Low Cycle Fatigue Failuer of Composite Materials/Aluminium Alloys At Different Heat Treatments Prossece – A review

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Abstract -Aluminum alloys and composite materials are of great technological importance. One of the essential goals in the fatigue process study is the prediction of the fatigue life of a structure or machine component subjected to a given stress—time history, it is subjected to repeated loading and unloading or alternating stresses, over a long period of time. Several parameters influence fatigue life of a component like grain size, corrosion, frequency of loading, vacuum, average mean stress, ductility, surface finish, microstructure, temperature, alloying element etc.

The shape of the structure will significantly affect the fatigue life, square holes or sharp corners will lead to elevated local stresses where fatigue cracks can initiate. Round holes and smooth transitions or fillets are therefore important to increase the fatigue strength of the structure. Examples of where Fatigue may occur are: springs, turbine blades, airplane wings, bridges and bones. Mechanical properties and the micro structure of material is affected under cyclic loading.. Heat treatment processes for increasing the strength and hardness of aluminium/composite materials utilize the mechanism of precipitation hardening. The micro structural and mechanical characterization of heat treatable for composite materials/aluminum alloys are very much affected by the fatigue. For fatigue failure of a material a heat treatment process or any nano fluids can be used for heat treatment and Temperature dependents on heat transfer co-efficient and the wet ability of the medium that are the two important parameters that can be used to characterize a nano quenchant to assess its suitability for industrial heat treatment. Metal matrix composites (MMCs) are promising materials for lightweight, high strength structural applications. In particulate MMCs non-metallic particles are incorporated in metallic alloys to improve their elastic modulus and strength. However, introducing reinforcement particles with high modulus to the matrix alloy can reduce the fracture toughness and change the fatigue resistance of the material. The effects of reinforcement on cyclic fatigue damage and crack initiation, its role on constraining matrix plastic flow during cyclic deformation and the response of the material are important aspects in low cycle fatigue (LCF) of MMCs.

The present work gives a broad review of the available literature on low cycle fatigue Failure of aluminium alloys and composite materials analysis and effects were investigated in terms of microstructure analysis and mechanical properties by tensile tests and hardness measurements under different heat treatment process.

Index Terms—low cycle fatigue damage, mechanism of metal failure, heat treatment, microstructure

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1 INTRODUCTION

All materials have different properties that result in advantages and disadvantages. Study and understanding of these properties is critical to the design of a mechanical system and the selection of the correct materials for a given part. One crucial failure mode is fatigue. Fatigue is the weakening or failure of a material resulting from prolonged stress. However, it is understood that when a mass is repeatedly cyclically loaded at a location on the material, cracks begin to form. These cracks spread enough to eventually cause failure and break the piece at the location. Consequently, when designing a mechanical system, it is important to know these limits. Not only could catastrophic fatigue failure cause a large loss in money due to a poor design but it could result in a loss of lives as well. Critical examples of fatigue failure range from train axles to wing cracking on airplanes [1].

The damage evolution mechanism is one of the important focuses of fatigue behavior investigation of composite materials and also is the foundation to predict fatigue life of composite structures for engineering applications [2].

The classical way to describe fatigue consists of splitting the domain of the numbers of cycles to rupture into three parts corresponding to different strain behaviors and also different fields of applications. Elasticity corresponds to relatively small stress amplitudes, which induce large numbers of cycles to failure (larger than iü cycles); this is “high cycle fatigue HCF”. Elasto-plasticity corresponds to stresses above the yield stress, which induce lower numbers of cycles to failure (smaller than io4 cycles); this is “low cycle fatigue LCF”. Elasto-visco-plasticity also corresponds to small number of cycles to failure (smaller than 10″ cycles), but with time effects induced by creep, it is generally called “creep fatigue interaction” [3].

