MECHANICAL CHARACTERIZATION BASALT AND GLASS FIBER EPOXY COMPOSITES BY THE RING-TYPE TEST SPECIMENS

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Abstract
The interest in basalt fibers as polymer reinforcement has been worldwide crescent. Basalt fibers are competitive with glass fibers, mainly in comparison to mechanical properties. The aim of this work is to compare mechanical properties between basalt and E-glass rings manufactured by filament winding. Split-disk (ring segment) tensile tests provide reasonably accurate information with regard to the apparent tensile strength of polymer reinforced composite. Basalt and E-glass fiber reinforced epoxy laminates with open-ended cylinder geometry were manufactured using filament winding technique. All cylinders were produced with stacking sequence $[90º_2/-30º/+30º/90º_2]_T$. Tensile strength by split-disk test was carried out according to ASTM D2290 specifications. Fiber and void volume fraction and specific mass was obtained. Basalt composite showed 45% higher tensile strength compared to glass. This result is consistent to values found in literature. DSC analysis showed glass transition temperature of 128ºC for both composites. Fiber volume fraction of 55% obtained for both composites can be considered low to filament winding technique, as well the void volume fraction of 3% for both composites can be considered quite high. Adjusting production parameters as filament tension, winding step length, mold and bath temperature could improve these levels.

1. Introduction

Basalt is volcanic mineral, dark or black. Its rocks are heavy, tenacious and resilient. Its density is about 5% higher than the glass. It's the most abundant crustal rock and the seabed is predominantly composed of basalt. The chemical composition of the basalt is variable according to the mineral deposit. The weight percentage of the constituent oxides: SiO_2, 48,8–51; Al_2O_3, 14–15,6; CaO, ≈10; MgO, 6,2–16; FeO + Fe_2O_3, 7,3–13,3; TiO_2, 0,9–1,6; MnO, 0,1–0,16; Na_2O + K_2O, 1,9-2,2 [1].

Current technology for producing basalt fibers (BF) is very similar to that used in E-glass fiber (GF) production, but requires less power to be produced [1]. This fact, coupled with the high availability of raw material around the world, justifies the low price of BF compared to GF. The main difference between the BF and GF is the raw material used. GF are produced from various components, while BF is made with the fusion of basalt rock without other additives. The fact of being environmentally friendly makes BF use very attractive and unlike GF, BF does not require additives in their production. The replacement of GF by BF can reduce the risk of environmental pollution with and highly toxic metals and oxides, which are generated in the production of GF [2]. Moreover, BF is an alternative to asbestos fibers, banned for being carcinogenics.

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The application of BF is possible in many areas thanks to its multiple and good properties. It exhibits excellent resistance to alkalis, similar to GF, at a much lower cost than carbon and aramid fibers. Its thermal properties make them excellent substitutes for high temperature resistant fibers (carbon fibers) and is commonly used in the manufacture of heat shields, heat insulating barriers and articles for fire protection – in addition to working temperature markedly higher than GF, from -260 °C to 700 °C, against -60 °C to 250 °C for glass [1]. The vibration damping of BF is much higher than of GF, which made them suitable for applications under high loads and acoustic vibrations, such as in structures where such conditions exist, for example, in the aerospace and marine industry [1]. Its high water resistance also explains the wide application in the marine industry, as in production of boat hulls. For their good electrical insulation properties (10 times greater than glass) [1], BF are used in printed circuit boards, extra-thin insulation for electrical cables and underground pipelines. Regarding the mechanical properties, BF overcomes GF 15% in elastic modulus and 11% in tensile strength [3, 4].

2. Materials and Method

Basalt and glass fiber reinforced epoxy laminates with open-ended cylinder geometry were manufactured through filament winding technique. The BF was supplied by Kammeny Vek company in continuous filament with a linear density of 1200 tex, made from fibers of 13 μm diameter, with silane agent sizing compatible with epoxy and phenolic resins. The GF was supplied by CPIC company in continuous filament, E-glass type, with silane agent sizing compatible with epoxy and amine resins. All cylinders were produced with total six plies laminate with stacking sequence $[90°_2/-30°/+30°/90°_2]_T$. The average wall thickness of basalt and glass cylinders was 1.58 and 2.58 mm, respectively.

Three filament winding cylinders were produced with BF and another three with GF reinforcement. The mold was taken to oven for a curing cycle of 8h, reaching a maximum temperature of 150°C, with slow cooling in the air at oven. In each produced cylinder, two ring specimens from opposite ends were cut in 10 mm width for tensile strength split-disk test using a diamond saw. Tensile strength split-disk test was carried out according to ASTM D2290 specifications.

3. Results

Table 1. Tensile strength, failure mode and dimensions of ring specimen BF composites.

Specimen	Ultimate tensile strength (MPa)	Failure mode	Width (mm)	Thickness (mm)
B1	768	MGM	10.03	1.58
B2	714	MGM	10.03	1.59
B3	711	MGM	10.02	1.57
B4	705	MGM	10.06	1.61
B5	738	MGM	10.04	1.56
B6	727	MGM	10.02	1.58
Mean	727	-	10.03	1.58
Std. dev.	23	-	0.02	0.02

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Table 2. Tensile strength, failure mode and dimensions of ring specimen GF composites.

