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Composite Materials in Automotive Industry : Review

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Abstract:

Composite materials play a significant role in new automotive and aviation industry due to its significant characteristicslike high strength - weight ratio which is led to reduce the weight of structures of vehicles and better fuel efficiency . This paper will review composite materials fatigue failure when it is underthe repeated cyclic loads taking in the consideration the main instruments and procedures to evaluate the fatigue strength for different types of composite materials .

Keywords--Composite materials, fatigue strength, S-N curve, cyclic loads.

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I. Introduction

Composites have a high strength and hardness to weight ratio, as well as a long fatigue life. Because the composite materials are non-homogeneous and anisotropic, theybehave differently from that of homogeneous and isotropic materials like metals. Varying kinds of failures, interactions between layers, and various growth rates mayhappen in composite materials as a result of this complexity. The most common failure modes are [1]:

1. Gaps in the matrix.
2. Cracking of the Matrix.
3. Failure of Fibers.
4. Fiber buckling .
5. The damage of the fiber-matrix connection.
6. The layers of Separation.

Composites are being regarded in the automotive industry to create vehicles that are safer, lighter, and more fuel-efficient. The fiber-reinforced composite is manufactured up of a high-strength fiber (such asglass or carbon) embedded in a matrix material (polymer and metals such as Al, Mg, and others) that can provide improved characteristics over the individual materials. Composite materials used to manufacture many components like the roof, seat, steering wheel,hatch , dashboard, mats, interior and exterior panel,energy absorber wheels, engine cover and leaf spring [2].

Fatigue failure is a term used to describe the long-term damage that dynamic loads cause on engineering structures and materials. When repetitive strains impinge on a material at tensions much below the yield stress, this phenomena occurs. New commercial and military aircraft vehicles and space rockets make extensive use of the best materials available, which have reduced density, higher strength, and stiffness, as well as a reasonable cost, excellent fatigue resistance, and are more stable at a variety of temperatures [3].The good fatigue features and fatigue attitudes of composite leaf springs have inspired commercial manufacturers to use composite materials rather than steel for vehicle suspension systems [4-9]. This paper will review the recent researches about the fatigue failure of composite materials.

II. Literature Review

AmélieMalpot et al. The tension fatigue of the glass fiber reinforced polyamide resin reinforced composite was investigated in this study. A static tensile test was used to characterize the material's mechanical properties. Two layups, denoted $[(0/90)_3$ and $[(45)]_3$, were investigated to determine the effect of fiber direction in the material. The optimization step was required in order toreview the coupon shape for fatigue tests. S-N curves for both layups carried out under a specified stress ratio of 0.1 (R). Three models of fatigue life were presented according to these curves: one based on hybrid model, constant-life diagramsand a two-material-parameter model. The composite $(45)_3$was analyzed using the S-N curve. Fatigue tests were performed using a combination of an acoustic emission monitoring and infrared camera to evaluate fatigue. The peak temperature recorded. These three parameters, in conjunction with the evolution of the secant modulus, are excellent indicators of the degree of failure in the composite materials. Eventually, SEM analyses of the post-mortem data were achieved. Conducted in order to determine the mechanisms of failure that occur within the composite during fatigue tests [10].

VahidGhaffariMejlej et al. The goal of this article is to improve a model for predicting the material property degradationin addition to fatigue life of oriented composite laminates under different stress ratios. The influences of stiffness reducing strength were thought to provide a more accurate prediction than the stressbased method. The Hashin criteria were utilized to evaluate the point of failure initiation in the matrix, fiberand in-plane shear of layers[11].

