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EVALUATION OF MECHANICAL PROPERTIES OF THE POLYMER COMPOSITE (GRP) IMMERSED FOR A LONG PERIOD

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Abstract. *The use of reinforced plastics is growing in the oil industries in manufacturing platforms, storage tanks, pipes; in the automotive sector in making fender, and construction materials of this type is being used in slabs, pre-molded parts. Since these plastics are very light and resistant to corrosion compared to conventional materials such as metals. The composite polymer matrix has been gaining attention in this high-tech market as it allows working with advanced designs. Given this context, the aim of this study is to evaluate the mechanical performance of a polymeric composite with a polyester matrix (orthophthalic) reinforced with chopped strands mat -type E. This composite was manufactured through the manufacturing process of manual lamination (Hand Lay- up) and the plate obtained test samples were fabricated for testing of tensile, using the ASTM D3039-06. Then, they were immersed in oil for a period of four years (1460 days). At the end of the conditioning period, it was observed that the limit of the tensile ultimate strength of the composite immersed in oil approximately 26% compared with the same material in their original condition. It was also observed that despite the drop in tensile strength limit of the material condition, the characteristic of the final fracture was similar for both conditions.*

Keywords: *Composite Materials, Oil, Fracture, Mechanical Properties.*

1. INTRODUCTION

Composite materials are also known as materials of the future, due the particularity of being formed by combining, at macroscopic level, of two or more materials that work together, functioning as a unit , to obtain a set of properties that none of the individual components present Mendonça, 2002. The composites are formed from the presence of a material known as reinforcement, which aims to interfere in the mechanical properties of the composite and matrix, acting in the implementation of mechanical stress to the reinforcement. The use of these new materials is rising due to its good mechanical properties, resistance to aggressive chemicals and effects of environmental exposure, such as radiation, humidity and temperature Barjasteh *et al.*,2009.Thus, these materials can be used in environments with high temperatures Boccaccini *et al.*,1998, in addition to their high versatility in design, contributing even with minimal maintenance over time of service and an unlimited life Thomason and Groenewoud, 1996.

Among the various types of reinforcement, we highlight the fibrous reinforcements, which may be synthetic and natural. Among the natural reinforcements, we can cite the fibers of pineapple, ramie, sisal and coconut, which have good mechanical and thermal properties Yan *et al.* 2000. The synthetic reinforcements such as aramid fibers, carbon and glass, have a higher cost compared with natural fibers. However, glass fibers, in turn, when compared with other synthetic reinforcements, have advantages such as high mechanical strength, good commercial availability and low cost Almeida, 2004. With this, they are commonly used in thermoplastic composites, together with polyester resin, to produce fiberglass reinforced plastic (FRP). This composite is distinguished by having excellent mechanical properties compared to conventional metallic materials and can operate in temperature ranges of 85 to 115 °C and pressure up to 15 bar Pessanha *et al.* 2008.

Due to the numerous advantages, fiber reinforced plastics are being used extensively as advanced materials of engineering in cutting edge technologies in the aerospace, automotive, construction and oil industries Ray *et al.*, 2007 .In the aerospace industry, these materials are present in the composition of 25% of the total weight of the fuselage sections of aircraft being used extensively in wings, tail surfaces and doors Meyer, 2008. In the oil sector, the polymer composites find a job in the ducts, pipes of transfer lines, floor gratings, ladders and structural steel Costa *et al*, 2006.

With regard to the influence of temperature, it is known that the polymer composites withstand temperatures between 70 °C to 200 ºC. Moreover, during the curing process, in the case of thermofixed resins, there is an increase in temperature due to chemical reactions necessary for hardening. Therefore, may occur in this period the formation of microcracks and voids, and these come to influence the performance of the composite. Allied to this, when the composite is subjected to a relatively high temperature, its degradation occurs by the process of chemical decomposition of the polymer. According to the literature, the polymer, when subjected to ultraviolet radiation, is to present a low resistance, and in fact have variation in color and becomes a brittle material. Given this behavior, it is expected that the composite formed by the polymer matrix will suffer the same mechanism Noda *et al*, 2008.

