaluation of the mechanical properties of composite sandwich structures with these new polymer foams is an important research field.

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In this study, we have evaluated the effect of different surface finishing options on the mechanical behaviour of sandwich composites, by performing four-point bend tests and digital image correlation (DIC).

2.Materials and Expriments

2.1. Materials

In this study, PVC foam cores with various surface finishing options – (i) knife cut, (ii) flexi cut, (iii) saw cut, (iv) mini cut and (v) plain – have been used. The foam cores were supplied by AIREX AG. The mechanical properties of PVC are shown in Table.1 [6-8].

Table 1. Mechanical properties of the PVC cores

Core material	Density (kg/m^3)	Shear Strength (N/mm^2)	Shear Modulus (N/mm^2)
PVC	60	0.85	22

Gurit XE603, which is a +/- 45 biaxial E-glass reinforcement fabric, was used as the reinforcing material. A mixture of Prime 20 LV epoxy resin and slow hardener (which is suitable for the production of sandwich composite structures) was used a matrix material. The skins of the sandwich structures were fabricated by using these two materials [9].
Sandwich composite panels were manufactured with resin infusion under flexible tooling (RIFT). The panels were cut down to specific dimensions to perform four-point bend tests, using a bench saw machine with crosscut saw blade, to protect the panels from failure during cutting. The dimensions of four-point bend samples are 300 × 75 × 18 mm (as in length (direction x)× width (direction z)× thickness (direction (y)).

2.2. Experimental

The four-point bend tests were performed in a Instron 5580H testing machine in accordance with ASTM C393. The span of the supporters in the four-point bend test rig was 200 mm, and the span of the indentors was 100 mm.The cross head displacement rate of the indentor was 6 mm/min, and the diameter of the indentors and supporters was 12 mm.

In order to obtain a better understanding of the behaviour of the sandwich structure during the test, digital image correlation (DIC) was used.

Equivalent shear stresses in the core were calculated using the equation below:

$$\tau_{\mathrm{c}} = P/(d+c)b \tag{1}$$

where:
τ_{c} is the core shear ultimate strength, MPa,
P is the maximum force prior to failure, N,
t is the nominal facing thickness, mm,
d is the sandwich thickness, mm,

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c is the core thickness, mm,($c = d - 2t$)
b is the sandwich width, mm [10].

Graphs of shear stress vs. displacement will be used to represent the results. The beginning of the graphs was corrected for initial slack in the range of shear stresses between 300 to 700 kPa. The reason for this correction is that rubber was used to avoid failure under the indentors.

3.Results

The shear stress vs. displacement curves of sandwich composites with PVC core with plain surface finishing are given in Figure 1, together with DIC images. As seen in Figure 1-a, the shear stress vs. displacement curves of the samples exhibited cosnsitent behaviour. The maximum shear stress appeared at a displacement of 10 mm, with a shear strength of approximately 1000 kPa.
The numbers plotted in the graph (Figure 1- b) represent the order of the DIC photos in Figure 1-c. The samples deformed elastically up to point 2, and afterwards plastic deformation became dominant between points 2-5. First damage of the foam was observed at point 6 as a shear crack throughout the foam, which can be clearly seen in the DIC image and led to a load drop. At point 7, a second shear crack appeared on the right-hand side of the sample. Despite the cracks that appeared in the core, the sandwich structure maintained its load carrying capacity until point 7. As seen in Figure 1-c, the core undergoes relatively high deformations, and plastic strains are localized after yielding.

