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INFLUENCE OF ACIDIC AND SALT MEDIA ON THE FATIQUE BEHAVIOR OF COMPOSITE MATERIALS

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Abstract: Fatigue behavior of composite material of woven fiber glass with polyester resin was investigated in 5% HCl (Hydrochloric acid) and salt water has salinity about 3.5% (35 gram/liter) at room temperature. The specimens are immerged in HCl and salt water for different periods of 2, 3 and 4 days then the fatigue test was carried out. The results showed that the Acidic media (HCl) have signification effect on the fatigue life of composite material when it compared with salt water. On the other hand, the fatigue life of test material decreases when the specimens remain in the HCl and salt water to long period, also it can be notice that the strength reduced by about 20 %, 28 % and 50% for 2, 3 and 4 days respectively for the specimens immersed in (HCl). While the strength reduced by about 8%, 20% and 29% for 2, 3 and4 days respectively for the specimens immersed in salt water.

Keywords: *Fatigue behavior; Composite material; Hydrochloric acid; Salt water.*

تأثير الوسط الحامضي والملحي على سلوك الكلال للمواد المركبة

الخلاصة: تم التحقق من سلوك الكلال للمواد المركبة الالياف الزجاجية مع البوليستر في 5٪ حامض الهيدروكلوريك والماء المالح وبنسبة ملوحة حوالي 3.5٪ (35 غرام / لتر) في درجة حرارة الغرفة. تم غمر العينات في حامض الهيدروكلوريك والماء المالح لفترات مختلفة (2 ، 3 و 4 أيام) ثم أجري اختبار الكلال عليها. أظهرت النتائج أن الوسط الحامضي (حامض الهيدروكلوريك) له تأثير كبير على عمر الكلال للمواد المركبة بالمقارنة مع الماء المالح. من ناحية أخرى، فإن عمر الكلال لمادة الاختبار تنخفض عندما تبقى العينات في حامض الهيدروكلوريك والماء المالح لفترة طويلة, كما يمكن ملاحظة ان قوة التحمل انخفضت بحوالي 20%, 28 % و 50% لمدة (3,2 و 4 ايام) على التوالي للعينات المغمورة بحامض الهيدروكلوريك. بينما انخفضت قوة التحمل حوالي 8%, 20% و29% لمدة (3,2 و4 ايام) على التوالي للعينات التي تم غمرها بالماء المالح.

1. Introduction

The interest in composite materials became common for now, because of began an alternative to metals and alloys. Composite materials such as fiber glass reinforced polyester resin are offer an attractive potential for reducing the weight, as consequence of their high specific strength and stiffness, low cost, good mechanical properties, good resistance and corrosion, good thermal expansion and simplified fabrication. These are increasingly used in many and variety of applications Salt water and Acids have been related to reduction of properties of composite materials [1].

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The microstructure of the matrix degraded more under acid exposure as indicated by increased surface roughness, cracks and diffusion of Acid into the cracks. On the other hand, the Acid media decreases the tensile properties (ultimate tensile strength and modulus) [2].

In NaCl (sodium chloride) solution, two mechanisms can be assumed as subscribe towards the overall hygrothermal effects on the plastics reinforced. First, at the macroscopic level, the 28 expansion of the matrix due to absorption of water may lead to tensile stresses in the fibers and compressive stresses in the matrix which is similar to differential thermal expansion. Second, at the molecular level, the diffusing molecules of water and NaCl may strain the intermolecular bond in the matrix and at the interface. When the resin was unreinforced the only possible mechanism is the microscopic damage and in the reinforced plastics also this mechanism predominates because the fibers have more stiffness than the matrix [3]. Swelling can be seen in the polyester matrix because of the effect of seawater and debonding at the fiber/matrix interface that may decrease the mechanical properties [4].