Thus, our objetive is to determine and compare the mechanical properties of uniaxial tension of the composite consisting of polyester resin and fiberglass-E, when immersed in oil for a period of 1460 days. To this end, the test specimens were prepared according to ASTM D790-03. These specimens were immersed in oil for a period of 1460 days. They were then tested for uniaxial tensile and the results were compared with those obtained with the same material, but without being subject to any conditioning. After these tests, the final fracture was characterized by each sample.

The period of 30 days of immersion was used because, in previous work undertaken by the authors Dantas, 2008, it was found that immersion of the composite polyester /E-fiberglass in oil and distilled water by greater period didn't change the mechanical properties significatively. For the preparation of this material, we used the hand lay-up process, which presents a simple procedure and involves no investment in manufacturing process equipment Pardini, 2006.

2. MATERIALS AND METHODS

2.1 Materials

The composite was confectioned using, as matrix, pre-accelerated orthophthalic unsaturated polyester resin, produced by the company NOVOCOL, with the following features (supplied by manufacturer): density between 1.10 and 1.15 g/cm^3, viscosity BROOKFIELD, at 25 °C, between 260 and 300 cP. The catalyst used for the resin curing (time to get the complete polymerization of the compound) was methyl ethyl ketone (MEKP), manufactured by AKZO NOBEL. The material used as reinforcement was a blanket of chopped strands of E-glass, made by OWENS CORNING, with a weight of 450 g/m^2. The oil used for immersion of the specimens was supplied by PETROBRAS / UN-RNCE, having an API 30.1518 (as provided by the laboratory of UN-RNCE/ATP-MO unit).

The equipments used in this study were: Pavitest universal testing machine (CONTENCO); analytical electronic scale, model FA2104N (BIOPRECISA); a muffle furnace, model F 100 (EDGCON 3P) and an optical microscope, model Pantec XJL03.

2.2 Materials

The composite was fabricated by hand lay-up process, and the polyester resin catalyzed with 1% of catalyst in relation to the total volume of the resin, using as a reinforcement four layers of blanket of chopped strands of E-glass, obtaining, thus, a plate. After curing, specimens were cut for characterization of the composite and determination of the three-point bending properties.

3. CHARACTERIZATION OF THE MATERIAL

To characterize the material, tests were conducted, as discussed below.

3.1 Test of Volumetric Density

The density of the composite was determined according to the procedure specified by ASTM D 792-08. The density was calculated by averaging the results obtained with five specimens (CP), all prepared with dimensions of 25 x 25 mm.

3.2 Test of Calcination

For this test, we used five specimens of 25 x 25 mm, which were pyrolyzed in an muffle furnace at a temperature of 450 °C for 45 min. Then we determine the volumetric fractions of reinforcement, resin and void.

3.3 Test of Moisture Absorption

For this test, five specimens were made according to ASTM D570-06, with the following dimensions: 25 mm in width and 76 mm in length. First, the specimens were weighted and then immersed in distilled water to reach saturation

of moisture, i.e., until no significant change in mass occur. At the end of the test, we determined the total percentage of moisture absorption.

3.4 Test of Uniaxial Tension

Specimens prepared in accordance with ASTM D 3039-06, with 127 mm x 61,5 mm (useful length and distance from gages, respectively), see in "Figure 1", were immersed in oil for 1460 days. For the uniaxial tension test, both dry specimens (not subject to immersion) and specimens immersed in both fluid (oil). This test was performed with the Pavitest universal machine at a speed of 1 mm/min.

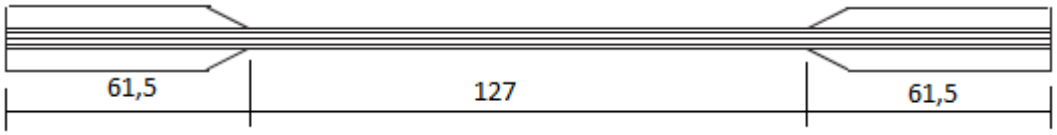

Figure 1. Profile of the spcimens for tensile test

4. RESULTS AND DISCUSSION

4.1 Characterization of the Composite

Determined the density of the composite and their percentages in weight of matrix, reinforcement and voids. The values are reported in "Table 1".

Table 1. Density and percentages of matrix, reinforcement and voids. Average results of 8 specimens.