Specimen	Ultimate tensile strength (MPa)	Failure mode	Width (mm)	Thickness (mm)
V1	499	MGM	10.04	2.57
V2	494	MGM	10.02	2.58
V3	490	MGM	10.04	2.55
V4	498	MGM	10.04	2.63
V5	503	SGM	10.04	2.57
V6	521	SGM	10.01	2.58
Mean	501	-	10.00	2.58
Std. dev.	11	-	0	0.03

One way to perform fracture characterization of these ring specimens is to follow terminology of ASTM D3039/D3039M, which defines failure mode and location in tensile test for flat rectangular section polymer composites specimens, once the ring specimens obtained at this work and tested under ASTM D2290 have similar test conditions and geometry. Furthermore no information about failure mode is mentioned at D2290, instead of D3039/D3039M. The failure mode codes for specimen failure are reported in Table 1 and 2. The first letter in the code is relationed to failure type, in which "M" means mixed and "S" means split; the second letter refers to failure area, where "G" means failure occurs at gage; and the third letter refers to failure location, and "M" means middle. Fig. 1 shows BF and GF reinforced rings after tensile test.

Figure 1. Fracture regions of ring segment specimens: basalt fiber composite B1 (left) and glass fiber composite G1 (right) reinforced composite.

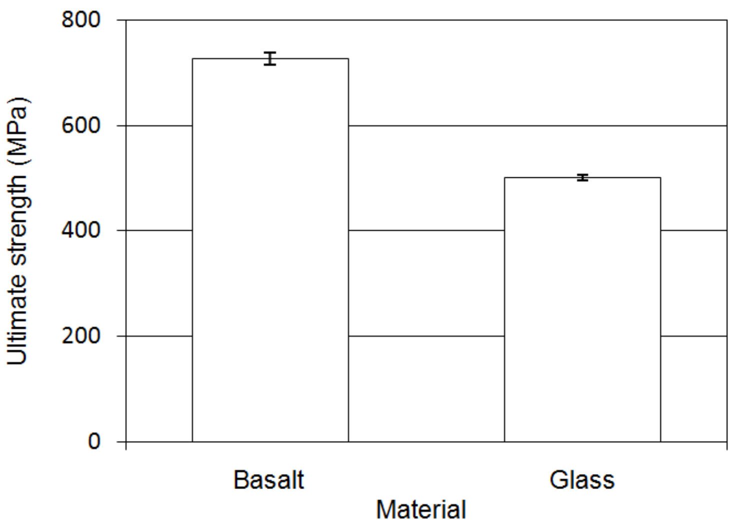

Figure 2. Comparison of ring tensile ultimate strength between basalt and E-glass fiber composites.

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The reported data of Fig. 2 and 3 consist of the mean values of six specimens with the standard deviations represented by vertical bars. As presented in Fig. 2, BF composite showed 45% higher tensile strength compared to GF. This result is consistent to values found in literature [5, 6] (between 13–15% higher). In addition, BF surpassed GF in remarkable higher levels comparing to this data and other literature.

Difference in density between BF and GF motivated presentation of another perspective of comparison between the fibers by means of specific strength in Fig. 3. A higher value of 43% specific strength is found for GF composite compared to GF.

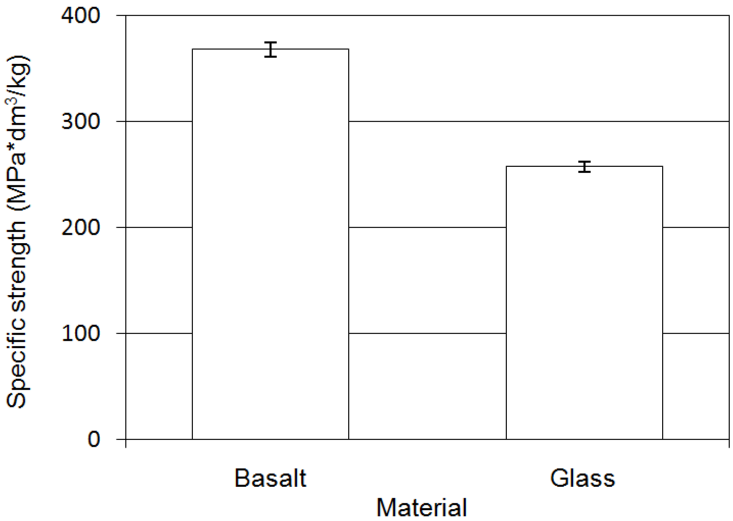

Figure 3. Comparison of ring tensile specific strength between basalt and E-glass fiber composites.

Glass transition temperature of 128ºC for both BF and GF composites was obtained by DSC analysis.

3. Conclusions

BF reinforced cylinders has 45% higher tensile strength than the GF reinforced cylinders, subjected by split-disk test.

Fiber volume fraction of 55% obtained for both basalt and glass composites can be considered low to filament winding technique, as well the void volume fraction of 3% for both materials can be considered quite high (once void volume fraction less of 2% is recommended to structural composites). Adjusting production parameters as filament tension, winding step length, mold and bath temperature could improve these levels.

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