Eliseu A. Münchow et.al [5] studied the effect of acidic solutions on the surface properties of a micro-hybrid composite resin (Filtek Z-250). Sorption (SO) and solubility (SL) tests was carried out on specimens according to ISO 4049:2009. All solutions used in these tests show decreased hardness and produced similar SO and SL phenomena. The solutions affected negatively on surface properties of the composite resin. A.M. Amaro et.al [6] investigated the impact strength and the flexural properties of glass fibre/epoxy composite after immerged in hydrochloric acid (HCl) and sodium hydroxide (NaOH). The results show that the flexural strength and the flexural modulus decrease with the exposure time and alkaline solution shows higher decrease of the flexural properties than the acid solution. The same behavior was seen for impact strength. David Miller1 et.al [7] studied the influence of synthetic sea water (SSW) on the static and cyclic strength of epoxy and vinyl-ester composites. Specimens were artificially aged at 40°C and 50°C while submerged in SSW and then tested at ambient and off-ambient temperatures. The results show that the salt fog conditioning did not affect the NaCl diffusion of the specimens. Corrosion behavior of pure Al and Al/ Al2O3 composite with five weight percent of Al2O3 particles (5, 10, 15, 20 and 25) were investigated in 0.1M H2SO4 and 3.5 % NaCl solutions at room temperature were investigated by Niven J.Abdal Kadir et.al [8].

It was observed that Al/ Al2O3 composites exhibited excellent corrosion resistance in NaCl medium than in the H2SO4 medium. The unreinforced pure Al exhibited slightly superior corrosion resistance than the composites in NaCl media but the composites had better corrosion resistance in H2SO4 media. A comparative study of effects on characteristic properties of FRP composites when exposed to Distilled water, NaCl- water solution and sea water separately was performed by Dipak Kumar Patel and Shubhonil Banerjee [9]. Composite of E- glass fiber reinforced in epoxy resin (araldite LY556) in 40:60 weight ratios was used. Samples were immersed for 2, 4, and 8 days in the three mediums separately at 60°C and 95% humidity in a humid chamber. Based on

the results, all solutions degraded the mechanical properties and the diffusivity was being maximum in case of 3.2% NaCl solution and minimum in sea water. The immigration in sea water had least effect on mechanical properties. W.Van Paepegem and J.Degrieck [10] presented an investigation of the fatigue performance of plain woven glass with epoxy resin and studied the behavior of composite material under fatgue by using numerical modeling. In this study the test materials are plain woven glass with epoxy resin, the experimental results show that the materials have a quite different damage behavior and that the stiffness degradation follows a different path.

2. Experimental work

2.1. Description Of The Fatigue Test Rig

The fatigue tests were performed by the fatigue test rig in AL-Mustansiriya University/Mechanical engineering department to find the relation between force (Newton) and number of cycle for all test specimens. The parts of the fatigue test rig illustrate in Fig. 1, while Fig. 2and Fig. 3 illustrate the strain gage and digital counter respectively.

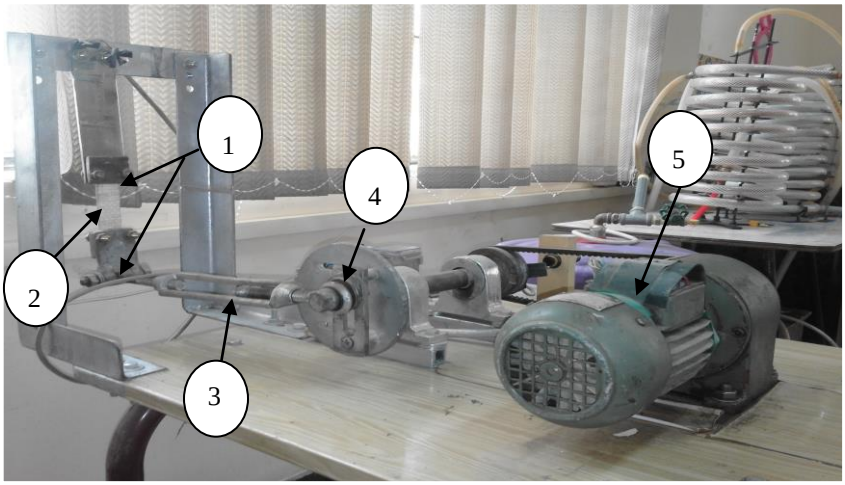

Figure (1): Fatigue test rig: 1.Grips 2- Specimen 3- Connected rod 4- CAM 5- Motor