VelusamyMugeshRajaa, SekaranSatheesKumarb. Carbon fiber reinforced polyester suspension was preferred for this study due because of its flexibility. Leaf springs with a 20 % short carbon fiber reinforced polyester, a 20% length carbon fiber reinforced polyester, and a 20% unreinforced polyester content were molded and their joint strength determined. We conducted static performance evaluations of moulded leaf springs to determine their energy storage capacity, capability and strain rate sensitivity. Check joints were under completely reversed fatigue loads. the performance of leaf springs was evaluated using a range of loads up to 2 $x10^7$ cycles. SEM analysis revealed the tensile surface failure morphological characteristics of the cracks. The results showed that carbon fiber has a higher load utility than the other materials considered[12].

Ali S. Al-Turaihi et al. The influence of volume fractions (0%, 10%, and 20%) on the fatigue behavior of an unsaturated polyester matrix reinforced with chopped E-glass fiber was investigated numerically and experimentally in this paper. Hand layup technique was used to manufacture the composite materials, which were composed of E-glass fibers and polyester resin. The experimental tests achieved to determine the material's mechanical properties such as fatigue tests under reversed load and tensile test. The datashowed that increasing the volume fraction from 0% to 20% increased the tensile strength and elastic modulus of such composites by 44.4% and 60.8%, whereas the fatigue strength increased by approximately 45% by increasing the volume fraction from 0% to 20%. The numerical section employs the finite element method in conjunction with the ANSYS/16 finite elements software to compare with experimental results, and good agreement between them [13].

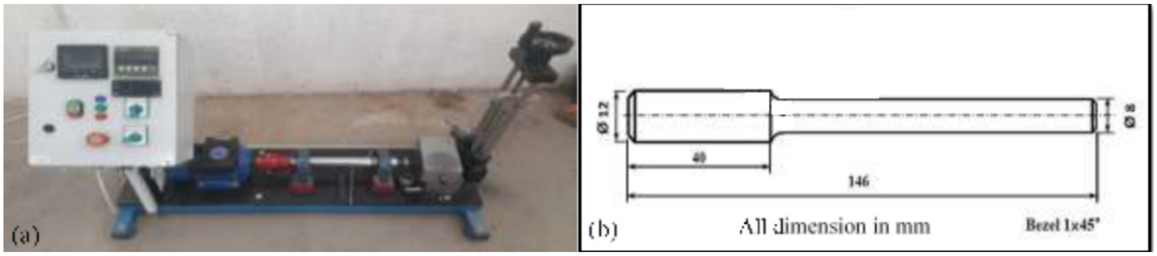

Fig 1. Fatigue testmachine and specimen dimensions [13].

Najim A .Saad et al. The fatigue failure behavior of composite materials based on Polyphenylene sulfide (PPS) reinforced with glass fiber and carbon is investigated in this work. The laminated technique has been used to prepare different composite materials, and the layers stacking process has been used to produce the composite plate. In the stacking process, the pressure and temperature are (300C, 1.7 MPa (250psi) and for (30 min). The result showed that adding layers of carbon fiber to the material boosts the fatigue strength [14].

Trevor Sabiston et al. The fatigue test development and fatigue behavior of a biaxial [0/90] carbon/epoxy non-crimp fabric composite for automotive applications were the subjects of this article. At room temperature and 130 °C, a modern fatigue test specimen was successfully developed R=-1. Without using an anti-buckling fixture, the designed test sample prevented buckling during testing. A uniform strain distribution on the surface of this sample geometry was also found using 3D digital image correlation strain mapping. The fatigue behavior at room temperature and at 130 °C is matrix dominated, according with outcomes of fatigue tests [15].

