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Testing of Al 7075 specimen using dual specimen Rotating Bending Fatigue Testing Machine

Shreyas P.[1], Trishul M.A.[2], Chethan Kumar R.[3], Karthik Babu K.R.[4]

Assistant Professor, Mechanical Engineering Department,
CMRIT, (Visvesvaraya Technological University), Bengaluru, India[1]

Assistant Professor, Mechanical Engineering Department, PMCE, (Anna University), Hosur, India[2]

M.Tech Student (Research Scholar), Thermal Power Engineering,
The Oxford College of Engineering, Bengaluru, India[3]

Design Engineer, SaiCorp Trailers, Peenya, Bengaluru, India[4]

Abstract: A dual specimen rotating bending fatigue test machine was developed and was operated successfully[1]. This newly developed fatigue testing machine was used to test the fatigue behaviour of Aluminium 7075 specimen. Two specimen of identical design were tested on the machine simultaneously. The results that were obtained, as expected, showed the fatigue strength reducing continuously with increasing stress for both the specimen. The results of both the specimen that were tested simultaneously produced similar results which proved that the equipment was operating well. In some cases the two specimen were loaded unequally even then the machine ran as expected without any glitch.

Keywords: Fatigue Testing Machine, Moore Test, Rotating Bending, Al 7075, Fatigue test specimen.

1. INTRODUCTION

Fatigue is the condition whereby a material cracks or fails as a result of repeated (cyclic) stresses applied below the ultimate strength of the material. Fatigue failures often occur quite suddenly with catastrophic (disastrous) results and although most insidious for metals, polymers and ceramics (except for glasses) are also susceptible to sudden fatigue failures. Fatigue causes brittle like failures even in normally ductile materials with little gross plastic deformation occurring prior to fracture[2]. The process occurs by the initiation and propagation of cracks and, ordinarily, the fracture surface is close to perpendicular to the direction of maximum tensile stress.

Applied stresses may be axial (tension-compression), flexural (bending) or torsional (twisting) in nature. In general there are three possible fluctuating stress-time modes possible. The simplest is completely reversed constant amplitude where the alternating stress varies from a maximum tensile stress to a minimum compressive stress of equal magnitude. The second type, termed repeated constant amplitude[3], occurs when the maxima and minima are asymmetrical relative to the zero stress level. Lastly, the stress level may vary randomly in amplitude and frequency which is merely termed random cycling.

Tensile stresses are normally considered positive and compressive stresses are considered negative. The **Fatigue Life (Nf)** of a component is defined by the total number of stress cycles required to cause failure. Fatigue Life can be separated into three stages where

$$Nf = Ni + Np$$

Crack Initiation (Ni) -

Cycles required to initiate a crack. Generally results from dislocation pile-ups and/or imperfections such as surface scratches, voids, etc.

Crack Growth (Np) –

Cycles required to grow the crack in a stable manner to a critical size. Generally controlled by stress level. Since most common materials contain flaws, the prediction of crack growth is the most studied aspect of fatigue.

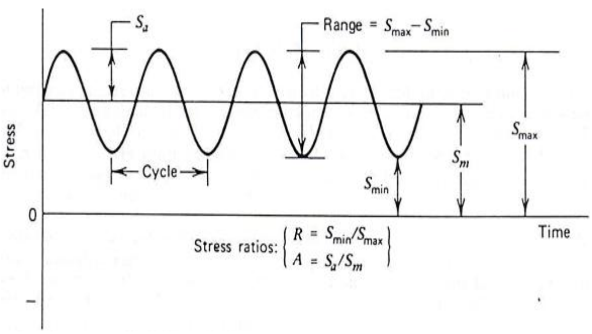

Fig 1.1 Schematic Illustrating Cyclic Loading Parameters

2. TEST SPECIMEN

Aluminium 7075 was utilized to prepare specimens for the fatigue test. The reason for selection of Al 7075 as it is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than

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many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable. The machined samples were mounted on the chucks of the machine. The distance from the neck to the specimen's contact surface with the bearing was measured. The concrete weight was then applied. The revolution counter was set to zero and the electric motor switch turned on. The test terminates once the specimen fractures; after which the electric motor is switched off.