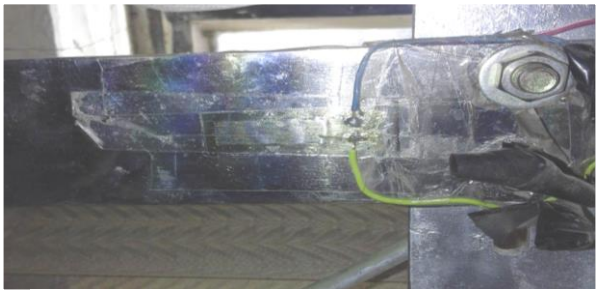

Figure (2): Strain gage.

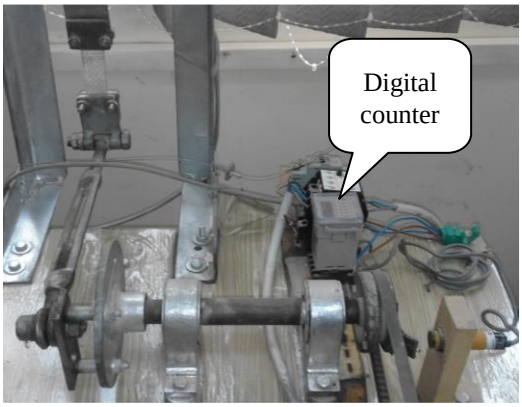

Figure (3): Digital counter.

2.2. Materials and Preparation of Specimens

In this work, the woven fiber glass with polyester resin specimens were tested. All specimens are manufacture by hand layup method with volume fraction (30%). The shape of the specimen is present in Fig. (4).

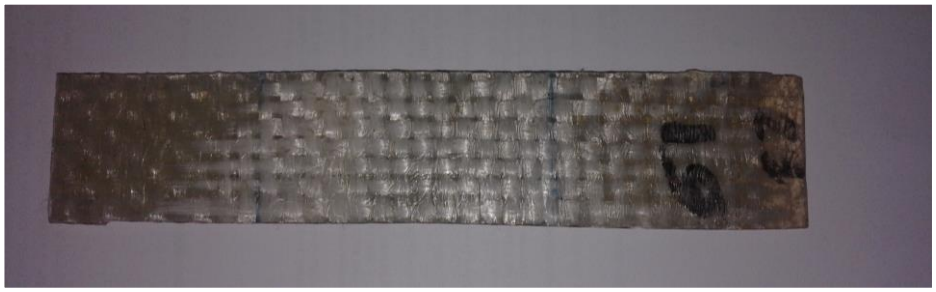

Figure (4): Shape of test specimen.

2.3. Procedure of Experimental Test

2.3.1. Immersion Specimens

After obtaining the final shape of specimens, the specimens were immersed in Hydrochloric Acid and some of these specimens were immersed in salt water at different period (2, 3, and 4 days). These experiments carried out in National Center for construction Laboratories and Research/ Ministry of Construction and Housing.

2.3.2. Fatigue Tests

The test specimen is fixed in the grips then adjusts the displacement ratio and starting the machine. After about an hour and a half from the machine startup, the number of cycles had been reading by using digital counter and the reading of strain meter has been recorded.

3. Results and Discussion

The force versus number of cycles is presented for two groups of test specimens. The first group included the test specimens which were immersed in Hydraulic Acid (HCl) for different periods of 2, 3 and 4 days. The second group consists of the test specimens which were immersed in salt water for different periods of 2, 3 and 4 days. Fig. 5 show the relation between force and number of cycles for the composite of glass with polyester resin without immersed it in HCl and salt water.

