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Comparison of Fatigue Life Cycle of Different Aluminium Alloy AA 5083-AA6062

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ABSTRACT

Fatigue failure is one of the main reasons for the mechanical failure in engineering materials. To improve the fatigue strength of the material one of the most used method is surface treatment of the materials in which hardness, wear resistance and aesthetics is improved. In this paper a comparative study of fatigue of two different aluminium alloy [AA 5083-AA6062] was conducted. CT specimen of both the alloys was formed as per ASTM-E647 Standard. The result shows that the fatigue life of AA5083 greater than AA6062. In this paper fracture that occur in material during fatigue testing and effect of fatigue life on material is studied. The main purpose of the research presented herein was to study the fatigue crack propagation under loading mode I.
Keywords : CT specimen, ASTM, Fatigue.

I. INTRODUCTION

Metal fatigue involves the initiation and growth of cracks under the action of cyclic stresses caused by repeated application of service loads. Residual stresses remaining from fabrication also play an important role in aggravating metal fatigue. Metal fatigue takes on greater importance with increasing yield strength level because higher strength alloys seldom, if ever, offer superior fatigue crack growth resistance as compared to lower strength materials, yet are expected to sustain higher working stresses in service. The result of this fact is a tendency to over work high-strength alloys in fatigue situations, thus hastening fatigue failure [1]. Fatigue is by far the most common causes of failure for mechanical components (about 80% of all the fractures of metals), and it is the most feared one, since it “occurs suddenly without any noticeable plastic deformation, i.e. without warning”. Fatigue starts when a load is high enough to cause plastic deformation on a component, even when it happens only at a small volume of the material, i.e. localized plastic deformation could occur at the highest stress location. When such load is repeated cyclically, the damage accumulates and eventually a crack is formed. If the cyclic load continues, the length of the crack increases until the stress on the component is high enough to cause its sudden fracture. The phenomenon of fatigue is generally divided into three steps: (1) crack initiation, (2) crack growth/propagation and (3) final fracture. The first two steps of the process are not easy to characterize and a great amount of work on research has been performed to try to understand the mechanisms involved on each one of them; it is even hard to identify a sharp limit to divide when the crack initiation ends and the crack propagation starts [2]. The presence of cracks inside materials is critical for the fundamental understanding of materials behavior, especially under specific loading conditions like fatigue. Unlike brittle materials, ductile metals can fail in a fatigue test without any appreciable external stress. In general, small cracks that do not influence the strength of a ductile material diminishits fatigue strength. At the same time, the elastic fields associated with cracks lead to interactions with other defects (like dislocations) that influence fracture behavior, thereby affecting the strengthening mechanisms. In particular, dislocations in the vicinity of the crack tip play an important role in fracture[3].

The typical fatigue behavior of most metals at dry conditions shows a stress level low enough at which the metal will no longer fail under fatigue, and it is said that the material shows infinite life. For instance, a run out (no failure) is observed for each of the curves at certain stress level; taking the un notched curve as example, the run out is present at 345 MPa. This maximum stress that the material can endure without failure is called fatigue (endurance) limit. Below this stress level there is a 50% probability that no failure will occur on a material at the same conditions. Most nonferrous metals and ferrous metals under corrosive environments do not exhibit an endurance limit [4]. In such cases, the S-N curve does not even out at certain stress value, but instead it continues falling at a slow rate at high number of cycles . When this happens, fatigue strength, rather than fatigue limit, is reported. Fatigue strength is defined as the stress level that a material can withstand to reach a defined number of cycles, generally enough to be considered as 'infinite life'. In these cases, the plot must specify the number of cycles at which the fatigue strength is reported [5].Fracture mechanics has shown to be an important issue towards design and maintenance of several components subjected to fatigue, in order to promote a safe life, a fail safe, or a damage tolerance design philosophy. For applying these methods, it is common to use parameters such as the stress-intensity factor, K, In fact, it's common practice to design components against yielding, preventing plastic deformation to occur [6].

Fatigue damage of components subjected to normally elastic stress fluctuations occurs at regions of stress (strain) raisers, where the localized stress exceeds the yield stress of the material. After a certain number of load fluctuations, the accumulated damage causes the initiation and subsequent propagation of a crack, or cracks, in the plastically damaged regions[7]. Analytical research of fatigue behaviour of CT specimen has been the subject of matter for this present research. Basically a structural life is classified into two parts where former part is crack initiation and latter part will be crack propagation after that catastrophic failure occurs. Fatigue life determination is important for defects tolerant design of structural component for safety which is associated with serviceable period. Total fatigue life of any component is the sum of number of cycles required to initiate and propagate a fatigue crack .

$$Nt = Ni + Np \ldots \text{(i)}$$

If a structural component contains flaws or any pre-existing notch, this will reduce fatigue crack initiation life and hence decrease total fatigue life of that component. Stress intensity factor (K) is the Linear Elastic Facture Mechanics (LEFM) parameter with which we characterize effect of loading at the crack tip reason. For higher k values crack growth rate is undesirably higher. So stress ratio should be selected between -1 and 0.1[8].