Aluminium alloys are the alloys in which aluminium is the predominant Metal. Typical alloying elements are copper, zinc, manganese, silicon and magnesium. Aluminium and its alloys have been used since long time in Aerospace and other applications, because of its high strength to weight ratio and good corrosion resistance. Aluminium alloys also have been used in the construction of transportation equipment. These alloys greatly reduce the weight of the equipment and hence improve their efficiency. Discovery of precipitation hardening led to extensive use of aluminium alloy. The alloy used for the study is 7075 aluminium alloy, it is classified under 7xxx series of alloys and the major alloying element is zinc. It is one of the high strength aluminium alloys, used in aircraft parts, valves, etc. The material is subjected to conventional heat treatment involving solution heat treatment, quenching and followed by aging[4]. The AA 7075 alloy is procured in rolled condition was subjected to homogenization, followed by solutionization for 2 hours at 465°C followed by water quenching . The heat treatment process was carried out as follows: The alloys were solutionised at 465^0C for 2 hours followed by water quenching (room temp) and aged to 120 ^{0}C for 16, 20, and 24 hours and then air cooled to room temperature. The above alloys were designated as 465-16h, 465-20h, and 465-24h where, 465 represents the solution temperature and 16h 20h, and 24h indicate hours of ageing. Finally these specimens were tested for Mechanical properties viz. Fatigue strength, tensile strength, and hardness.

The heat treatment resulted in improved mechanical properties, compared to that of as cast material. Different researchers have conducted tests on different aluminum alloys for different parameters. In the present study, Evaluation of Mechanical and Fatigue properties are considered for 7075aluminum Alloy both for as cast and specimen subjected to different ageing temperatures.

ELEMENT	WEIGHT (%)
Zn	5.784
Mg	2.112
Cu	1.261
Mn	0.077
Cr	0.221
Ti	0.077
Fe	0.252
Si	0.101
Al	90.115

Table 2.1 Chemical Composition of Al 7075

3. TEST SPECIMEN SPECIFICATIONS

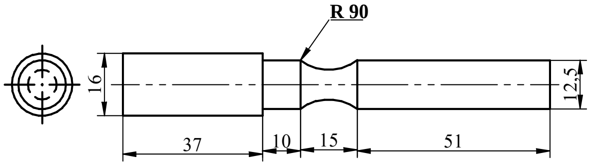

Fig 3.1 Fatigue Test Specimen

4. EXPERIMENTATION

4.1 Test Description

A simple fatigue test can be done with your hands. Take a thin wire and bend it back and forth many times, the wire will break after a number of cycles depending on the stress level. Increasing the applied load will reduce the number of cycles required to break the wire and you can test this by increasing the displacement of your hands during bending. However, for good testing we need more accurate control of the cyclic load and this can be done by a rotating reversed bending Fatigue Testing Machine. The initial load causing bending stress equal to 75 % of the ultimate tensile strength obtained from the tension test. The loads were progressively reduced in steps of around 10%. The graphs of bending stress (S) versus number of cycles for failure were recorded for every reduced value of stress. The machine. A minimum of 5 specimens were tested for fatigue to draw the S-N curve . The fatigue strength of the alloy was based on 10^6 cycles.

The same test is repeated for many specimen each conducted at different stress level and the number of cycles it would take to fail is recorded. The S-N curve is a plot of the applied stresses versus the logarithm of the number of cycles to failure (N) for each specimen.

4.2 S-N Curve

Figure 4.2.1 below shows the S-N curves for three metallic alloys: steel, aluminum, and brass. Note that as the stress is decreased, the fatigue life is increased for all alloys. However, only the steel alloy shows a stress level below which fatigue failure will not take place. This stress level is a property of the material and called the endurance limit or the fatigue limit and can be observed only in the S-N curves for steel alloys. For example, a cyclic stress of 350 MPa will cause fatigue failure in a part made out of 2014-T6 aluminum alloy in just 10^4 cycles while a part made from 1045 steel will not fail until approximately $4x10^5$ cycles. Note that the fatigue limit for the 1045 steel is around 310 MPa. Hence, to design against fatigue failure for a part made from 1045 steel, we must make sure that the stress amplitude must be less than 310 MPa.