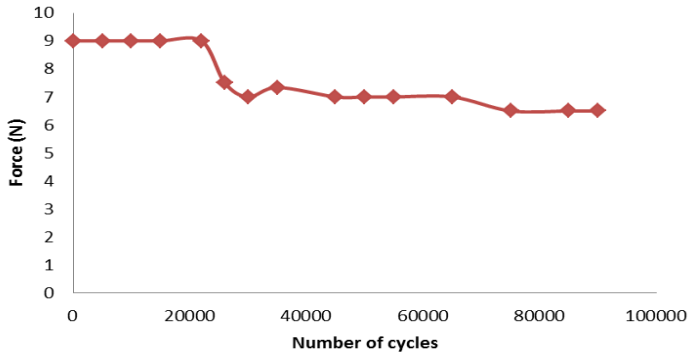

Figure (5): Force vs. no. of cycles for the fiber glass with polyester resin without immersed.

It can be noticed that the material began to degrade significantly after 23000 cycles. The relation between forces – cycles for different periods for the test specimens which immersed in HCl are shown in Fig. 6, Fig. 7 and Fig. 8.

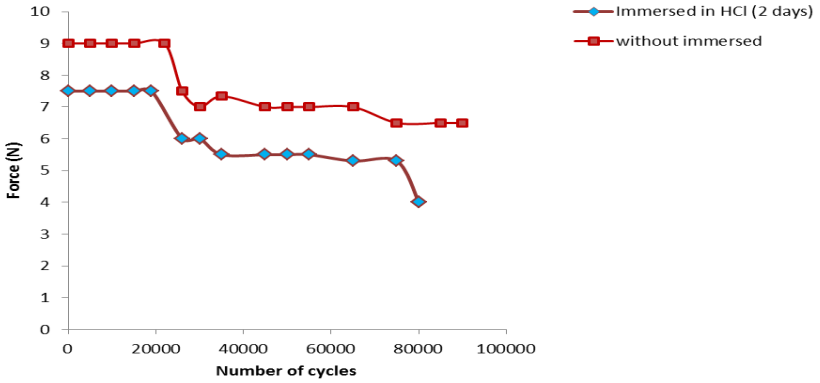

Figure (6): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in HCl (2 days).

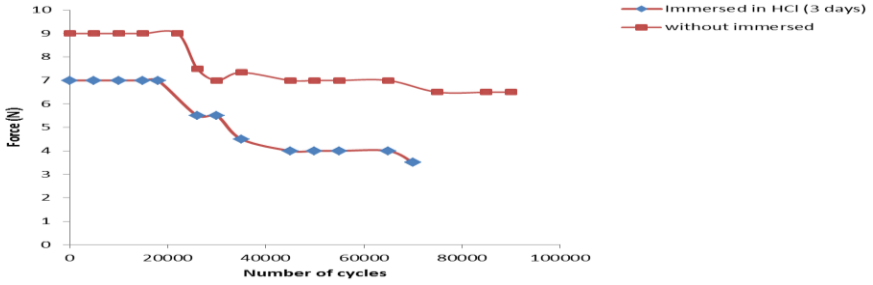

Figure (7): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in HCl (3 days).

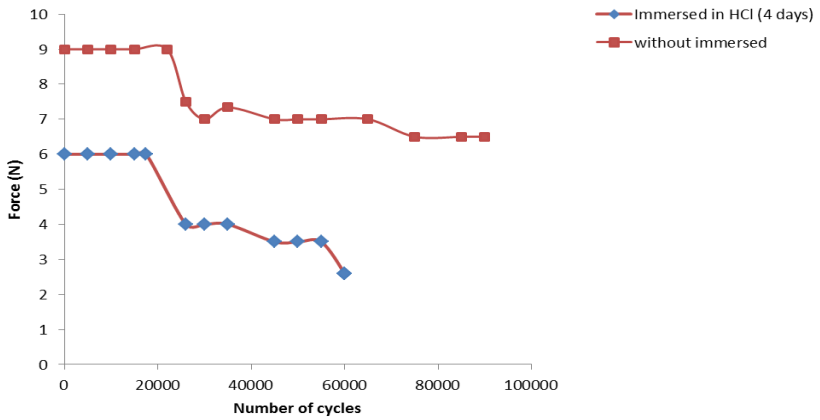

Figure (8): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in HCl (4 days).

