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Creep Behavior of Glass Fiber/Epoxy Composite Cylinder Subjected to Hydrostatic Pressure

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1. Introduction

The current engineering composites have shown great potential for the use in a variety of materials such as carbon, glass, basalt and many other combinations and varieties of fibers. Those applications cover almost all industry segments including the nuclear field. In several industrial applications, the use of carbon fiber and glass fiber have been very widespread. Furthermore, glass fiber presents itself as a less expensive and better alternative due to its increased availability and easy manufacturing process, especially in emerging countries. The matrix made by a combination of glass fibers and epoxy usually offers excellent engineering properties for the composite material. Moreover, it may increase the application possibilities of fiberglass as a reinforcement inside of the structure engineering components of polymeric composites.

This study aims to investigate creep behavior of a Glass Fiber/Epoxy Composite cylinder when it is subjected to hydrostatic pressure at room temperature, and when heated at 50 ºC. The geometrical viscoelastic deformation was identified by processing signal data positioned at the cylinder surface. Then, electronic data processing was performed to obtain the characteristic of the creep phase phenomenon attributed to this polymeric composite.

2. Methodology

According with [1] Creep is defined as “the phenomenon in which materials under the influence of a constant mechanical load at constant temperature and humidity show an increase in deformation over time”. Conversely, the phenomenon called recovery is observed with the instant removal of the constant mechanical load and a time-dependent reduction in deformation occurs. A graphical representation of both phenomena is given in Fig. 1a [1].

a) b)

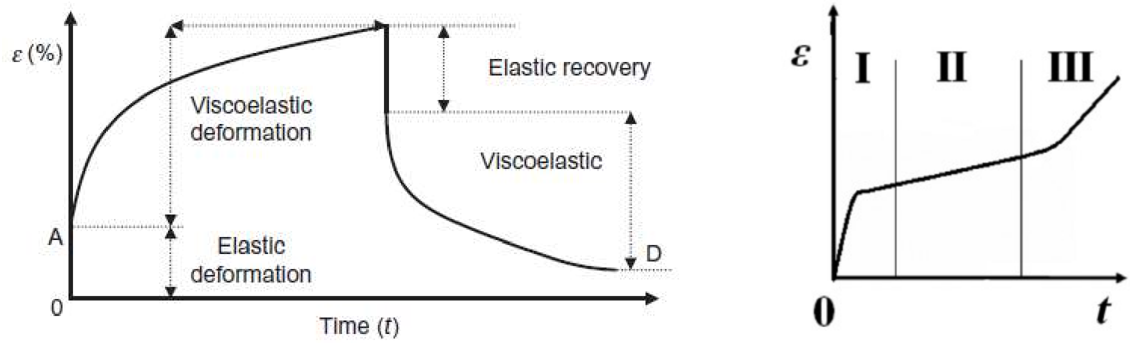

Figure 1:a) Strain vs. time curve showing the creep and creep-recovery phenomena [1], b) Creep stages [2].

As described by (PAPANICOLAOU; ZAOUTSOS) [2] in many experienced tests, creep can be observed in three stages: primary, secondary, and tertiary. In the first stage, the material undergoes deformation at a decreasing rate, in the second it proceeds at a nearly constant rate. In the last stage (third or tertiary stage), the creep phenomena occur at an increasing rate finishing with fracture of material as shown in the following Figure 1b.

The cylindrical specimen was manufactured using a 4-axis CNC filament winding machine and a CNC control the rotation and the translation movements of the machine axes. The winding angles were 90º and 30º. This type of equipment is widely used for a large production of components with cylindrical and spherical geometric profiles by the composite industry.

The creep test was carried out at room temperature in reinforced fiberglass cylinder, with a duration of 500 hours. The cylindrical specimen was subjected to a hydrostatic load, with a controlled injection of a fluid inside it, until the constant pressure defined at 50 bar was reached. Data was collected through the installation of strain sensors (strain gauges) fixed by adhesive at pre-defined points on the cylinder surface so that it is possible to obtain circumferential strain measurements and longitudinal on the surface of the cylindrical specimen.

Moreover, void volume test and density determination test of this composite material was performed. Those tests aimed to identify the constituent content and to follow physical changes in density of this composite. They also help to evaluate the quality of fabricated material, assess the processes used during manufacturing model. The void volume of a composite material may significantly affect some of its composite properties (mechanical, physical, thermal, or electrical). The analytical evaluation must be done to provide some critical characteristics affected by the reinforcement or matrix. The density determination test is conveniently measured to identify a material, to indicate degree of uniformity among different specimens, or to indicate the average density of a large item. Both tests were carried out according to [3] and [4] standard methods. Additionally, the Differential Scanning Calorimetry (DSC) test was performed to determine the transition temperature of the fiber glass composite and was carried out following [4] standard method.

3. Results and Discussion

The performed DSC test results show the transition temperature of the fiber glass composite analyzed was 120 ºC as the results carried out according to [5] standard method. This result can also indicate a high level of reliability in the manufacturing parameters of these composites.

