ANALYSING THE FLEXURAL STRENGTH PROPERTIES OF UNIDIRECTIONAL CARBON / EPOXY COMPOSITES

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Introduction

Unidirectional carbon-epoxy composites are commonly used for advanced applications, such as blade, where specific strength and stiffness are the properties sought. Bending and tension are both major forms of loading for this type of components. The ability to predict the strength of components subject to bending, tension, compression and shear or a combination of these is, therefore, of significant practical interest.

The bending test used to a large extent for testing and evaluation the strength properties of composite materials, although it typically induces tensile, compressive, and shear stresses simultaneously.

The flexural tests (three- and four-point) are popular, because of the simplicity of both specimen preparation and testing. The usual objective of flexure test is to determine the flexural modulus of the beam material.

The effect of testing parameters on the three-point bend testing of unidirectional carbon fiber-reinforced epoxy resin composites has been investigated. The specimen produced as impregnated continuous tow bundle. The span-to-thickness ratio (L/h) and width-to-thickness ratio (b/h) were varied.

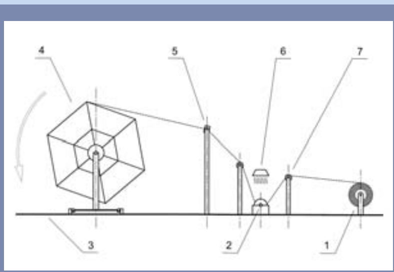

Fig. 1. The impregnation device

Fig. 2. The open-ended mould

Thickness of specimen h [mm]	Width of specimen b [mm]	Number of carbon tow	Density of composite [g / cm³]	Fiber content Volume fraction [Vol%]
2 ± 0.1	10 ± 0.1	7	1.57	60.33
4 ± 0.1		14	1.59	60.12
6 ± 0.1		21	1.61	59.29
8 ± 0.1		28	1.59	58.84
10 ± 0.1		35	1.56	58.61

Tab. 1. Physical properties of the UD specimens

Materials and experimental procedure

The composite used in this study was unidirectional carbon fibre-reinforced epoxy resin composite (UDCF). The carbon fibre was PANEX 35 continuous tow from ZOLTEK Ltd. and the epoxy resin system was ARALDITE Ly556 + ARADURE 2954 from VANTICO AG. The carbon roving was impregnated (Figure 1) and laid in the open-ended moulds (Figure 2). The cross-linking was taken place at elevated temperature (at 80°C for 1h and post cured at 150°C for 4h) under pressure. The thickness (h) of the UD specimens was 2, 4, 6, 8 and 10 mm, the width (b) 10mm. The test specimens were cut to the necessary length with a diamond disk. Typical physical properties of the carbon/epoxy composite were determined and are presented in Table 1. The fibre contents were measured by burn out tests.

The UD specimens were bend tested using a ZWICK Z020/TH3A universal material testing machine equipped with three-point loading apparatus. The radius of supports were 2 mm, and the radius of the loading nose was 5 mm. The specimen was loaded at a constant 1 mm/min crosshead speed and the deflection (f [mm]) and the measured force (F [N]) was recorded.

In the present study the flexural tests were carried out changing the span-to-thickness ratio (L/h) from 5 to 25, where L [mm] is the support span.

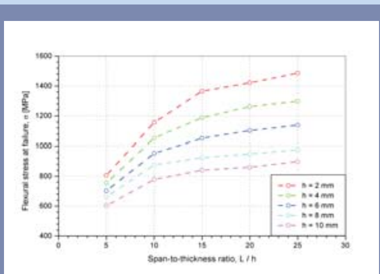

Fig. 3. Typical flexural strength versus span-to-thickness ratio (L / h)

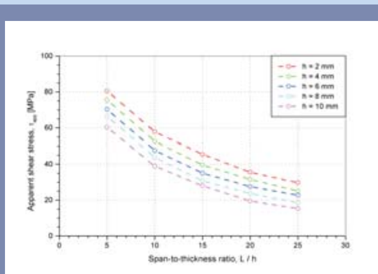

Fig. 4. Typical apparent shear stress versus span-to-thickness ratio (L / h)

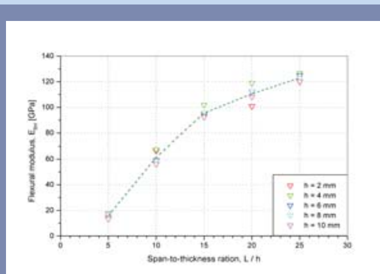

Fig. 5. Flexural modulus versus span-to-thickness ratio (L / h)

Results

Flexural properties of the UD composite beam were derived from the recorded force deflection at midspan curves. Classical beam theory was used to calculate the experimental data of three-point bending test. Figure 3 depicts the experimentally determined flexural stresses (cross breaking strength), apparent shear stresses (Figure 4) and the flexural modulus (Figure 5), respectively.

Classical Weibull-strength theory has been applied to analyze the flexural strength of the UD carbon-fiber composites. The objective of this work was to provide further experimental data to estimate the magnitude of size effect in carbon-fiber composites. Table 2 shows the Weibull parameters for the h = 4 mm case, Figure 6 depicts the Weibull distributions.

L / h	m	σ_1 [MPa]
5	17.06	757.28
10	19.10	1018.10
15	19.85	1194.87
20	21.56	1336.58
25	17.74	1434.65

Tab. 2. Weibull parameters (h = 4 mm)

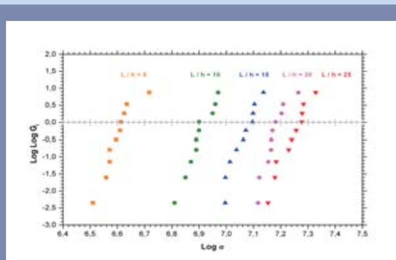

Fig. 6. Weibull distributions

Conclusion

The present experimental work revealed that a composite specimen with lower span-to-thickness ratio exhibits a lower flexural strength and Young's modulus and a higher apparent interlaminar shear strength in case of three-point bending. There is a significant size effect in the bending strength of unidirectional PANEX 35 carbon fiber epoxy.

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