It is evident that the Acidic media have a significant effect in reducing the strength of the composite of fiber glass with polyester resin. When comparing the behavior of fatigue for the composite of fiber glass with polyester resin before and after it immersion in the HCl, it clearly that the strength is reduced as illustrate in table (1).

Table (1): Strength reduction of the specimens immersed in HCl for 2, 3 and 4 days.

	period	Strength reduction (%)
1	2 Days	20
2	3 Days	28
3	4 Days	50

In order to clarify the effect of salt water on fatigue behavior of the fiber glass with polyester resin, the no. of cycles vs. force relations are plotted for different periods as shown in Fig. 9, Fig. 10 and Fig. 11.

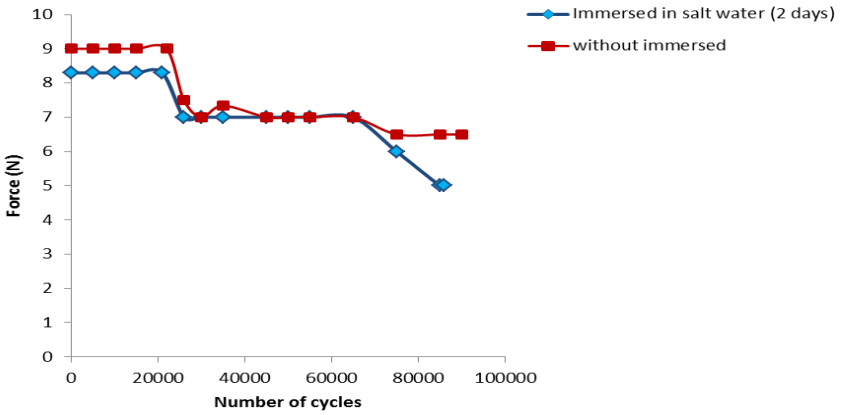

Figure (9): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in salt water (2 days).

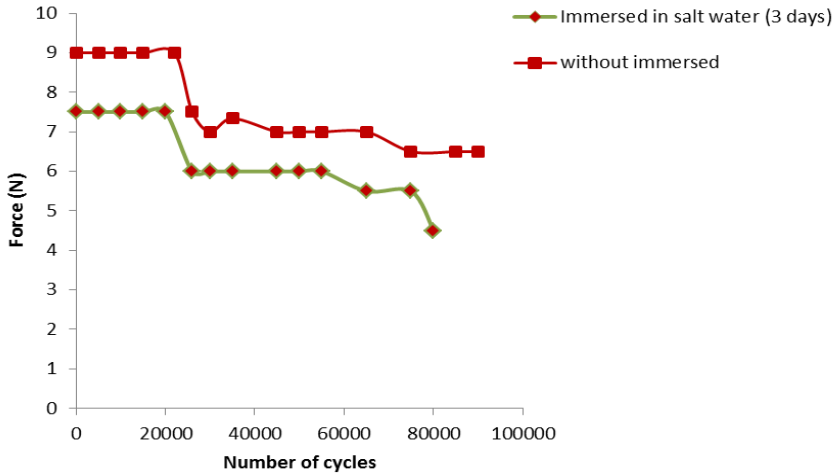

Figure (10): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in salt water (3 days).