The cyclic stress - strain path are dependent on the material microstructure [4]. Fatigue cracks frequently initiated

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from intensively stress concentration regions, increasing volume fraction and particulate sizes result in early crack initiation [5]. Aging resulted in the formation of second phase with associated reduction in the toughness and LCF lives of the alloy [6]. Fatigue life was found to decrease with increase in the duration of hold time in both tension and compression and it is increased and decreased according the type of heat treatments [7,8]. Alloying can increase the strength; hardness; electrical and thermal conductivities; corrosion resistance or change the color of a metal. The addition of a substance to improve one property may have unintended effects on other properties e. g. the best way to increase the electrical and thermal conductivity of copper is to decrease the impurity levels [9 - 11].

Cyclic fatigue involves the microstructural damage and failure of materials under cyclically varying loads. Structural materials, however, are rarely designed with compositions and microstructures optimized for fatigue resistance. Metallic alloys are generally designed for strength, intermetallics for ductility, and ceramics for toughness; yet, if any of these materials see engineering service, their structural integrity is often limited by their mechanical performance under cyclic, loads [12].

2 Damage Accumulation For Low Cycle Fatigue

S. Khan et al. [13] studied the Detection of cracks in A12024 T351 specimens subjected to low cycle fatigue loading by a certain nondestructive inspection technique is demonstrated.

I. A. Volkov et al. [14] introduced a ‘mathematical model that describes the processes of fatigue damage accumulation in structural materials (metals and alloys) under rnultiaxial disproportionate combined thermomechanical loading is advanced from the standpoint of the damaged medium mechanics, and founded the long-term experimental and theoretical investigations of fatigue damage accumulation in structural materials have demonstrated that fatigue covers three essentially different regions of cyclic loading.

J. Szusta, A. Seweryn [15] states that the fatigue damage accumulation model created to analyse fatigue life of structure elements operating in conditions of multiaxial, non-proportional low-cycle loadings. And they used the approach connected with the critical plane in the presented model. These were preceded by uniaxial loading state tests (cyclic tension—compression or torsion) on the basis of which parameters of the calculation model should be calculated.

U. Sánchez-Santana et al [161 studied the dynamic response of fatigue damaged 6061-T6 aluminum alloy and AISI 4140T steel specimens subjected to impact loading was investigated. And they founded the quasi-static mechanical properties of aluminum are not affected by the way the fatigue damage is induced. The dynamic properties, however, are sensitive to the previous fatigue damage, but are not affected by the strain rate, and showing how the previous fatigue damage can modify the quasi-static and dynamic mechanical properties of the tested materials.

Zhi Yong Huang et al [17] while Continuum Damage Mechanics model is employed to estimate the fatigue damage of LCF and is extended to VHCF regime. The VHCF damage is obtained from varying test resonance frequency of specimen. Moreover, the effect of LCF load on VHCF is studied by an improved cumulative damage model they investigated the low carbon—manganese steel LCF and VHCF behavior, respectively. Then, cumulative fatigue damage tests, with first LCF level followed by VHCF loading have been executed. Fatigue damage models based on CDM are applied to describe the LCF, VHCF damage evolution and their cumulative fatigue behavior.

M. Naderi, M.M. Khonsari [18] Introduced an experimental approach to fatigue damage in metals based on thermodynamic theory of irreversible process. And an irreversible Fatigue damage is progression of cyclic plastic strain energy that reaches its critical value at the onset of fracture. And irreversible cyclic plastic energy in terms of entropy generation is utilized to experimentally determine the degradation of different specimens subjected to low cyclic bending, tension- compression, and torsional fatigue. Experimental results show that the cyclic energy dissipation in the form of thermodynamic entropy can be effectively utilized to determine the fatigue damage evolution. An experimental relation between entropy generation and damage variable is developed.

A. Seweryn, A. Buczynski, J. Szusta [19] description of damage accumulation for analysis of fatigue life of structural elements under non-proportional loading states. Damage accumulation rule has been formulated incrementally and connected with a monotonic work-hardening curve, and They proposed model of damage accumulation enables to define the number of cycles or the time of safe application of complex fatigue loads to arbitrarily shaped machine components.

