EFFECT OF WATER AND OIL ON THE STRENGTH OF COMPOSITES MATERIALS

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Abstract. *This works presents the results of investigation of two composites materials used in pipeline repair in the petroleum industry. The studied composites materials had the following constitutions: MC0 - polyureia matrix and fabric glass fiber and MC1 – epoxy matrix and mixed of mat and continuous and aligned fibers. The investigation was made using microstructural and mechanical characterization. The mechanical characterization was made with tensile test, in accordance with ASTM norm procedure, and the microstructural analysis with photographic registration obtained in the optic and stereoscopic microscope. The composite materials were aged by immersion in water and oil at 60 ^{o} C and atmospheric pressure. The mechanical properties and microstructural characterization of the composites were evaluated for a period of 30 days. The evaluated properties were the maximum stress and deformation in maximum stress. The properties were evaluated before and after aging process. The evaluation of the influence of water and oil in the mechanical properties associated with the microstructure characterization were discussed.*

Keywords*. Pipeline Repair, Composite Materials, Pipeline Failure, Properties of Composite Materials*

1. Introduction

Internal and external damage caused by corrosion occur in steel pipelines for oil and gas transportation. Internal corrosion is caused by the presence of humidity and water mixed with acids originated from dissolved gases, mainly CO_2 and H_2S (Palmer and Paisley, 2000). Mechanical damage can also occur in the pipes due to impact loading during their operation. As a consequence of the different source of damage the defective pipe walls normally present a reduction of thickness with the resulting risk of leakage with production, economic and sometimes human life losses and environment damage.

Several methods are used for pipeline repair and recently have been used composite material. In the case of pipe repair using composite materials, these materials are normally made using fiberglass in a polymeric matrix. Repair of external defects with composite materials are already considered permanent whereas the repairs of internal defects are only considered temporary (Palmer and Paisley, 2000).

There is a sequence of operations which must be followed in the application of the composite repair like: careful preparation of the pipe surface, application of a primer layer, application of a layer of resin with the same composition of the matrix of the composite material, application of the necessary layers of the composite and application of an extra layer of material to protect the composite against the environment and ultra-violet rays. The composite material to be applied in the repair can have several configurations depending on the type of fibers arrays and matrix type.

In the present work the mechanical and microstructural characteristics of two composite materials used for repairing steel pipelines for oil transportation are presented. The mechanical characteristics presented are the fracture stress and deformation obtained through tensile tests. The microstructural characteristics were obtained using optical microscopy. The composite materials were aged by immersion in water and oil at 60^o C and atmospheric pressure. The mechanical properties of the composites and microstructural characterization were evaluated for a period of 30 days of exposure. The evaluated properties were the maximum stress and deformation in maximum stress. The properties were evaluated before and after aging process. The evaluation of the influence of water and oil in the mechanical properties associated with the microstructure characterization were discussed.

2. Composite Materials

The composite materials can be classified in accord with matrix and also fiber types. The properties of this materials ware influenced by several factors (Jones, 1998): type of fiber, orientation, distribution, geometric arrange, length, diameter, section, volumetric fraction, interface fiber-matrix and manufacture process.

A large number of the composite materials are used in manufacturing process and production of components and structure militare and aeronautic (Jones, Smith, 1995 and Jones, Chiu, Smith, 1995). The application in the repair of components and structure have been used in the petroleum and gas industry (Leewis, 2000, Venzi 1993 and Frassine, 1997).

3. Effects of Water and Oil in the Properties of Composite Materials

Research of degradation of composite material in water usually involves the matrix plastification, thermal dilatation, absorption of moisture, fragilization, cracking of the matrix and interface fiber-matrix (Shenoi, Wellicome, 1993 and Apicella, Tessieri, DE Cataldis, 1984). The temperatrue is a factor that influence in the mecanism of degradation in water. The deterioration occour by hydrolise process (Apicella, Tessieri, DE Cataldis, 1984 and Perreux, Suri, 1997), compromising the mechanical properties of the composites.

The mechanics properties of composite materials decrease in the presence of water (Karama, Pegararo, Touratier, 1998 and Hong, Yalizis, Frantziskonis, 1995. The plastification of the matrix is the main factor that influence in the redution of the ultimate strength, deformation e elasticity modulu (Morgan, O'Neal, Fanter, 1980).

In the presence of oil, the polymer and composite material also reduce the mechanics properties (Mhieux, Lehmann, Deslignris, 2002 and Shenoi, Wllicome, 1993 and Loos, Springer, 1980).