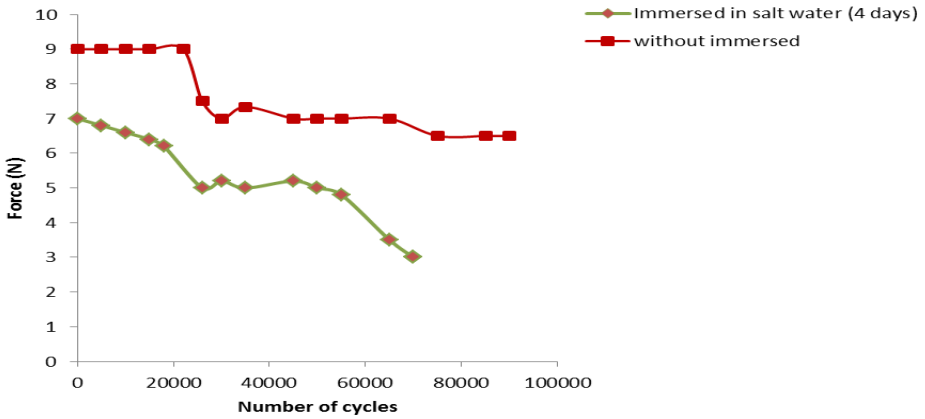

Figure (11): Force vs. no. of cycles for the fiber glass with polyester resin before and after immersed in salt water (4 days).

It can be seen that from the above figures that the salt water effects on the strength of the composite material, but when compared it with fatigue behavior of the first group, it can be seen that the Acidic media have a significant effect on the fatigue behavior of composite material, this is evident from the low values of strength. On the other hand, when comparing the behavior of fatigue for the composite of fiber glass with polyester resin before and after it immersion in the salt water, it observed that the strength it reduced as shown in table (2).

Table (2): Strength reduction of the specimens immersed in salt water for 2, 3 and 4 days

	period	Strength reduction (%)
1	2 Days	8
2	3 Days	20
3	4 Days	29

The variation of no. of cycles for various periods of the composite material was immersed in HCl and salt water shown in Fig. 12 and Fig. 13 respectively.

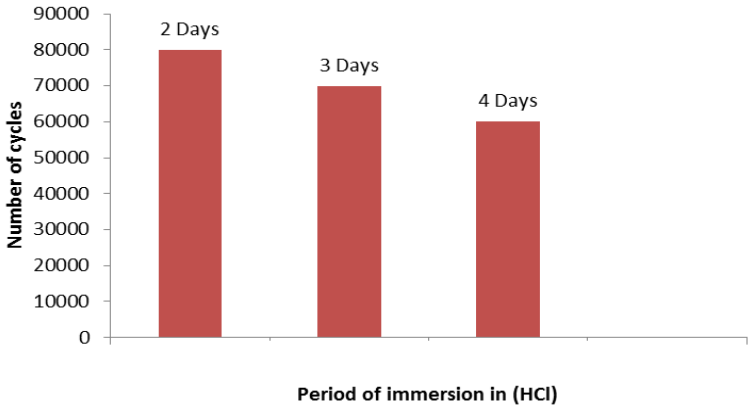

Figure (12): Variation of number of cycles for the composite material immersed in (HCl).

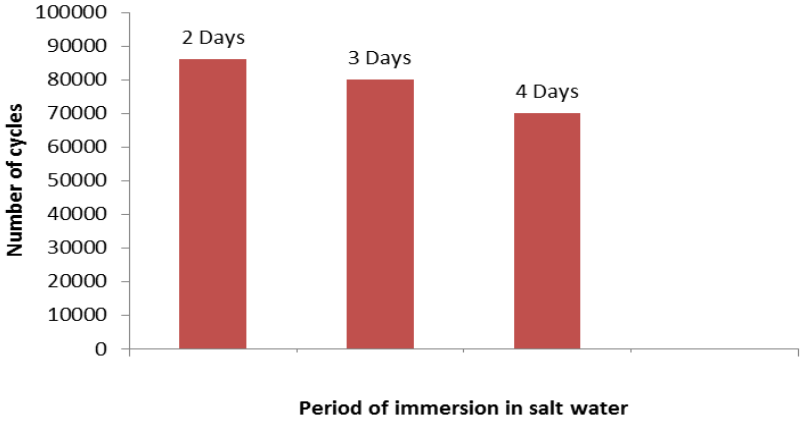

Figure (13): Variation of number of cycles for the composite material immersed in salt water.

