Investigation of stress concentration factor for natural composite material

Investigation of stress concentration factor for natural composite material

Ammar Fadhil Hussein[1], Fadhel Abbas Abdulla[*1], Zahra Khalid Hamdan[1], Wasan Abbood Ali[2]

[1]Mechanical Engineering dept. University of Mustansiriyah
[2]Civil Engineering dept. University of Mustansiriyah

[*]fadhel975@yahoo.com , fadhel975@uomustansiriyah.edu.iq

Abstract. In this study, the natural composite materials consisting o2f polyester and palm leaves were used by weight fraction 25%, where the mechanical properties were tested (tensile test) for natural composite materials. Five groups of samples were tested, some of them containing a U-notch and a section containing circular hole with different dimensions and the other section without anything. After the test found that the work of U-notch or a hole in the samples reduced the value of the peak stress for the material and therefore leads to increased stress concentration factor (SCF), Where the results showed the max value of stress recorded for the specimen which has U-notch in one side G2 where the max stress equal 300Mpa, while the test specimen which has circular hole 2mm diameter G5 recorded less stress value about 160Mpa.

Keywords: natural composite materials, polyester, stress concentration factor

1. Introduction

The ease of manufacture, low cost and availability of natural fibers attracted the attention of researchers to promote the use of natural fibers to improve the mechanical characteristics and properties of polymers for structural application and industrial. [1]. Due to the different advantages of natural and vegetal fibers that meet the economic interests of industry such as low cost, innovation and biodegradability, they are environmentally friendly materials, these reasons have encouraged their widespread use in industries [2,3] . The use of natural materials, no doubt will have a significant effect in obtaining low cost, low density and other various mechanical properties that are greatly improved. Stress concentration is obtained in the different mechanical parts that arise when the holes and sudden changes in that part, so are considered the most important factors that cause failure. The most common forms of stress concentration are the sudden changes in geometry, where the transition from one section to another at an angle at the intersection is not an acceptable design, because the stress at that edge is too high. The presence of grooves or cracks in the engineering sections causes the concentration of stress leading to the occurrence of thin cracks that continue to grow as a result of successive loading cycles until failure [4]. the effect of fiber orientation (θ) for fiber reinforced on SCF (stress concentration factor) was studied by N D Mittal [6] in composite laminate have rectangular shape with circular hole in center under transfer static loading by using finite element method. The results were obtained for four different boundary conditions, where it was used three different types of materials to find the sensitivity of stress concentration with hole (in the center) under effect of static loading. V. G. Aradhye [7] calculated the stress concentration SCF of the orthodontic and orthodontic plate is with circular holes (multiple) under tensile stress on the pressure gauge and the

universal computerized test machine. The materials used for the plate are mild steel and epoxy carbon in nature for orthopedic. The results (experimental) are compared with ANSYS results (theoretical) with limited elements. The analytical results by ANSYS show the value of the stress factor in the isotonic plates (MS) and the composite panels are more than the experimental results. B.B. Farande[8] investigated the stress concentration factor around countersunk hole in composite plate experimentally. The material used is carbon epoxy. And stress concentration is determined under tensile loading by using universal testing machine and strain indicator. The investigations are carried out by varying the tensile load and diameter of the hole. The stress concentration characterization of a laminate (carbon/epoxy) carried out by Lotfi Toubal [9]. It can be noted that there is a difference between the results obtained and mentioned in different experiments due to the accuracy of experimental measurements. The resulting pressure in the numerical and analytical models is greater than the experimental results. The load direction effects strain concentration in composite materials woven fabric with holes ; there is a high agreement between an on-axis (weft direction 0) tensile load with those stresses for composite (woven fabric) .

2. Experimental work

2.1. Material and Preparation of Specimens

In this work the samples of natural composite materials were casting from polyester as the base material and Palm leaves used as natural fibers for preparation tensile test samples with weight fraction 25%. The casting method was almost identical to the casting process in the paper [10,11,12] the samples were preparation in several consecutive steps:

1. A glass mold is used with dimensions of (30 * 40) mm and thickness 6mm as shown in figure(1)

Figure 1. A Glass Mold

2. The glass mold is coated with anti-adhesion material.

3. The weight of the palm leaves is measuring that used according to the weight friction which have already been identified and then arrange the palm leaves regularly in the mold as shown in figure (2).

4. The weight of polyester is measured, then added hardener with weight fraction 2% as shown in figure (3).

Figure 2. The Palam Leaves

Figure 3. The Resin

5.The mixture is then poured on the leaves of the palm in the glass mold and left for 24 hours to solidify natural composite material as shown in Figure (4). Finally, the samples are cut by using CNC machine.