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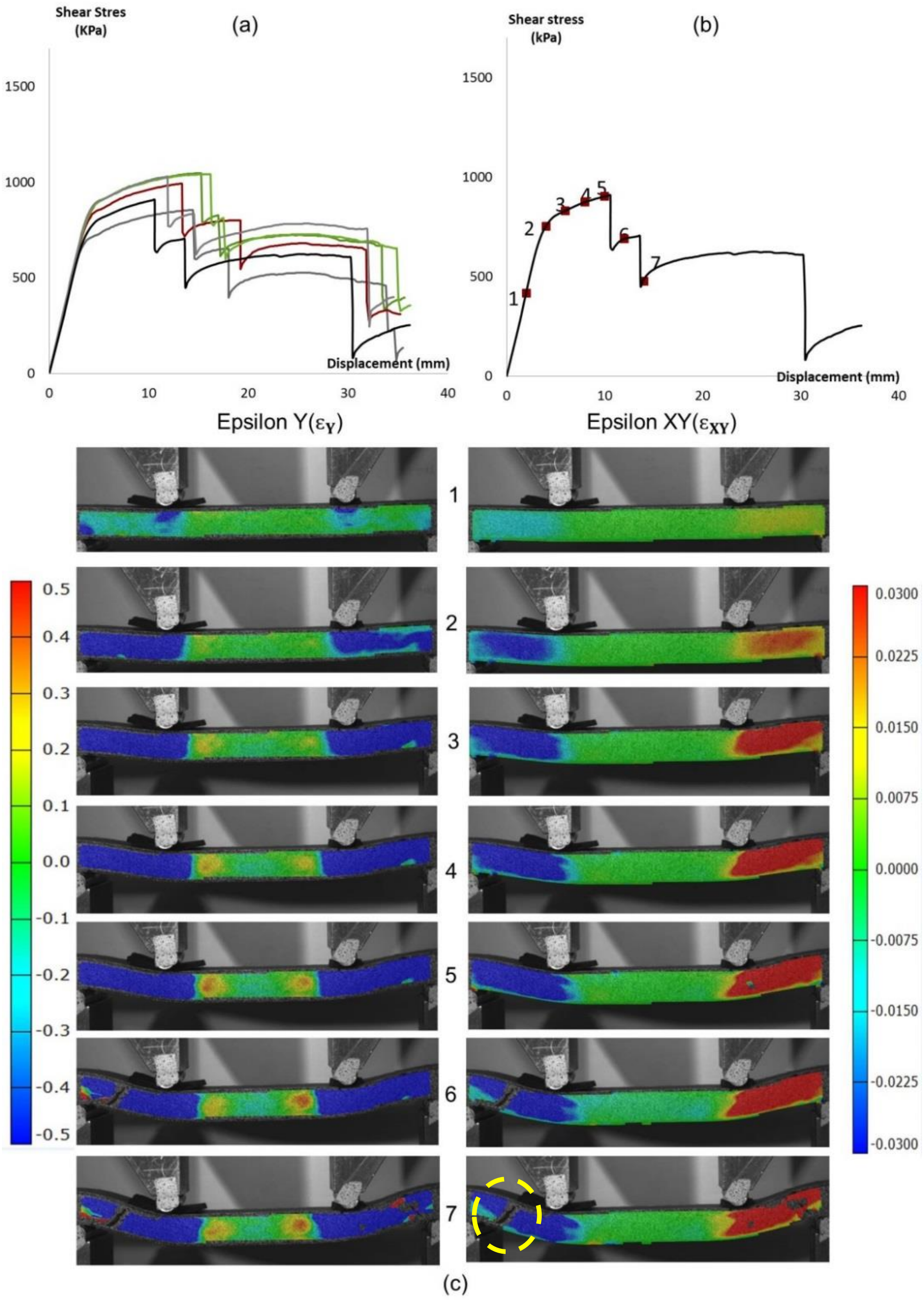

Figure 1. Strain visualization and four-point bend test results of plain PVC cored sandwich structures: (a) shear stress vs. displacement curves for all samples, (b) four-point bend test result of a selected sample, (c) Strain visualization for every 5 mm of displacement of the selected sample.

In Figure 2, the stress vs. displacement curves and strain maps of the sandwich composite structures with PVC foam with mini cut surface finishing options are given. In the linear-elastic regime, the shear stress of the core increased rapidly up to approximately 1300 kPa. Afterwards, a sharp decrease occurred due to the formation of a first shear crack on the left-hand side of sample. At point 3, the shear stress of the structure decreased dramatically with the formation of a second shear crack on the right-hand side of the sample. The shear cracks propagated as delaminations between the skin and the core, and finally the structure failed at a displacement of approximately 23 mm.