It should be noted that the S-N curve is very sensitive to many variables including the mean stress, the presence of notches, testing temperature, surface-finish of the specimen, surface hardness, and the corrosivity of the environment. Care must be taken in test preparation to stimulate the actual service conditions to get meanimgful data.

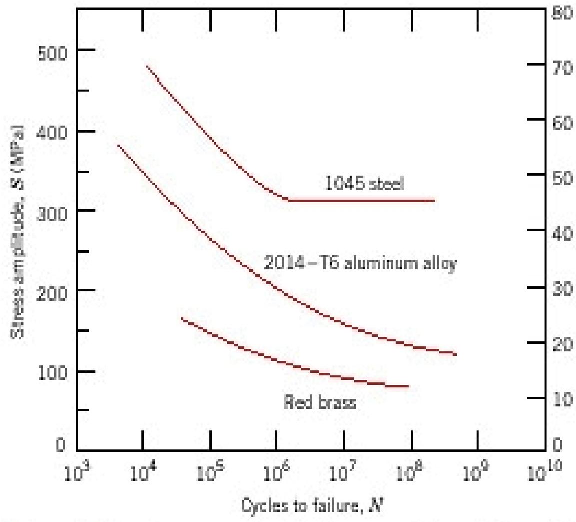

Fig 4.2.1 S-N Curve of three alloys

4.3 EXPERIMENTAL PROCEDURE

1. Measure the diameter at the neck of the specimen and inspect the surface roughness.
2. Slide one end of the specimen into the adapter at the shaft end and slide the other end into the adapter at the load end.
3. Measure the distance from the neck to the specimen's contact surface with the bearing.
4. Apply the given load. Check about loading the specimen in order to have a precise bending loading condition.
5. Set the revolution counter to zero and start the motor.
6. Normally the test terminates itself through the fracture of the specimen opening the micro switch and hence stopping the motor. As the onset of fracture approaches the specimen will bend more, and this may open the micro switch before complete fracture occurs. In this case move the micro switch down slightly and restart the motor.
7. Collate the results and plot them as they occur on a graph of stress range against number of cycles N.

5. RESULT AND CONCLUSION

Two specimen of identical design specifications were simultaneously tested on the two chucks of the fatigue testing machine. For the same stress level both the specimen fractured after similar number of cycles. This proved that the fatigue testing rig was working correctly.

In some of the trials the two specimen that were being tested simultaneously were subjected to different loading conditions, even then the fatigue testing machine ran smoothly. This indicated that the testing rig was balanced accurately.

As expected the fatigue strength of the specimen reduced gradually with gradual increase in stress level. As Al specimen was used it did not show an endurance limit. So the test was stopped at 100MPa stress level. The S-N Curve of both the specimens that were tested in the two spindles of the test rig is plotted in the graph below.

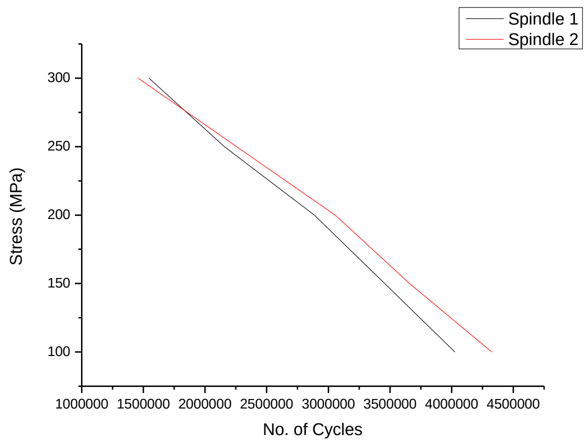

Table 5.1 S-N Curve

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