Figure 4. Natural Composite Material

The specimens used in this study are five specimens, which classified into five groups as shown in below:

1. Un notch specimens (G1) as shown in figure (5)

Figure 5. Un Notch Specimens (G1)

2. Notch specimen (G2) : these groups includes specimens geometry (one U-notch) form in one side as shown in figure(6)

Figure 6. Notch Specimen (G2)

3. Notch specimen (G3) : these groups include specimen's geometry (two U-notches) form one U-notch in each side as shown in figure (7)

Figure 7. Notch Specimen (G3)

4. Circular notch specimen with circular hole (G4): with hole diameter (2 mm) as shown in figure (8)

Figure 8. Circular Notch Specimen with Circular Hole (G4)

5. Circular notch specimen with circular hole (G5): with hole diameter (1mm) as shown in figure (9)

Figure 9. Circular Notch Specimen with Circular Hole (G5):

2.2. Procedure of Experimental Work

the samples are tested in tensile machine (TINIUS OLSEN H50KT) with the shape and the dimensions of specimen accord to (ASTM-D638M) standards as shown in figure (10) and the tests are held in University of Mustansiriyah /College of engineering/the laboratories of materials engineering department as shown in figure (11)

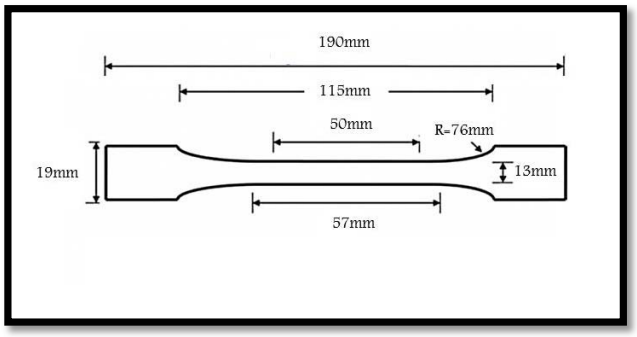

Figure 10. The Sample Dimension of The Tensile Test

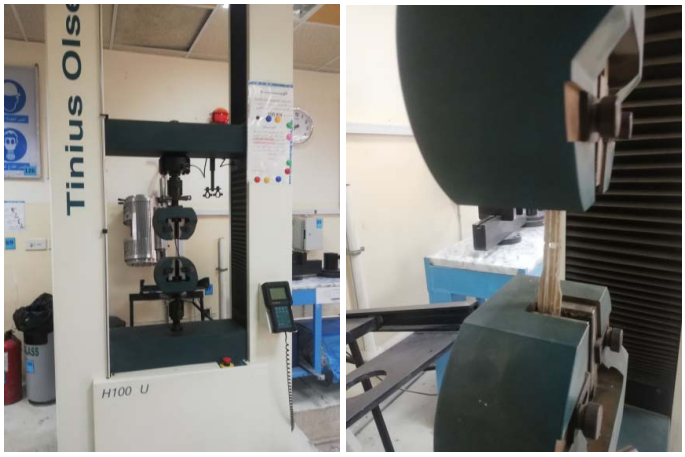

Figure 11. The Machine Tensile Test

3. Results and Discussion

3.1. The Relation of Stress and Strain Relation

The strain versus stress is presented for five groups of test specimens. The first group included the test specimens which without notch. The second and third group consists of the test specimens with notch (U-notch) from one side and two side. The fourth and fifth group consist of the test specimens with circular hole 2mm and 1mm diameter respectively. Figure (12) shows the relation between stress and strain for the specimen without notch. It can be noticed that the material began to degrade after the stress value about 300 Mpa and the max value of stress record about (410 Mpa). The relation between stress strain for different test specimen are show in figure (13), figure (14), figure (15) and figure (16). It is evident that, the max value of stress recorded for the specimen which has U-notch in one side G2 where the max stress equal 300Mpa, while the test specimen which has circular hole 2mm diameter G5 recorded less stress value about 160Mpa.

3.2. Stress Concentration Factor (SCF)

The experimental value of SCF (stress concentration factor) is calculated from a ratio of the peak stress for the specimen without hole to the peak stress for the specimen with hole or notch.