Fuqiang Wu , WeiXing Yao [2] studied The characteristics of damage development and accumulation of composite materials subjected to variable loading, when The mechanical properties of composite materials degrade progressively with the increasing of the number of cyclic loadings.

3 EFFICT OF HEAT TREATMENT PROCESSES FOR COMPOSITE AND ALUMINIUM ALLOYS

K. Narayan Prabhu and Peter Fernades[20] expressed The outlines the possibility of using nanofluids for industrial heat treatment. Development of nanoquenchants having (i) high quench severity for enhancement of heat transfer for thick sections with low quench sensitivity and (ii) low cooling severity for thin sections with high quench sensitivity would be extremely useful to the heat treating community. The temperature dependent heat transfer coefficient and the wettability of the medium are the two important parameters that can be used to characterize a nanoquenchant to assess its suitability for industrial heat treatment.

D. Ortiz et al. [21] evaluated the tensile properties, conductivity, hardness, and grain size measurements and were heat treated Aluminum alloys 6061, 2024, and 7075 to various tempers and then subjected to a range of plastic strain (stretching) in order to determine their strain limits. They found the effects of the plastic strain on these properties are discussed and strain limits are suggested.

Yalin Lu, Miaoquan Li, Yong Niu, and Xingcheng Li [22] showed The effects of the isothermal temperature and holding time on the microstructure and element distribution have been investigated during partial remelting of the semisolid Al-4Cu-Mg alloy. The experimental results show that the optimal process parameter should be chosen at isothermal temperature of 540-5 80 °C with the holding time of less than 10 mm. Meanwhile, the higher the isothermal temperature and the longer the holding time, the more segregation of Cu at the grain boundary would be, which conform to the theory of element distribution affected by heating condition.

N. Stefansson and S,L. Serniatin [23] They observation the Microstructural suggested that the process of globularization can be divided into two stages. The first includes microstructural changes during deformation and the initial stages of static heat treatment; the second occurs during prolonged static annealing. The initial stage consists of segmentation of the lamellae via boundary splitting, whereas microstructural coarsening characterizes the latter stage. And the mechanisms controlling static globularization of Ti-6Al-4V after deformation and annealing at 900 C and 955 C were established. Thus, the process of static globularization is only moderately dependent on the formation and evolution of dislocation substructure; the additional driving force is provided by the reduction in interface energy. The duration of the initial stage of static globularization was calculated by estimating the time required for the completion of the boundary splitting process. and calculated in excellent agreement with microstructural observations and showed that the duration of the initial stage at 900 C and 955 C lasted approximately 10 hours and 1 hour, respectively.

Abdulwahab, M., Zaria, Nigeria [24] introduced The made on the mechanical properties upon age- hardening treatment to Al-Si-Fe-Mn (Aluminium- Silicon- Iron- Manganese) alloy. The produced alloys consist of varying manganese content from 0.l to 0.5 percent with constant Si-Fe composition and Al as the dominant constituent. As-cast alloys were produced and also age-hardened. There mechanical properties; Tensile properties, Hardness and Impact strength were investigated according to standard procedures. From the results, addition of Mn to the alloy increased the tensile properties and hardness subject to 0.4 percent for both the as-cast and age- hardened conditions. While the impact energies upon addition of Mn decreased with the age- hardened samples having better mechanical properties than the as-cast one.

YY Zhao et al. [25] Found the relationship between strength and hardness was reasonably linear, whereas the relationship between hardness and strength with electrical conductivity was non-linear for Al alloy 7010 under different temper and ageing conditions. The ageing conditions and therefore the mechanical properties of the components can be predicted more accurately by the simultaneous combination of hardness and conductivity values.