The values of maximum and minimum strength force for the material had been tested are presented in the following tables:

Table (3): Maximum and minimum strength for the specimens immersed in (HCl).

period	Maximum strength (Newton)	Minimum strength (Newton)	Time (Hour)
2 Days	7.5	4	1.5
3 Days	7	3.5	1.5
4 Days	6	2.6	1.5

Table (4): Maximum and minimum strength for the specimens immersed in salt water.

period	Maximum strength (Newton)	Minimum strength (Newton)	Time (Hour)
2 Days	8.3	5	1.5
3 Days	7.5	4.5	1.5
4 Days	7	3	1.5

It is worth mentioning that the strength and number of cycles for all materials had been tested reduced when the period of immersion increased. Also, it can be seen that the material began to degrade significantly and strength was reduced after (19000, 18000 and 17500 cycles) for specimens immersed in (HCl) for periods of 2, 3 and 4 days respectively, while the strength of specimens immersed in salt water reduced after (21000, 20000 and 18000 cycles) for 2, 3 and 4 days.

The specimens were viewed under the microscope at different magnification ranges as shown in Fig. 14, Fig. 15 and Fig. 16.

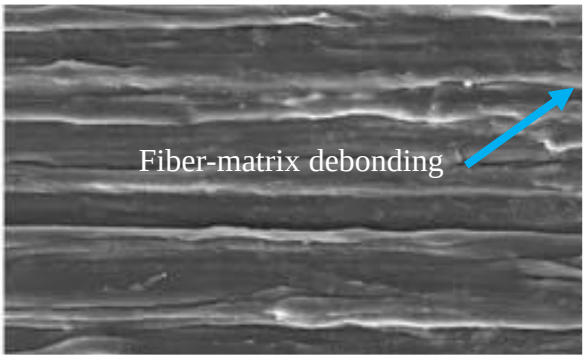

Figure (14): scanning electronic micrograph for specimen without immersed.

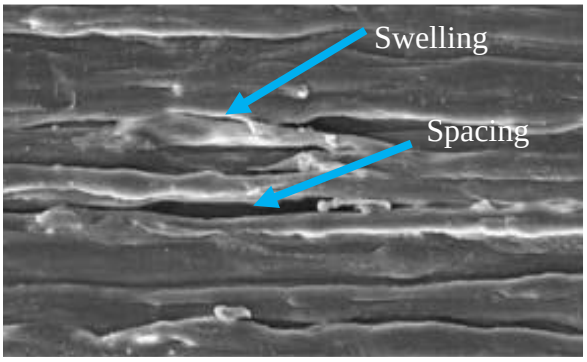

Figure (15): scanning electronic micrograph for specimen immersed in HCl (3 days).

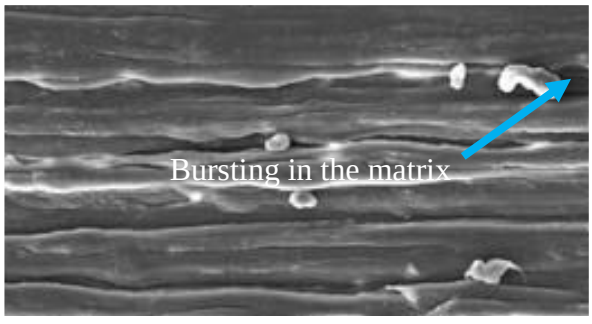

Figure (16): scanning electronic micrograph for specimen immersed in salt water (3 days).

It can be seen from Fig. 14 that the fiber glass there has been no spacing out or swelling, as is evident in specimens immersed in salt water and HCl, but the start of the damage in the matrix and then gradually transferred to fiber glass.

On the other hand Fig. 15 present the specimen damaged which be immersed in HCl, the spacing and swelling can be seen clearly, this is led to the fracture for fiber-quickly and coincide with the damage in the matrix which affected significantly as a result of chemical reactions with HCl, causing it to weaken the bonds of the matrix material. The same behavior can be observed in Fig. 16 but the spacing and swelling in the fiber be less, also it can be seen the bursting in the matrix.