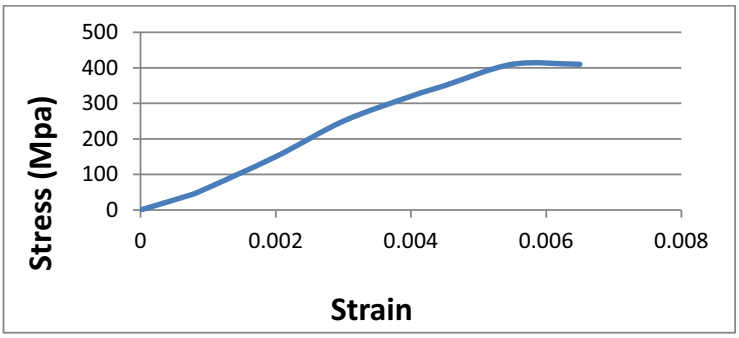

Figure 12. The Relation Between Stress and Strain for G1

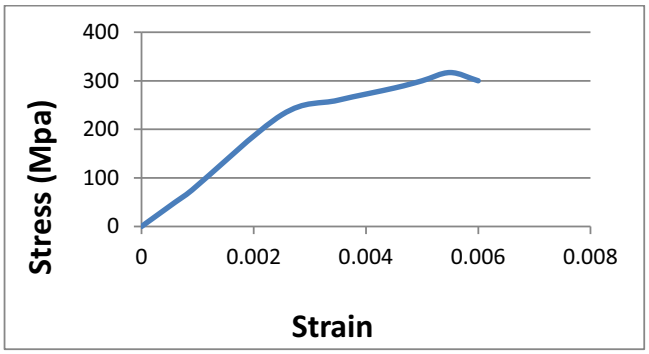

Figure 13. The Relation Between Stress and Strain for G2

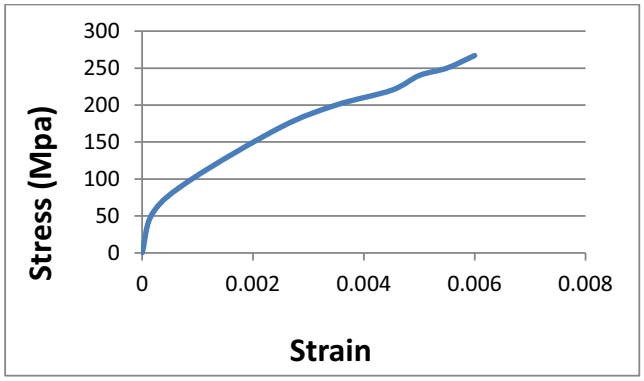

Figure 14. The Relation Between Stress and Strain for G3

This calculation depends on the relationship:

SCF= $\frac{\sigma\ max}{\sigma\ normal}$

It can be noted that stress concentration factor increased with increased the diameter of the notch or hole in the samples, because increasing the diameter caused increasing concentration of stresses around this the region, which leads to failure sample with less peak stress.

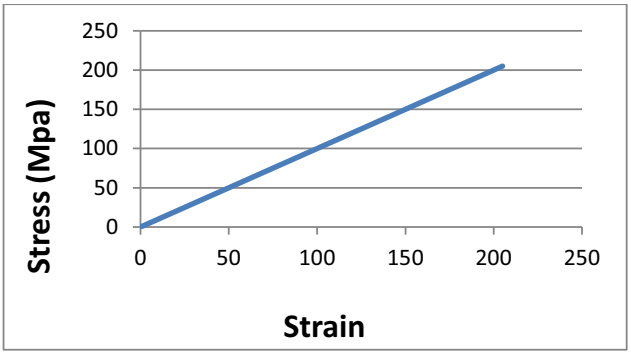

Figure 15. The Relation between Stress and Strain for G4

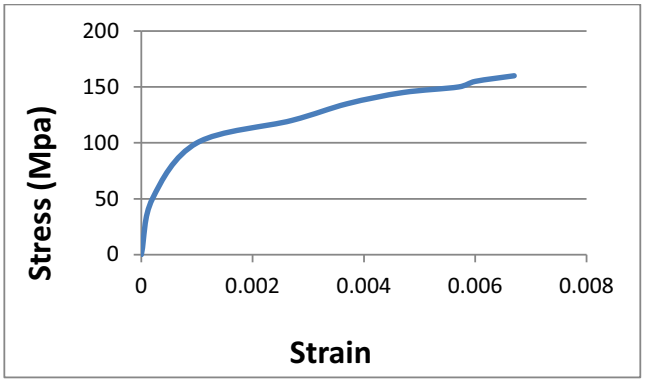

Figure 16. The Relation between Stress and Strain for G5

As shown in the table (1) and figure(17), where it can noticed SCF for G5 more than SFC for G4 with increasing diameter from 1mm to 2mm respectively and peak stress less by 21% .On the other hand, it can be also noticed the peak stress decreased with increased in the number of notch and thus increased the SCF as indicated above where the stress reduced from 300Mpain G2 to 267Mpa in G3 with increasing SCF because in the concentration of stress increased around the area of notch.