Stress Ratio $R = \sigma min \sigma max = Kmin Kmax$ … (ii)

(Where σmin and σmax are minimum and maximum values of stress respectively)

The demand for use of lightweight structures in the transportation industries has increased attention in the use of light materials of Al and its alloys as structural materials due to the weight reduction of structures [9].

II. EXPERIMENTAL PROCEDURE

The materials used for Preparation of tensile test sample to determine mechanical strength of materials were Al alloy 5083 and Al alloy 6062. Al 5083 and Al 6062 material used for test specimen. Al 5000 and 6000 series alloy used in Shipbuilding, Pressure vessels, Railroad cars, pipe and tubing, aircraft and automobile components. Preparation of specimen- (ASTM-E647 Standard) [10]. Specimen is prepared by cutting Al-6062 and Al-5083 alloy on WEDM of dimension (55x53x6.1) mm, notch length of 11 mm from the loading line.

Table 1. Chemical Composition of AA5083 and AA6062 aluminium alloy3

Al alloy	Si	Fe	Cu	Mn	Mg	Ti	Cr	Zn	Al
AA5083	0.190	0.230	0.02	0.6	4.53	0.030	0.08	0.15	94.350
AA6062	0.420	0.160	0.001	0.001	0.53	0.013	0.00	0.00	98.875

III. Tensile Testing

A tensile test is performed to determine the tensile behaviour of a sample while an axial stretching load is applied. It is commonly used to determine the maximum load (tensile strength) that a product can withstand .The values of ultimate tensile strength for AA 5083 and AA 6062 is achieved 72 Mpa and 80 Mpa respectively[11].

Fig 1- Specimen of AA 5083 and AA 6062 for tensile testing

IV. Preparation of CT specimen

Preparation of specimen- (ASTM-E647 Standard) Specimen is prepared by cutting Al-6062 and Al-5083 alloy on WEDM of dimension (55x53x6.1)mm, notch length of 11 mm from the loading line. CT specimen is used to find out the safe numbers of cycles in fatigue test. The total numbers of CT specimen were six, three of AA 5083 and three of AA 6062[12].

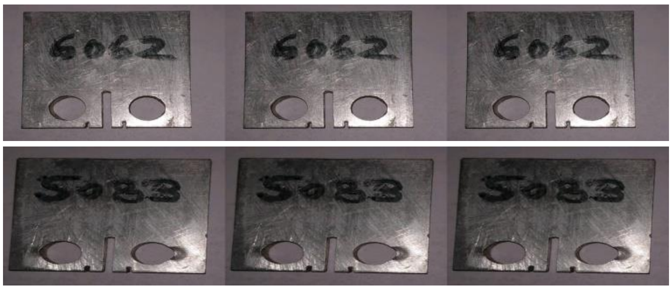

Fig 2- CT specimen of AA 6062 and AA 5083

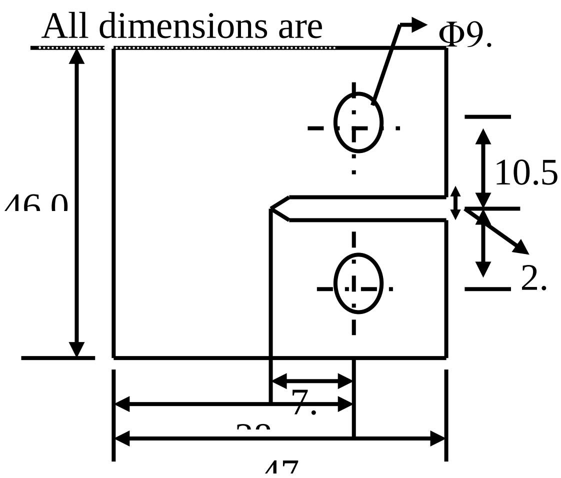

Fig 3-Dimensions of CT specimen as per ASTM-E647 Standard

V. FATIGUE TEST

Fatigue test is carried out on fatigue testing machine with a loading of ± 2.5 KN, Frequency 10 Hz Stress ratio(R)=-1. All specimens tested were firstly pre cracked in fatigue, using load control and a sinusoidal waveform (R=-1), in order to allow a short fatigue crack to nucleate from the machined V-notch root (starter notch) and propagate beyond the plastic zone induced during machining of specimen. The crack initiation and propagation was carefully controlled on the front and back surfaces of the specimen using hot and cold lights, together with a magnifying glass (x30) connected to a measuring device and a Veho® USB camera linked to the computer, which enable to acquire screenshots, videos and to measure the crack with the help of an appropriate software . The length of the fatigue pre crack extension varied from 7 to 13.5 mm, for AA 6062 and number of cycles varying between about 450 and 10,000 cycles. The length of the fatigue pre crack extension varied from 8 to 13 mm, for AA 5083 and number of cycles varying between about 600 and 20,000 cycles FCGR tests followed procedure and recommendations given in standard ASTM E647.