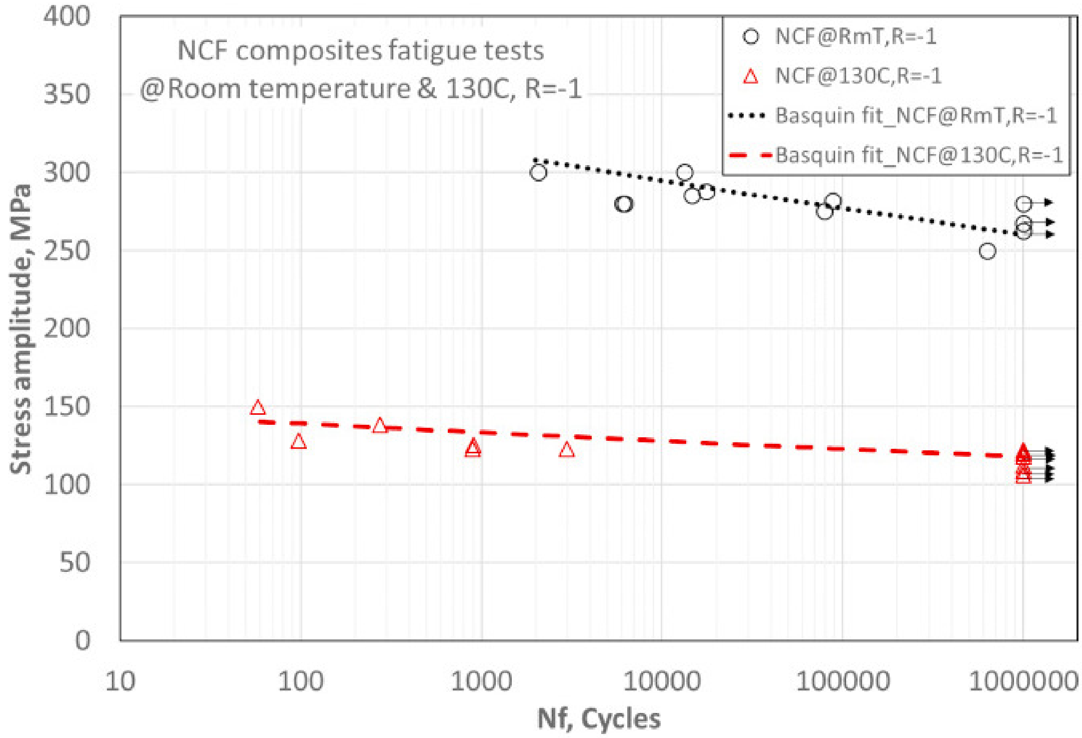

Fig 2. comparison between Basquin equation with fatigue test results at130 °C room temperature [15]

Kazem Reza Kashyzadeh et al. The goal of the research was to analyze the fatigue properties of the composites by studying the fatigue behavior of their components. To achieve this goal, first and mainly, modeling and simulation were required. Glass fiber (E) and matrix (epoxy) fatigue tests were done independently.

Using Finite Element Software (Ansys). After that, it was able to determine the S-N graph of a unidirectional fibrous composite under various situations. Next, axial tension loading with R=0.1 stress. The results of fatigue testing are based on experimental data. They were in satisfactory accord with each other. Extend SN as a result .Composite curve based on three-point bending fatigue .Get fatigue damage curves and investigate the impact of fiber angle on fatigue damage. Fibrous composite materials with unidirectional fibers are subjected to fatigue degradation [16].

AgnieszkaDerewoko and Roman Gieleta. The research demonstrates a numerical method for calculating the laminated carbon–epoxy composite's fatigue strength. Experiments were analysed to investigate the complete set of stiffness characteristics Eij, Gij, ij, strength propertiesi,n, i,n., and S-N curves. The material anisotropic model of the particular composite layers was subjected to static and fatigue numerical simulations.The specimen's numerical model was created using eight-node 3D finite elements with the composite's properties.The contact problem between the composite layers was considered, allowing for the reflection of reciprocal interaction. The state of effort analysis and fatigue life assessment of the composite were also part of the numerical inquiry. The MSC.Fatigue code was used to evaluate the fatigue life of the composite. For composite specimens built of CE 8201-245-45/120 prepreg, model verification and numerical analysis were performed. The experimental resultsshowedthat the locations with the minimum fatigue life, as determined by numerical procedure, were in the gauge portion area [17].