In general, whenever a period of immersion increased for the specimens in the salt water and HCl, there is less time required to develop the damage.

4. Conclusions

Fatigue behavior under effect of the Acidic and salt media was studied for composite material (fiber glass with polyester resin). General observations are:

1. Acidic media (HCl) have significant effect on the fatigue life of composite material when it compared with salt water.
2. The material began to degrade significantly and strength was reduced after (19000, 18000 and 17500 cycles) for specimens immersed in (HCl) for periods (2, 3 and 4 days) respectively, while the strength of specimens immersed in salt water reduced after (21000, 20000 and 18000 cycles) for (2, 3 and 4 days). Depending on the results, the strength reduced by about (20 %, 28 % and 50%) for (2, 3 and 4 days) respectively for the specimens immersed in (HCl). While the strength reduced by about (8%, 20% and 29%) for (2, 3 and4 days) respectively for the specimens immersed in salt water.
3. By scanning electronic micrograph it can be seen clearly the spacing and swelling in the specimens which immersed in HCl and salt water, this indicate that the damage will be developed. On the other hand, the porosity is presence in the specimens immersed in salt water.
4. In general, as a period of immersion increased for the specimens in the salt water and HCl, the time required to develop the damage decreased.

5. References

1. Almeida GS, Poskus LT, Guimarães JG, da Silva EM. (2010). "The effect of mouthrinses on salivary sorption, solubility and surface degradation of a nanofilled and a hybrid resin composite", Oper Dent; 35:105-111.
2. Stamenovic M, Putic S, Rakin M, Medjo B, Cikara D. (2011). "Effect of alkaline and acid solutions on the tensile properties of glass-polyester pipes", Mater Design;32:2456e61.
3. S. K. Rege, S. C. Lakkad. (1983). "Effect of Salt Water on Mechanical Properties of Fibre Reinforced Plastics", Fibre Science and Technology, Volume 19, Issue 4, Pages 317-324

4. K. Liao, C.R. Schultheisz, D.L. Hunston, (1998). "Effects of environmental aging on the properties of pultruded GFRP", School of Applied Science, Division of Materials Engineering, Nanyang Technological University, Nanyang, Singapore 639798.
5. Eliseu A. Münchow, Ana Cláudia A. Ferreira, Raissa M. M. Machado, Tatiana S. Ramos, Sinval A. Rodrigues-Junior, Cesar H. Zanchi, (2014). "Effect of Acidic Solutions on the Surface Degradat ion of a Micro-Hybrid Composite Resin", Brazilian Dental Journal, 25(4): 321-326.
6. A.M. Amaro , P.N.B. Reis , M.A. Neto , C. Louro, (2013). "Effects of alkaline and acid solutions on glass/epoxy composites", Polymer Degradation and Stability 98, 853e862.
7. David Miller, John F. Mandell, Daniel D. Samborsky , Bernadette A. Hernandez-Sanchez and D. Todd Griffith, (2012). "Performance of Composite Materials Subjected to Salt Water Environments", AIAA SDM Wind Energy Session.
8. Niven J.Abdal Kadir, Dr. Payman S.Ahmed and Saja Amer Abdul Majed, (2014). "Influence of Acidic and Salt Media on The Corrosion Behavior of Aluminum Matrix Composites Reinforced by Al2O3 Particles", Eng. & Tech. Journal, Vol. 32, Part (A), No.10.
9. Dipak Kumar Patel and Shubhonil Banerjee, (2008). "A Comparative Study Of Effects On Characteristic Properties Of FRP Composites When Exposed To Distilled Water, NaCl- Water Solution And Sea Water Separately ", Thesis for Bachelor Degree, Department of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela.
10. W. Van Paepegem and J.Degrieck, (2001). "Experimental Set-up for and Numerical Modeling of Bending Fatigue Experiments on Plain Woven Glass / Epoxy Composites", Composite structures, Vol. (51), Issue (1), P.P. (1-8).