Study on stacking sequence on the flexural properties of basalt/carbon/epoxy hybrid composites using test and finite element analysis

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INTRODUCTION

- In recent years, basalt fiber has received increasing attention as a substitute for glass fiber on the basis of its ecologically benign and superior mechanical properties. Basalt fiber, which is made from basalt rock, has superior properties relative to glass fiber such as high tensile strength (~4800 MPa), thermal performance (-259°C to 960°C) and chemical resistance.
- It is considerably more economical than carbon fiber. And the basalt vitrification process of nuclear waste is a viable alternative to glass vitrification. Basalt roving, chopped basalt fiber strands and basalt composite rebars can significantly increase the strength and safety characteristics of nuclear waste and spent nuclear fuel storages.
- For this reason, basalt fiber is widely used in various industries and several studies have been carried out to understand the mechanical behavior of basalt fiber reinforced composites.

OBJECTIVES

- In this study, the effect of stacking sequence on the flexural properties of carbon/basalt/epoxy hybrid composites was investigated in order to verify the reliability of this composite model. Two types of carbon/basalt/epoxy hybrid composites with a sandwich form were fabricated: basalt skin-carbon core (BSCC) composites and carbon skin-basalt core (CSBC) composites. After fabrication flexural tests and finite element method (FEM) were conducted. FEM results of flexural analysis are compared with experimental results.

MATERIALS & METHODS

- Flexural tests were performed according to the ASTM D-790 standard in a three-point bending mode at across-head rate of 0.5 mm/min using 130 × 12.7 × 1.6 mm CSBC and BSCC specimens. Four flexural tests were performed to ensure reliability of the test results.
- To investigate the bending characteristics of the basalt / carbon / epoxy hybrid composite material, the stacking of the fiber order was accordingly carried out and FEM analysis was performed using a commercial FEM program. Pre-defined static loads on the bending specimen were applied to the model. Finite element analysis was conducted under a 2D plane stress state. The number of elements and nodes are 2,024 EA and 8,207.

Simulation for this model

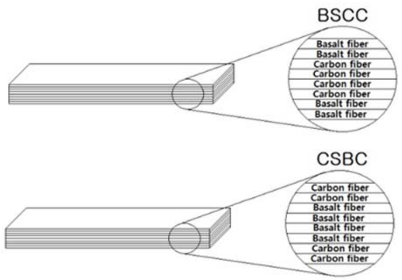

Fig. 1. Stacking sequence of composites

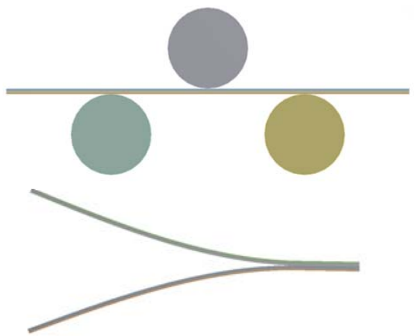

Fig. 2. Configuration of flexural test model and interlaminar fracture toughness

Properties	Carbon laminar	Basalt laminar
Exx	45.30 GPa	11.29 GPa
Eyy	8.38 GPa	4.18 GPa
Ezz	45.30 GPa	11.29 GPa
Gxy	1.58 GPa	1.06 GPa
Gyz	1.58 GPa	1.06 GPa
Gxz	1.73 GPa	1.81 GPa
Yxy	0.42	0.41
Yyz	0.42	0.41
Yxz	0.13	0.13

Properties	BSCC	CSBC
Maximum normal traction	11.92 MPa	6.96 MPa
Normal separation	1.83*10-5 m	2.68*10-5 m
Shear separation	-	-

Table. 1 Mechanical properties of laminar

Results

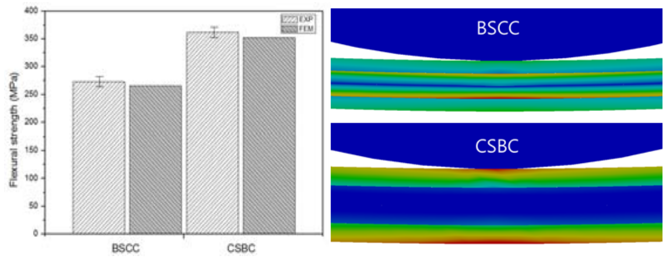

Fig. 3. Comparison of flexural strength of experiment and finite element results

- The results from the test and FEA are compared in Fig. 3. In case of BSCC, the bending strength obtained from the test is 272Mpa and it from the FEA is 266Mpa, showing a difference with about 2%. Whereas, the bending strength for CSBC sample is 362Mpa in the test and 352Mpa in the FEA, respectively. Similar to BSCC, the results of CSBC also displays a 2% difference.

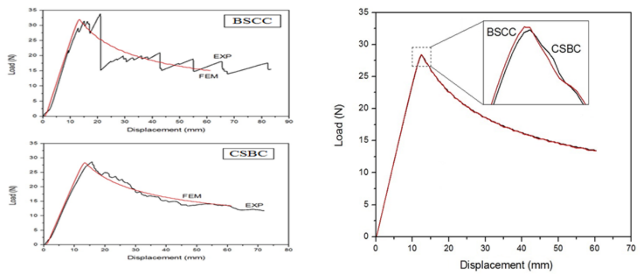

Fig. 4. Load-displacement curves of experiment and finite element results in the interlaminar fracture toughness

DISCUSSION & SUMMARY

- A FEA analysis model has been successfully developed in order to predict flexural behavior of basalt/carbon/epoxy hybrid composites. The simulation using the FEA model produces a similar flexural strength to that obtained from the experiment. Therefore, the developed FEA model in general will be highly useful for the prediction of stacking sequence of basalt/carbon/ epoxy hybrid composites for several industrial applications.
- The stacking sequence of basalt/carbon/epoxy hybrid composites did not affect on the interlaminar fracture toughness.