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Effect of environmental conditions on the mechanical properties of composite tubes

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ABSTRACT

Composite tubes are materials with a high strength-to-weight ratio. However, they can be exposed to hot and humid environmental conditions in working conditions. For this reason, the response of composite tubes to mechanical loading under environmental conditions should be investigated. In this study, the effect of hydrothermal aging on the tangential tensile strength of glass/epoxy and basalt/epoxy composite tube samples was investigated. After the samples were kept in distilled water at 70°C for 500 hours, hardness and hoop tensile tests were performed.

Introduction

Composite materials are widely used in oil and natural gas transmission lines, chemical transmission lines and geothermal applications [1]. In addition, its use in the defense, space and aviation sectors is gaining importance day by day. The use of composite materials is increasing rapidly due to many superior properties, especially in terms of strength/weight ratio compared to traditional materials such as metal and ceramics [2]. In addition to its superior features, it also has some negative features. The mechanical properties of composite materials exposed to humid and hot working environments deteriorate due to hydrothermal aging [3]. There is a need for studies on the effect of hydrothermal aging on composite materials in order to identify materials that are more resistant to environmental conditions and to predict the effects of existing materials against these conditions [4].

Filament wound composite pipes are generally exposed to tangential stresses due to their geometric shapes [5]. Therefore, it is important to investigate the tangential tensile strength of these materials. It is also very important to investigate the changes in the strength of composite materials, especially under environmental conditions. In order to determine the strength of the cylindrical samples, the hoop tensile test is applied to the samples [6].

In this study, basalt/epoxy and glass/epoxy composite materials were hydrothermally aged in distilled water at 70°C for 500 hours. At the end of the aging process, hardness and hoop tensile tests were performed on the samples.

Material and Method

In this study, Araldite MY 740, bisphenol A diglycidyl ether epoxy resin, Aradur HY 918 hardener, and DY 062 accelerator were used in the epoxy system. In the production of composite pipes, basalt and glass fiber filaments were used. The average diameters of basalt and glass fiber are 13 and 17 μm, respectively. The mechanical characteristics of matrix and fibers are given in Table 1.

Table 1. Mechanical properties of the materials used in composite pipes

Material	Modulus of Elasticity E (GPa)	Tensile Strength σ_t (MPa)	Density ρ (g/cm³)
Glass Fiber	73	2400	2.6
Basalt Fiber	90-95	2900-3200	2.48
Epoxy Resin	3.4	50-60	1.2

Composite pipes were produced by the filament winding method. The filament winding process was realized with a winding angle of ±55°. Six-layered produced composite pipes have 72 mm inner diameter and 76 mm outer diameter. The prepared samples are shown in Fig. 1.

A 64 L aging unit made of 6 mm thick glass was used to perform the hydrothermal aging process shown in Fig. 2. The aging temperature was determined as 70 °C. The aging periods were determined as 500 hours.

(a) (b)

Figure 1. a) Glass fiber/epoxy and **b)** basalt fiber/epoxy composite samples

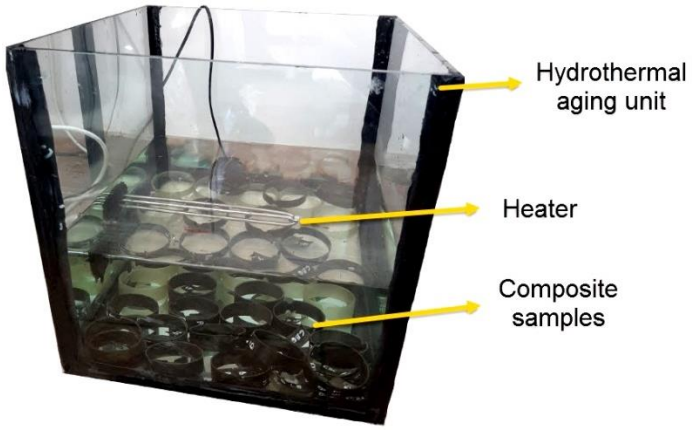

Fig. 2. Hydrothermal aging unit

Results and Discussion

Hoop tensile and hardness tests were performed on hydrothermally aged basalt/epoxy and glass/epoxy composite samples. As a consequence of the experiment, it was observed that the 500 hours aging process decreased the hoop tensile strengths of glass fiber/epoxy and basalt fiber/epoxy composite samples by 9.3% and 3.3%, respectively, and increased the hardness values by 4.2% and 5.9%, respectively. Hoop tensile and hardness test results are given in Table 2.

Table 2. Hardness and hoop tensile test results of the samples

Samples	Aging Time [hours]	Hardness [HRL]	Hoop Tensile Strength [MPa]
Glass fiber/epoxy	0	81.2	378.3
Glass fiber/epoxy	500	84.6	343.1
Basalt fiber/epoxy	0	106.0	398.1
Basalt fiber/epoxy	500	112.2	385.0

The main types of damage occurred as a consequence of hoop tensile test in composite samples were observed as fiber breakage, matrix cracking and delamination. In all samples, damage occurred in the fiber winding direction of ±55°. The damage images taken from the front of the damaged areas after the hoop tensile test are presented in Fig. 3.

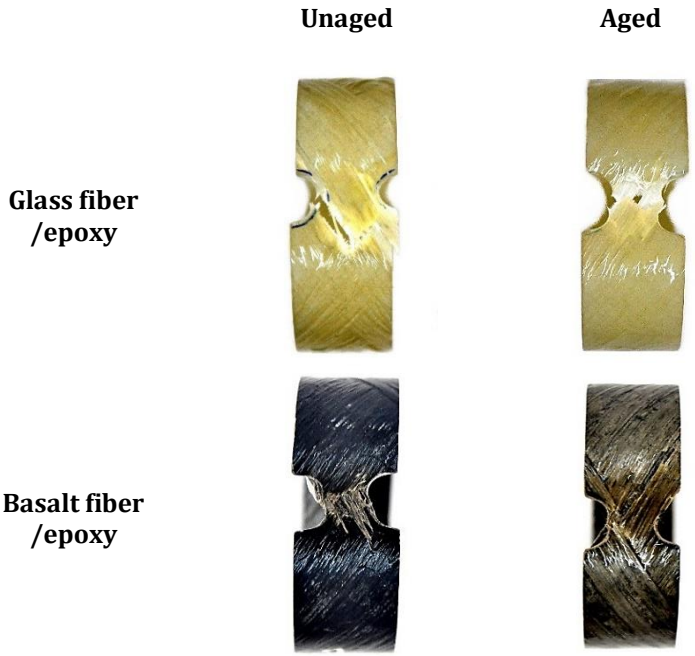

Figure 3. Damage images of composite samples after hoop tensile test

Conclusion

In this study, the effect of 500 hours hydrothermal aging on the mechanical strength of basalt fiber and glass fiber reinforced epoxy matrix composite materials was investigated. After the samples were kept in distilled water at 70°C for 500 hours, hardness and hoop tensile tests were performed. As a result of the study, there was a greater decrease in the hoop tensile strength of the glass fiber/epoxy composite samples compared to the basalt fiber epoxy samples. When the hardness of the samples was compared, it was seen that the hardness values of both samples increased at similar rates.

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Author contributions:

Yusuf Kepir: Writing-Original draft preparation, Data curation, Investigation, Visualization **Alper Günöz:** Data curation, Investigation, Visualization. **Memduh Kara:** Methodology, Validation, Writing-Reviewing and Editing.

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