Density (g/cm³)	Matrix (%)	Reinforcement (%)	Void (%)
1.55 ± 0.2	72 ± 2	26 ± 2	2 ± 0.1

4.2 Moisture Absorption

For composites reinforced with fiberglass, the saturation is normally reached in 2 or 3 months, with a weight increase of approximately 1.5%, Aquino *et al.,* 2007 and Liao *et al.* 1999, . However, it was observed that, for the confectioned material, the humidity saturation occurred at two and a half months, and this humidity percentage was somewhat higher. This is probably due to the fact that water has flowed by the voids of the material and also by capillary action and thus become trapped in the composite. The results are shown in "Table 2".

Table 2. Percentage of moisture absorption (%).

Moisture Content	Time
2.0%	1680 h

4.3 Test of Uniaxial Tension

In "Figure 3", brings typical tension curves versus deformation, showing that for both the dry as the composite immersion in oil showed the same mechanical performance.

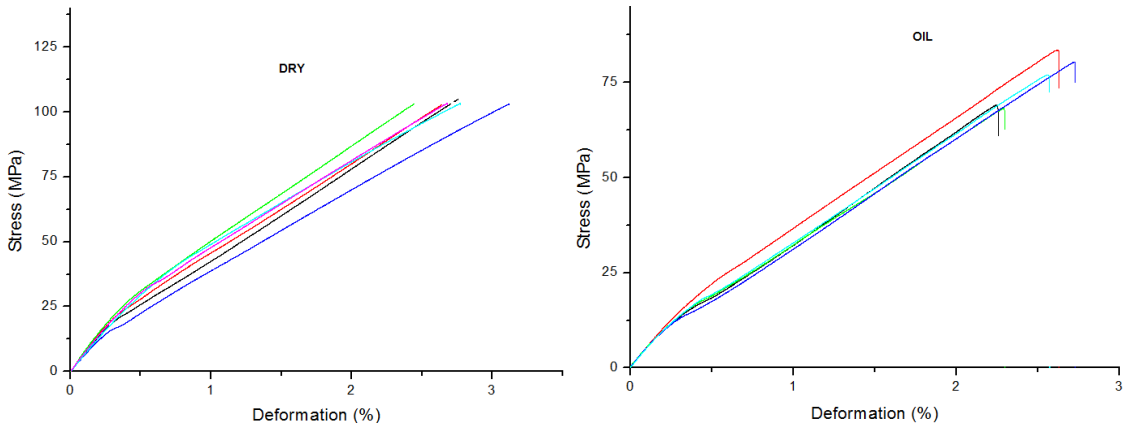

Figure 2. Diagram Stress X Deformation

That after immersion in oil for long period there was a lost in tensile strength, "Table 3", which represents a decrease of approximately 26% in this property, from 102.9 MPa to 76.56 MPa. However, when comparing the stiffness of the material was observed almost unchanged after immersion in oil.

Table 3. Mechanical Properties of the Composite – Uniaxial Tension

Properties	Dry	Oil
Ultimate Strengh (MPa)	102.9 ± 5.2	76.5 ± 6.3
Elastic Modulus (GPa)	0.4 ± 0.02	0.6 ± 0.02

4.4 Characterization of Fracture

4.4.1 Optical Microscopic (MO)

Thus in "Figure 3", there is the final break of the specimens after the uniaxial tensile test for immersion in oil, and dry state where it is possible to observe cracks for all conditions in which the composite was exposed, furthermore it can be seen that in all the micrographs fissure passed from one layer to another of the reinforcing material.