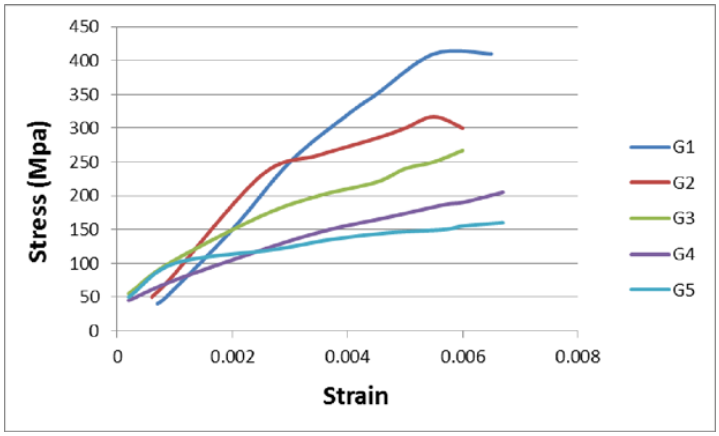

Figure 17. The Relation between Stress and Strain for All Cases

Table 1. The Value of the Peak Stress and The Stress Concentration Factor

The specimens groups	The peak stress(Mpa)	SCF
G1	410	1
G2	300	1.367
G3	267	1.535
G4	205	2
G5	160	2.56

4. Conclusions

The stress concentration factor for natural composite material was Investigated in this study. It can be noticed that the material began to degrade after the stress value about 300 Mpa and the max value of stress record about (410 Map). On the other hand, it can be also noticed the peak stress decreased with increased in the number of notch and thus increased the SCF as indicated above where the stress reduced from 300Mpain G2 to 267Mpa in G3 with increasing SCF because in the concentration of stress increased around the area of notch.

5. Reference

[1] Savita Dixit, Ritesh Goel, Akash Dubey and Prince Raj Shivhare 2017, *Natural Fibre Reinforced Polymer Composite Materials,* Polymers from Renewable Resources, Vol. 8, No. 2.

[2] Dr. A.T. Gouda, Jagadish S.P., Dr. K.R. Dinesh, Virupaksha Gouda H., Dr. N. Prashanth 2014, *Wear Study on Hybrid Natural Fibre Polymer Composite Materials Used As Orthopaedic Implants*, International Journal of Recent Development in Engineering and Technology, ISSN 2347-6435 (Online) Volume 3, Issue 1.

[3] T. Sonar, S. Patil, V. Deshmukh, R. Acharya. *Natural Fibre Reinforced Polymer Composite Material-A Review,* IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684.

[4] J. Sahariand S.M. Sapuan 2011, *Natural fibre reinforced biodegradable polymer composites*, 166/Rev.Adv.Mater. Sci. 30, 166-174.

[5] Nithish Prabhu T, Prithviraj Harish, Dhanush C, Pratheek Palanethra & V.L. Jagannatha Guptha 2014, *Experimental Investigation of Stress Concentration Factor in a Unidirectional Carbon/E-Glass Fiber Hybrid Composite*, International Journal of Metallurgical & Materials, Science and Engineering (IJMMSE) ISSN(P): 2278-2516; ISSN(E): 2278-2524 Vol. 4, Issue 2.

[6] N D Mittal and N K Jain 2008, *Effect of Fiber Orientation on Stress Factor in a Laminate with Central Circular Hole under Transverse Static Loading ,* Indian Journal of Engineering & Materials Sciences, Vol .15 December ,pp.452-458.

[7] V. G. Aradhye and S.S.Kulkarni 2015, *Experimental Investigation of Stress Concentration Factor in an Isotropic and Orthotropic Plate with Multiple Circular Holes* , International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 11, November.

[8] B.B. Farande and V. V. Kulkarni 2016, *Experimental Investigation of Stress Concentration Factor around Countersunk Hole in Composite Plat,* International Journal of Current Engineering and Technolog" E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[9] Lotife Toubal, Moussa Karama and Bernard Lorrai 2005, *Stress concentration in Circular Hole in Composite Plate,* Elseiver ,Composite structure 68, 31-36.

[10] Zahra khalid Hamdan and Dr. Fadhel Abbas Abdullah, "*Investigation of the Adding Nano Particles to Composite Material under High Strain Rate Torsion with Hygrothermal Effect*, International Journal of Mechanical Engineering and Technology Vol 9, Issue 6, June 2018, pp. 1098–1114.

[11] Fadhel Abbas Abdullah, Nader Majed Moustafa, Ammar Fadhil Hussein." EFFECT OF UV-RADIATION ON FATIGUE BEHAVIOUR OF NATURAL COMPOSITE MATERIALS", International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 8, Issue 4, Aug 2018, 727-740.

[12] Ahmed Ali Farhan Ogaili, Ehsan Sabah Al-Ameen, Fadhel Abbas Abdulla." An experimental study for different types of natural fiber reinforced composite material ", Periodicals of Engineering and Natural Sciences, Vol. 7, No. 4, December 2019, pp.1698-1709.

Acknowledgments
The authors wish to thank to the University of Mustansiriyah (www.uomustansiriyah.edu.iq) and in particular the College of Engineering/ Mechanical Engineering Department and Materials Engineering for the use facilities in their labs.