Instead of the fact that the comparation of the results in different studies do not use same supplier or sample, the results were presented generally in agreement. The table-1 shows a comparation of results of the volume fraction with the results from studies of (ABDALLA) [6].

The cylindrical composite fiber volume fraction found was 55.0 % and the density was 1.96 g/cm^3 [5]. That result indicate that the volume fraction was 7,4% above of reference, as shown in Table 1. Thus, it may indicate better mechanical properties can be performed in this composite. This fact can be attributed to enhanced manufacturing process used during production of the cylindrical specimen tested in this work.

Fiber Composite	Specific mass (g.cm^{-3})	Volume of Fiber V_f (%)	Volume of Matrix V_m (%)	Lack v_v (%)	M_f (%)	M_m (%)
This study	**1.96**	**55.0**	**44.0**	**1.0**	**73.0**	**27.0**
Study compared *	2.0	47.6	52.4	N/A	62.28	37.72

Table 1 Volume fraction for glass fiber/epoxy composite [6] and this study.

The creep strain test shows higher initial level in radial direction (stress) around four times higher than creep strain measured in longitudinal direction (compression). When cylinder specimen was subjected to heat at 50º C the creep strain gets increased in radial and longitudinal directions. This fact suggest that the final creep strain increases when subjected to temperature at same pressure levels.

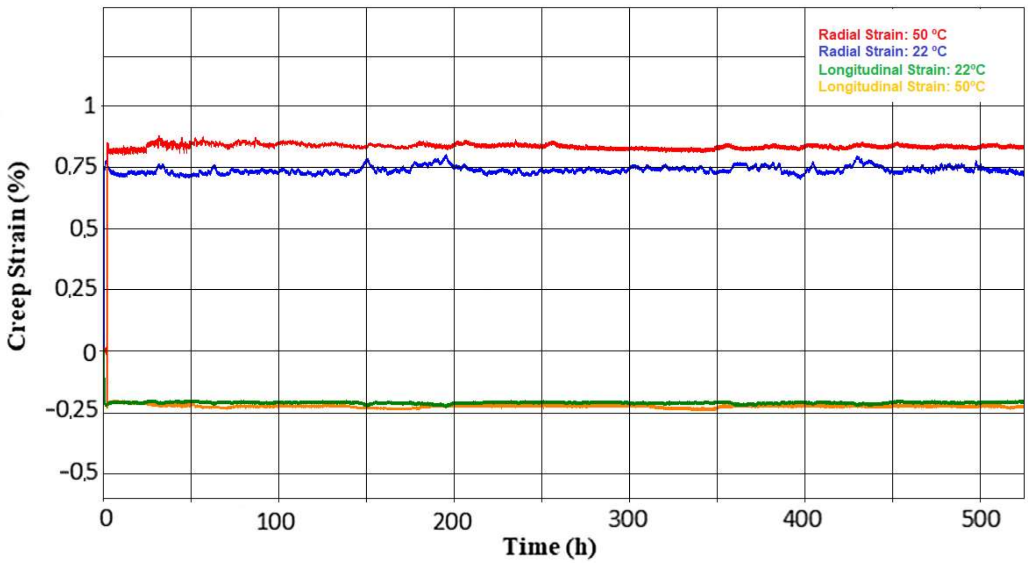

Figure 2 : Creep strain of cylindrical composites.

4. Conclusions

Despite fiber layers presence in radial direction (90º layers), the Figure 2 shows strain level associated of E-glass fibers low elasticity modulus, regardless of allowing high pressures due to their high strength properties. In the test with a temperature of 50 ºC, the polymer matrix showed loss of stiffness, which contributed to increase strain level in the composite material.

The structure did not show a significant creep effect after 500 hours, ensuring good dimensional and structural stability from the cylinder. For total time measured in the experiment, there were no significant creep behavior indication in this composite for the specific fiber layer configuration applied.

Acknowledgements

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References

[1] R.M. Guedes, *Creep and Fatigue in Polymer Matrix Composites*, Woodhead Publishing, Cambridge United State (2019).

[2] G.C. Papanicolaou, S.P. Zaoutsos, *Viscoelastic constitutive modeling of creep and stress relaxation in polymers and polymer matrix composites*, Woodhead Publishing, Cambridge United State (2019).

[3] ASTM D3171-15, *Standard Test Methods for Constituent Content of Composite Materials*, ASTM International, West Conshohocken, PA, (2015).

[4] ASTM D792-20*, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*, ASTM International, West Conshohocken, PA, (2020).

[5] ASTM D3418-15, *Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry*, ASTM International, West Conshohocken, PA, (2015).

[6] Abdalla, F.H., Determination of volume fraction values of filament wound glass and carbon fiber reinforced composites. *ARPN Journal of Engineering and Applied Sciences*. Vol.3. pp. 7-11 (2008).