M.N. Cavalli, V. Mandava [26] Studied the Effect of Temperature and Aging Time on 2024 Aluminum Behavior, similar changes in the fracture behavior of 2024-T4 aluminum as the processing conditions are varied. Above about 490°C, 2024 aluminum becomes a solid solution which is frozen in place by a subsequent quench to room temperature. The structure of the material changes over time even if it is left at room temperature (natural aging). Heating to an intermediate temperature (490°C) can result in the formation of precipitates. The evolution of the microstructure tends to lead to an increase in both strength and fracture toughness of the alloy.

Evren TAN and Bilgehan [27] Showed that the initial characterizations of Mg2 Si and (Fe,Mn,Cu)3 SiA112 (AA6066 Alloy) were the primary particles observed in the cc-Al matrix. Nearly 14OHB hardness was obtained with solutionizing at 530 ° C and aging at 175 ° C for 8 h, which was the optimum treatment for obtaining peak hardness.

4 EFFECT OF PARTECLE SIZE ON MECHANICAL PROPERTIES AND MICROSTRUCTUER FOR FATIGUE CYCLE

Chih-Ting Wu et al. [28] Explained How Mg content affects the microstructure and mechanical properties of Al-14.5Si-4.5Cu alloy by adding 0.45 and 0.90 wt pet Mg. Primary silicon, eutectic silicon, acicular b-A15FeSi, Al2Cu, and A15Cu2IVIg8Si6 phases were observed under the as-cast condition in low-Mg alloy. In high-Mg alloy, a large proportion of the acicular b-Al5FeSi phase was converted to Chinese script Al8Mg3FeSi6 phase.

Ilyas Uygur, Mustafa Kemal Kulekci [29]Tested powder metallurgy processed metal matrix composites under the strain control loading conditions. The influence of volume fraction (17 and 25 vol%), particulate size (2.5 and 15 tim) of reinforcement particles and strain ratio (R0, R0.5 and R= -1) are examined for 2124 Al-alloy-T4 composites, Increasing the content of SiCp results in the degradation of strain control fatigue properties. The monotonic and cyclic stress-strain response of the 2124A1 — (25 vol% 2.5 jim) SiCp composite was significantly altered by strain ratio values. Fatigue cracks frequently initiated from intensively stress concentrated regions, increasing volume fraction and particle sizes result in early crack initiation.

Huai-Wen Wang, Yi-Lan Kang , Zhi-Feng Zhang and Qing-Hua Qin [30] Investigated the size effects on fracture behavior of Cu foil by a new optical technique, the digital speckle correlation method (DSCM). Displacement and strain fields around a crack tip are analyzed for different thicknesses of Cu foil. Then, the J integral and fracture toughness JC are evaluated directly from the strain fields around the crack tip. The fracture toughness JC is obtained as a function of foil thickness. The results indicate that JC indeed depends on foil thickness within a certain range of thickness.

M. J. Hadianfard, Yiu-Wing Mai [3 1]They found the low cycle fatigue (LCF) resistance of two different 6061 Al/20 vol% alumina particulate metal matrix composites (MMCs) in a peaked-aged condition has been evaluated under fully reversed strain control testing. Test results were combined with scanning electron and optical microscopy investigations to determine the effects of reinforcement particles and strain amplitude on the LCF behaviour of these MMCs, Both materials show three stages of response to LCF: initial fast hardening or softening in the first few cycles, gradual softening for most of the fatigue life, and a rapid drop in the stress carrying capability prior to failure, Both MMCs exhibit short LCF life which follows a Coffin-Manson relationship. All tested specimens demonstrate ductile fracture morphology at final failure.

Amir Pakdela, R. Rahmanifarda, H. Farhangia and M. Emamya [32] Showed that the reinforcement particles (oxidized SiC) were refined by the extrusion process and increasing the extrusion temperature (extruded at 45 0°C, 5 00°C and 550°C) decreased the extent of the fragmentation.