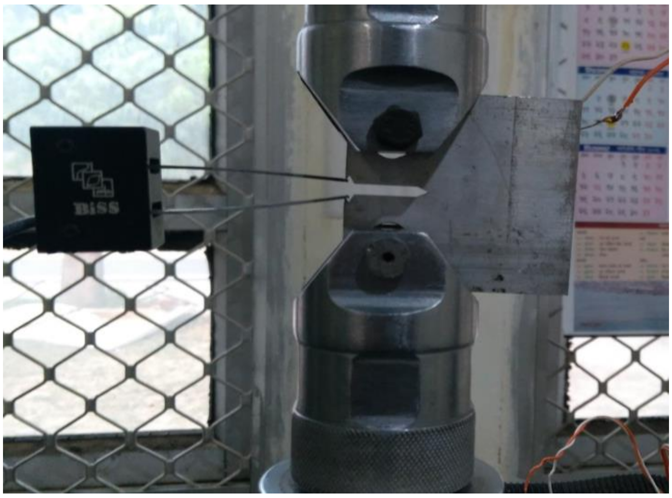

Fig. 4. – Specimen griped on fatigue testing machine

Fig 5 - Fractured specimens after fatigue test AA 6062

Fig 6- Fractured specimens after fatigue test AA 5083

Testing conditions

For fatigue crack propagation at constant amplitude

Machine Used – Fatigue testing machine Plug 'N' play (±2.5 kN) at room temperature

Control – Load mode, Crack length-COD gauge

Frequency – 10 Hz, Stress ratio- .1

Stress levels- 20-50 % of fatigue strength

VI. RESULTS AND DISCUSSION

Fatigue damage of mode 1 for CT specimen of AA 6062 under block loading condition fig.7 shows the relation between crack length and no. of cycles. The length of the fatigue pre crack extension varied from 7 to 13.5 mm, for AA 6062 and number of cycles varying between about 450 and 10,000 cycles. As shown in fig. the safe numbers of cycles for AA 6062 are 10,000 for crack length of 13.5 mm. with a loading of ±2.5 KN. Fatigue damage of mode 1 for CT specimen of AA 5083 under block loading condition fig.8 shows the relation between crack length and no. of cycles. The length of the fatigue pre crack extension varied from 8 to 13 mm, for AA 5083 and number of cycles varying between about 600 and 20,000 cycles. As shown in fig. The safe no. of cycles for AA 5083 are 20,000 for crack length of 13 mm with a loading of ±2.5 KN.

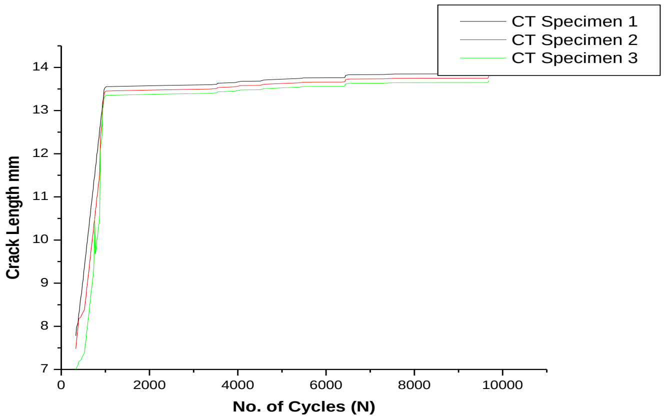

Fig 7- Crack length vs No. of cycles (N) for Al 6062

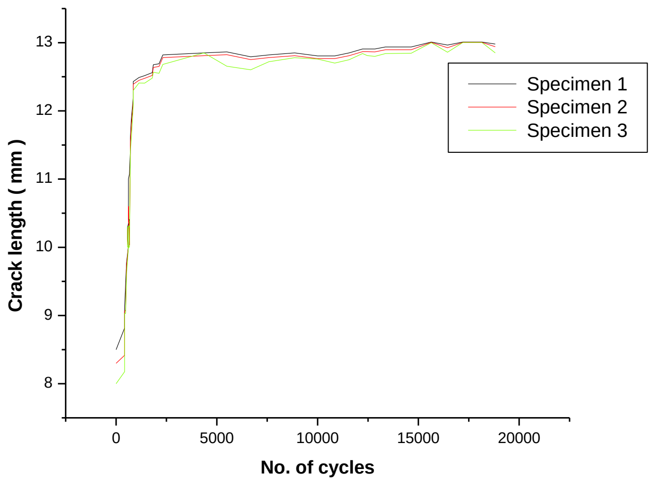

Fig 8- Crack length vs No. of cycles (N) for AL 5083

A deep analysis of the fatigue behavior of two different Al alloys AA 5083 and AA 6062 fatigue test is carried out to find out the safe numbers of cycles .The result shows in after comprising fig.7 and fig.8 numbers of cycles for AA5083 are 20,000 and for AA 6062 are 10,000 . Which indicates fatigue life of AA 5083 two times of AA 6062 at same loading condition ± 2.5 KN.

VII. CONCLUSION

A research work regarding fatigue crack propagation under opening-modes I, in two types of aluminum alloy AA 5083 and AA 6062 was developed and remarks could be drawn that fatigue life of AA 5083 is 20,000 cycles and the fatigue life of AA6062 is 10,000 which indicates fatigue life of AA 5083 is two times that of AA 6062 at same loading condition ±2.5 KN.

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