The degradation and deterioration in the water and oil occour by difusion (Loos, Springer, 1980) and cracking appear in the matrix of composite material (Mhieux, Lehmann, Deslignris, 2002 and Shenoi, Wllicome, 1993).

4. Materials and Methods

Two composite materials were used in this work: MC0 - polyureia matrix and fabric glass fiber and MC1 – epoxy matrix and mixed of mat and continuous and aligned fibers and were produced by manufacture process hand lay up. To obtain specimen for the proceeding test mechanics and microscopic ware produced composites sheet of dimensions 300 mm_250 mm_3 mm.

Table 1 shows the characteristics of the composite materials MC0 e MC1, showing the fibers volume percent, arrangement of the fibers and manufacturing process. The matrix of MC0 and MC1 are polyureia and epoxy, respectively.

Table 1- Characteristics of the Composites Materials.

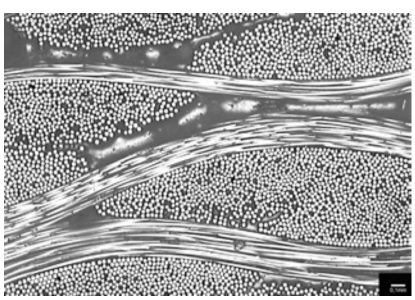
Composite Material	Fiber Volume Percent (%)	Fiber Arrangement	Manufacturing Process
MC0	51,14	Fabric	Hand-lay-up
MC1	58,98	Unidirectional and Mat	Hand-lay-up

Specimen for tensile test ware produced in accord of proceeding ASTM D 3039 (ASTM, 1995). Tensile testing of rectangular specimens of size 210.5 mm_25.4 mm_3 mm was carried out in an Instron universal testing. Aging in water and petroleum to 60^{o} C for a period of 30 days for tensile test and methalografic proceeding. Specimens for microscopic analyses ware prepared by methalografic proceeding. Rectangular specimens having 25 mm length and 10 mm breadth and 2.5 mm thickness were cut from the composite sheets were used for studying the degradation.

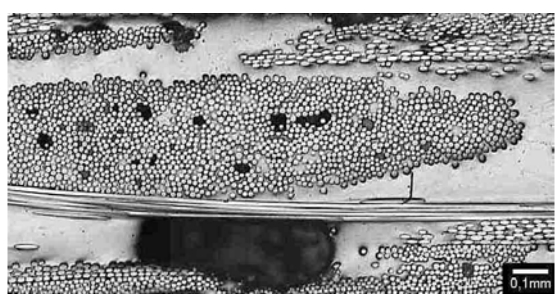
5. Results and discussion

5.1. Micrograph

Micrographs of transverse sections of composites MC0 and MC1 are shown in figure 1, before aging in water or petroleum, obtained in optic microscopy.



(a) Composite MC0 before aging water and petroleum.



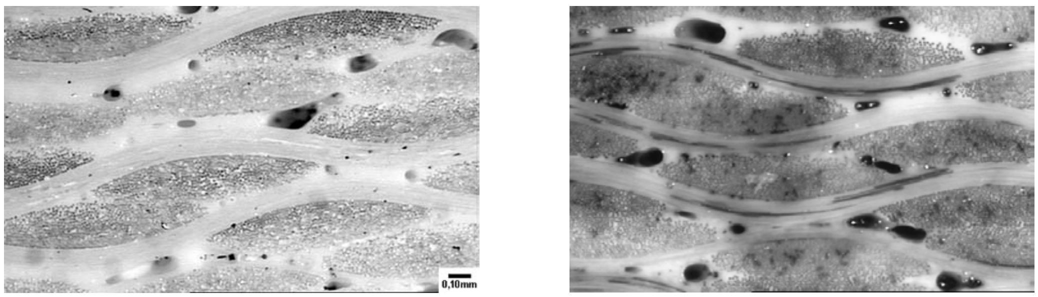
(b) Composite MC1 before aging in water and petroleum.

Figure 1- Micrographs of transverse sections of composites MC0 and MC1 before aging in water or petroleum.

Figure 1.a shows the typical microstructure of a composite with fabric fibers (MC0) whereas figure 1.b shows the transverse section of the unidirectional and mat glass fibers of composite MC1. The composite MC1 presents a large void content compared with MC0.

Figure 2.a shows the microstructure of a composite material MC0 that present polyureia matrix, after aging water and 2.b after aging petroleum.

The microstructures of the figure 2.a and 2.b show that degradation is presented in both composite materials. The images ware obtained in stereoscopic microscopy.