P. Poza and J. Llorca [33] They showed the deformation and failure mechanisms under cyclic deformation in an 8090 Al-Li alloy reinforced with 15 vol pct SiC particles.

Many researches [34-37] Studied the initiation and growth of surface cracks during low-cycle fatigue of an AA6061 alloy composite containing (a) 15 vol% of SiC particles and (b) 20 vol% of Saffil short fibres, For both of the composites, cracks are initiated very early in the fatigue life irrespective of the cyclic strain amplitude, (fig. 1, 2, 3).

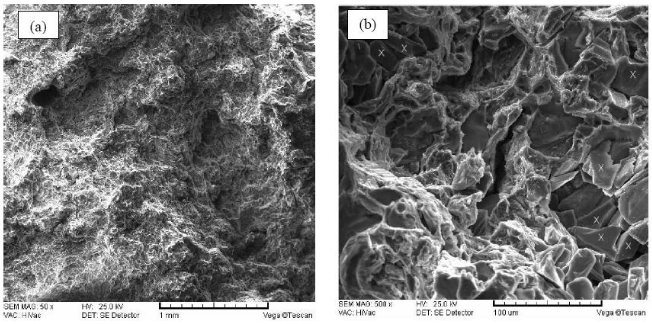

Figure 1 : SEM micrographs of the tensile fracture surfaces of the as-cast Al 6061/SiC/10p composite at room temperature, shoing : (a) overall morphology, (b) non-uniform distribution and fractured SiCp and crack formation in the matrix.

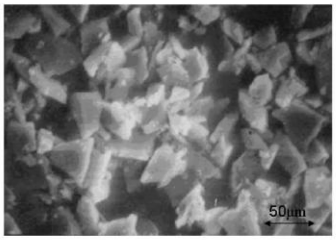

Figure 2 : SEM micrograph of the SiC particles used in this work

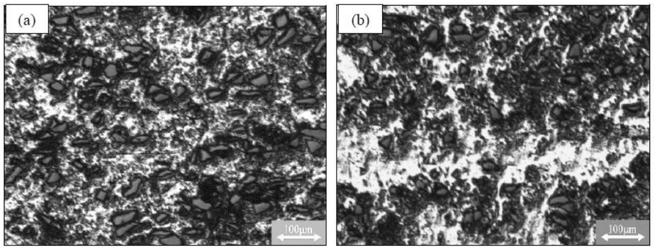

Figure 3 : Microstructuer 0f Al 6061/Sic/10p: (a) as-cast, (b) extruded at the ratio of 12:1

5 CONCLUSION

The study of the previous work, previews that the reinforcement of aluminium alloy and composite opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition is the improvement of the component properties. The metal matrix composites fabrication technology allows obtaining locally reinforced elements and nearing net shape products.

Some researchers showed the possibility of obtaining the new aluminium matrix composite materials being the cheaper alternative for other materials based on the ceramic fibers. Some researchers proved that developed technology of manufacturing of composite materials based on the porous ceramic performs infiltrated by liquid aluminium, alloy ensures expected structure and strength Hardness increased about twice compared to the matrix, and some researchers described who to use micromechanical element models to simulate both the static and cyclic mechanical behaviour of a metal matrix composite, whereas some others researchers observed that the increasing volume fraction and particle size of reinforcements decreased the strain controlled fatigue life response of the composites, for example a higher volume fraction and finer particulate sizes of the SiCp resulted in an increase in hardening behaviour with fatigue lives, some researches showed the increasing of stress ratio increased the crack growth rates of the composite.

Other researchers recommended for the heat treatment processes to increasing the strength and hardness of either wrought or cast aluminium alloys utilize the mechanism of precipitation hardening, the different properties were obtained with various amounts of alloying elements. Hence, the studies were to optimize the heat treatment and to investigate the effect of initial deformation (shaping) process on the mechanical properties of Aluminium alloy and composite materials.

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