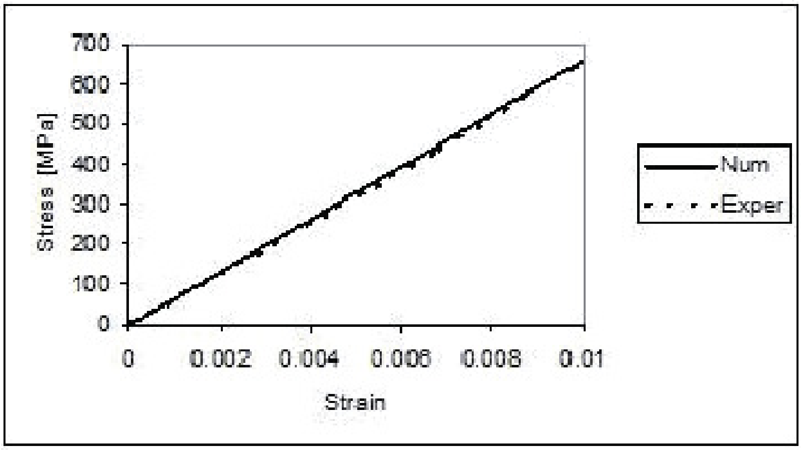

Fig 3. Compare betweenthe experimental and numerical results [17].

M Zaludek et al. Under cyclic repetitive bending stress, this article evaluated the lifetime of laminated materials made using several manufacturing procedures (vacuum bagging ,manual laminationand prepreg technology with oven curing). Composite materials with epoxy matrix and carbon reinforcement and second composite epoxy system with glass reinforcement, and also third prepreg systems fatigue tests were conducted using cyclic bending loads in a three-point system. At 90 % and 80 % of the maximum breaking stress, the number of cycles fractured the material was evaluated experimentally [18].

Mahmoud Baratia et al. carbon fiber reinforced epoxy fatigue behavior of was evaluated using a thermographic method based on surface temperature change in this work. The authors used four layers of woven carbon fibers with an equal weight ratio of epoxy glue to make composite samples. They measured stress levels in self-heating and classical fatigue testing using quasi-static tensile tests. R= 0.1 with frequency of 10 Hz, load controlled fatigue experiments were run. The principal mechanisms producing energy dissipation in fiber reinforced epoxy under cyclic loading were attributed to fiber fracture ,matrix cracking and interface cracking/friction.The fatigue tests analysis (determination of theYoung's modulus and hysteresis area) .The energy dissipation processes were examined based on the findings of self-heating tests. It's worth mentioning that the data acquired by self-heating measures are in good agreement with those obtained using traditional methods. In other words, an empirical relationship between self-heating and traditional tiredness outcomes could be examined. Furthermore, there was a direct relationship between the energies dissipation and stable temperatures in the self-heating experiments. ABAQUS software, which is commercially accessible, was used to do a finite element simulation.Modeling of temperature fluctuations in specimens subjected to cyclic loadings was also done [19].

Catangiu A. et studied thebehavior of bending fatigue of glass fibers and epoxy resin plate. In order toimprove fatigue behavior, the glass fiber in the longitudinal direction of samples has been found [20].

Marin, J.C et al. The fatigue behavior of cross ply and angle ply composites was investigated. The fatigue life of the cross-ply composite was non-linear, whereas the fatigue life of the angle-ply composite was linear[21].

III. Conclusions

The aim of this paper was presented the importance of composite materials in new automotive industry to its significant properties such as light weight and high strength and the ability to replace the traditional materials such as steel with composite materials. Many types of damage can occur in composite like fatigue failure due to the repeated cyclic loads. The fatigue test can be achieved experimentally and numerically and the fatigue life could be in by increasing the volume fraction of fibers. For the future works , it is recommended to add nano materials to composite materials and study the influence on the fatigue life.

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