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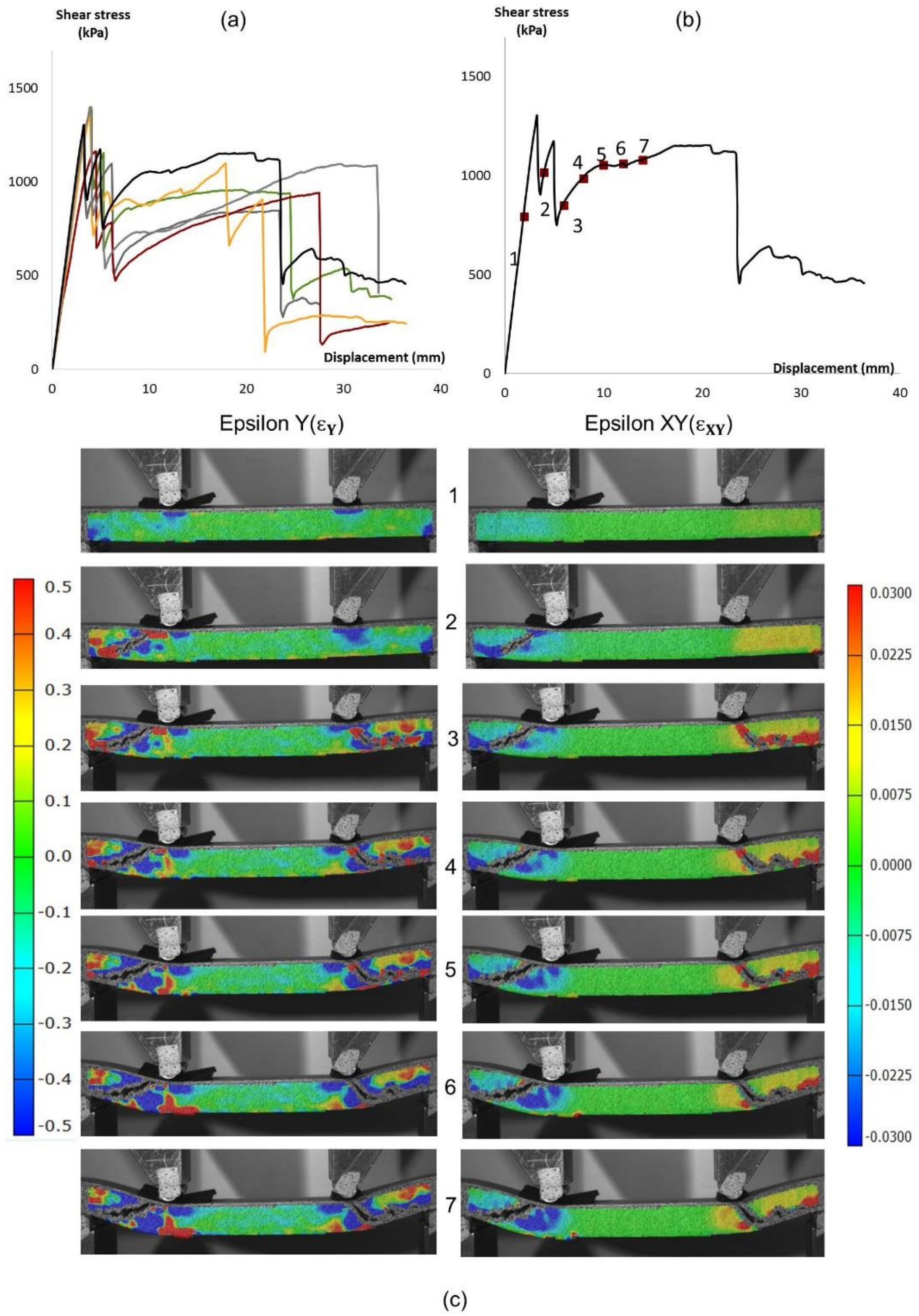

Figure 2. Strain visualization and four-point bend test results of mini cut PVC cored sandwich structures: (a) shear stress vs. displacement curves for all samples, (b) four-point bend test result of a selected sample, (c) Strain visualization for every 5 mm of displacement of the selected sample.

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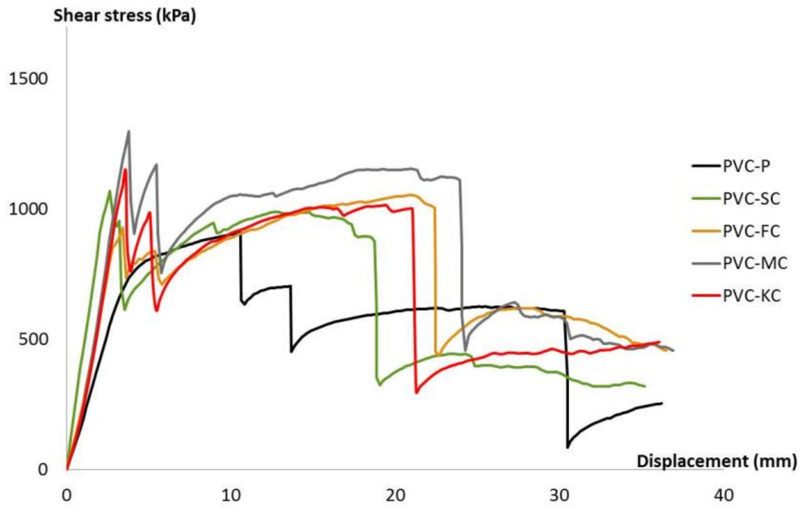

Figure 3. Comparison between the four-point bend test results for sandwich structures with different types of surface finishing.

In Figure 3, a comparison of the different types of finishing option is given. Considering the initial linear-elastic response of the samples, the saw-cut finishing option has the highest stiffness, while the plain finishing has the lowest stiffness and has also the lowest shear strength. Therefore, it can be concluded that additional surface finishing options improve the stiffness and shear strength; this can be explained due to (i) increasing of resin uptake in the grooves created by the additional finishing options, and (ii) improvement of the adhesion between core and skin with increasing bonded area. After the yielding point, the mini-cut finishing results in high plastic deformations due to the large total area of interface, which also inhibits shear cracks. Therefore, the energy absorption under load is maximum for mini-cut cored samples.

4. Conclusions

In this study, PVC cored materials with three different surface finishing were investigated by performing four-point bend tests of sandwich structures with DIC. This allowed us to further understand the effect of different surface finishing options on the flexural properties of sandwich structures:

- Surface finishing options on the core materials have increased the shear strength of the PVC-cored sandwich composite structures. This can be explained by the increasing resin uptake and improved adhesion between skins and core with the additional surface finishing;
- Different surface finishing geometries create local high-strain regions in the core, which affects the initiation and propagation of shear cracks. This caused the materials with additional finish options to partially lose their load carrying ability for large displacements.

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