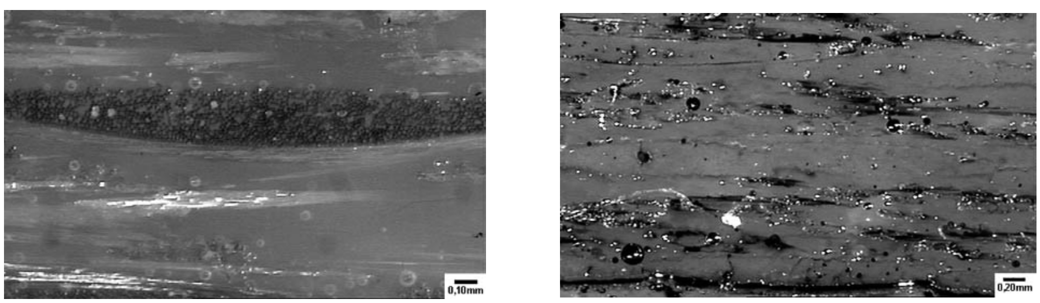


(a) Composite MC0 after aging water. (b) Composite MC0 after aging petroleum.

Figure 2- Micrographs of transverse sections of composites MC0 and MC1 before aging in water (a) and petroleum (b).

Figure 3.a shows the microstructure of a composite material MC1, that present epoxy, before aging water and 3.b before aging petroleum. The images also ware obtained in stereoscopic microscopy.

Degradation ware observed in both aging water and petroleum.



(a) Composite MC1 after aging water. (b) Composite MC1 after aging petroleum.

Figure 3- Micrographs of transverse sections of composites MC1 before aging in water (a) and petroleum (b).

5.2. Tensile Mechanical Properties of the Composite Materials

The tensile tests were done following the standard ASTM D3039 (ASTM, 1995). The results of the tests are shown in Table 2, average of 5 specimens.

Table 2- Tensile Properties of the Composite Materials.

Composite Material	Fracture Stress (MPa)	Fracture Strain (%)
MC0	369,05 ± 6,48	1,30 ± 0,08
MC1	383,75 ± 10,95	2,40 ± 0,10

Tensile test before aging are presented in table 3 to the composite material MC0 and MC1. The aging ware in water and petroleum to 60^{o} C for a period of 30 days.

Composite materials made of unidirectional and mat and fibers presented better tensile properties when compared to composites made of fiber fabrics. Composite material MC1 presented a failure stress 4,0% higher than that of material MC0. The elongation of MC1 is 46% lower than MC0.

Table 3 shows that aging water substantially effects the properties of polymer-matrix composites. The water molecules act as a plasticizer. A 36% and 42% decrease in tensile strength was observed to composite material MC0 and MC1, respectively.

The aging petroleum also reduced in mechanical properties of the composite material. A 12% and 8% decrease in tensile strength ware observed to composite material MC0 and MC1, respectively.

The effects plasticizer and molecules size ware responsive to reduced strain fracture, in accord table 2. The degradation of composites may thus occur not only with the degradation of the individual constituents but also with the loss of interaction between them.

The composite materials absorb water depends upon many factors, such as temperature, volume fraction, orientation of reinforcement, nature (that is permeable or impermeable), area of exposed surfaces, diffusivity, reaction between water and matrix and surface protection.

Table 3- Tensile Properties of the Composite Materials.

Composite Material	Fracture Stress (MPa)	Fracture Strain (%)
After Aging in Water		
MC0	233,87 ± 14,00	0,77 ± 0,22
MC1	219,37 ± 28,84	1,10 ± 0,20
After Aging in Petroleum		
MC0	326,62 ± 22,66	1,10 ± 0,30
MC1	351,80 ± 31,29	1,40 ± 0,30

6. Conclusion

The present work presented here described the influence of water and petroleum ageing conditions on the mechanical properties and microstructure of glass fiber and polymeric matrix composites. The matrix of the composite materials ware epoxy an polyureia. Tensile properties of the composites and the characterization microstructural were determined before and after immersion in water and petroleum for period of time of 30 days at 60^{o} C. The aging in water presented reduction in tensile properties due to the plasticisation effect of water. The aging water presented reduction higher than petroleum both composite materials. The same occur to the strain fracture registered in the test. The characterization microstructural shows degradation in aging water and petroleum both composite materials.

7. Acknowledgements

The authors acknowledge the financial assistance of ANP, CAPES, CNPq, CNPq/CTPETRO and FINEP/CTPETRO.

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9. Responsibility notice

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