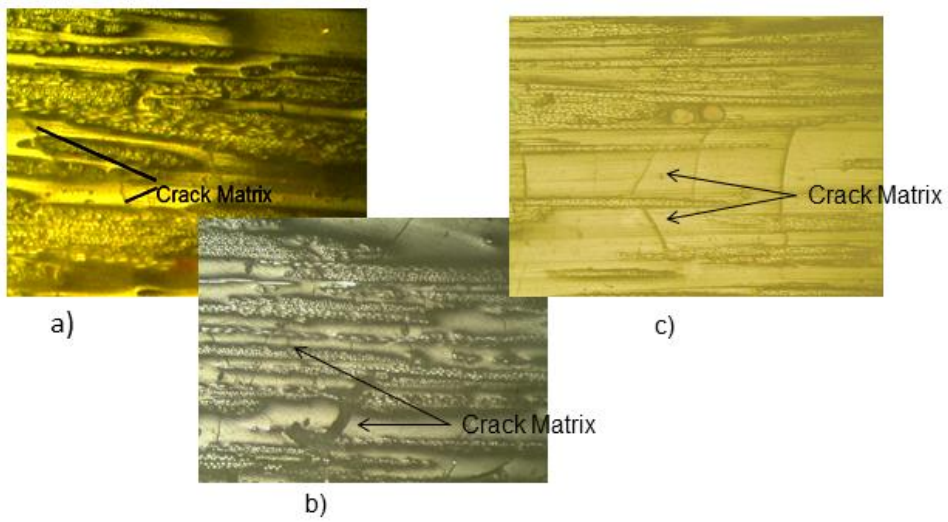

Figure 3. a) Dry Condition. b) Oil Immersion (100x). c) Oil Immersion (50x)

4.4.2 Scanning Electron Microscopic (SEM)

In "Figure 4", it is possible to observe the characteristic of the final fracture for the tested specimens captured with a scanning electron microscopy (SEM). Thus, for the specimen in original condition several damage mechanisms such as fiber rupture, cohesive and adhesive fracture in the fibers and also cohesive fracture was observed in the matrix; and

specimens fracture test after immersion in oil, adhesive fracture and rupture were observed in the fibers, cohesive fracture in the matrix and fiber; being evidenced by the presence of voids.

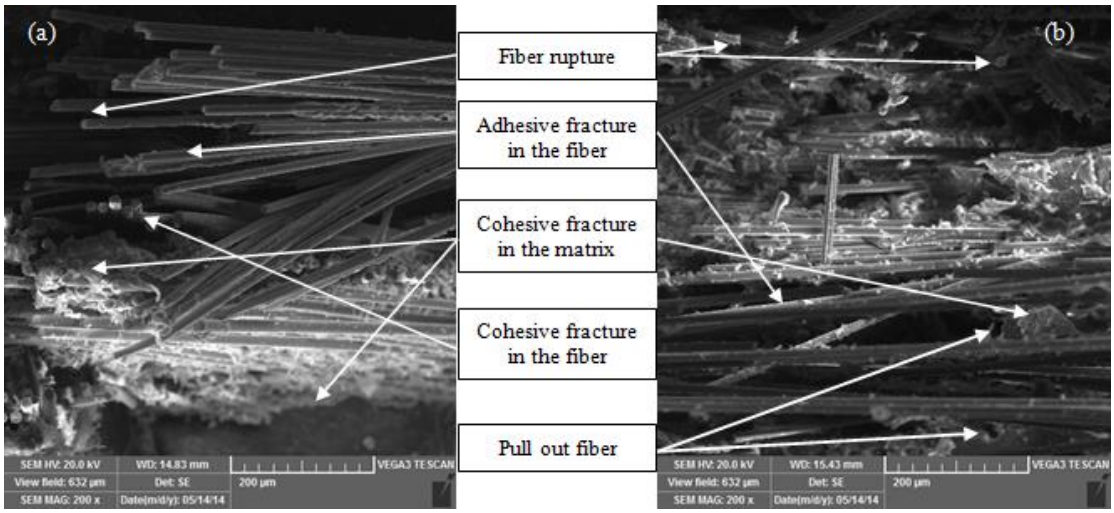

Figure 4. (a) Final Fracture Region of Composite - Original Condition; (b) Final Fracture Region of Composite - Condition Immersed in Oil. (SEM).

5. CONCLUSIONS

The results presented above:

- In the test of moisture absorption, it was observed that the material reached its saturation in period of 60 days of immersion, reaching a percentage of absorption at around 2%. This value was slightly higher, due to migration of water by capillary and voids in the material;
- The polymer reinforced with fiberglass (GRP), after the tensile testing, we observed lost of ultimate strength after immersion in oil, but it was observed that the stiffness remained constant after conditioning;
- Various types of damage was observed in the final fracture for both conditions of the material tested.

6. ACKNOWLEDGEMENTS

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