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Fabrication and Analysis of Fatigue Testing Machine

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ABSTRACT

Engineering of machines and structures needs to consider the impact of fatigue stresses to prevent catastrophic failures for this we make use of fatigue testing machine, this machine will determine the strength of materials under the application of cyclic load. Specimens are subjected to repeated varying forces or fluctuating loading of specific magnitude and the stress cycles to destruction are counted. In this project we have fabricated and analyzed the performance of the fatigue testing machine. To determine the efficiency of the machine, specimens various materials were taken and tested with initial test, at a stress value that is under the material's ultimate strength. Then the next test is made at a stress that is less that than that used in the first. The process is repeated with the values of stress decreasing and results are plotted.

Keywords: *Cyclic loading, Fatigue life, Fatigue strength, Low cycle fatigue, S-N curve*

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I. INTRODUCTION

Fatigue testing machine is used to determine the fatigue life or fatigue strength of a material. An overlook to the broken parts in most of the scrap will show that almost all failures occur at stresses below the yield strength of the material. This complex phenomenon is known as "Fatigue". Fatigue is responsible for 90% of the failures that occur in an industry. In the 19th century, it was considered mysterious since a fatigue fracture did not exhibit any visible plastic deformation, this lead to the belief that fatigue was an engineering problem. A major breakthrough in the understanding of the process of fatigue failure happened in the 20th century with the help of more powerful tools such as computer, powerful microscopic instrument, after which fatigue was not considered as an engineering problem but as both material and design phenomenon. The idea behind this work is not to provide answers to the unanswered questions, but to solve the difficulty in answering them from a different perspective. This involves defining the unpredictable nature of fatigue failure by conducting tests on various specimens and explain the known techniques of fatigue testing.

In the science of materials, fatigue is a phenomenon of weakening of a material caused by repeated application of loads. It is the progressive, unpredictable and structural damage that take place when a material is subjected to cyclic loading. The nominal maximum stress values that actually cause the material to fail may be much lower than the strength of the material typically quoted as the yield strength or ultimate strength. If the applied loads are greater than a certain threshold value, then microscopic cracks will begin to form at the stress concentrated areas such as grain interface or where there is surface defects. Eventually a crack will reach a critical size, the crack will expand at a faster rate, and the structure will fail.

II. COMPONENTS

2.1 Electric motor

An electric motor is a machine that consumes electrical energy and inturn produce mechanical energy. Here we are using an induction motor of 1/2hp having an rpm of 2880.

2.2 Bearing and its housing assembly

The bearings selected for the design were self-sealed spherical roller bearings that have a very high capacity. Bearings of 25mm bore diameter were selected for the design.

The bearing housing design was implemented by selecting dimensions that will result in smaller minimum bending moment which is desirable shaft geometry in order to produce the required bending moment. The housing was bored to seat the bearing firmly, to the size of the external diameter of the bearing which is 52mm. Two bearings were then forcefully inserted into the housing at both ends.

2.3 Frame
Frame is the main supporting element in the system. The frame has to bear all the weight of the experimental set-up. The force exerted on the system is distributed to the four legs. The material used for frame is GI rectangular pipe.

2.4 Testing specimens
Mild steel 1080 and stainless steel grade 302 was utilized to prepare specimens for the fatigue test. The specimens were machined having a total length of 153 mm with 12mm at both ends of the specimen to be held in the holder so that the length experiencing tension-compression (gauge length) is 51mm. The diameter of the specimen is 12mm while the neck diameter is 6mm.

2.5 Sensor
The sensor is utilized to detect the movement of objects with-in a limited range without having any physical contact with the object. The rotating motion of the shaft and sends signal to the counter.

2.6 Digital counter
A 6 digit digital counter was selected to record the number of stress cycles that the specimen had undergone during the test.

III. FABRICATION AND ASSEMBLY

In this design we have incorporated a momentum arm and spring-weighting system to load the specimen exactly in the middle portion were the neck formation have been provided. This ensures that the fracture occurs at the expected location. It also eliminates the need to carry heavy weights that are to be added to the momentum arm in order to apply the load on the specimen.
To reduce the complication of coupling of the motor and the main shaft, the main shaft was bored and internally threaded and the motor shaft was externally threaded.
To make the counting of number of revolutions to failure more accurate, we have used an infrared digital rotation counter

Figure: 3.1 Fabricated experimental set-up

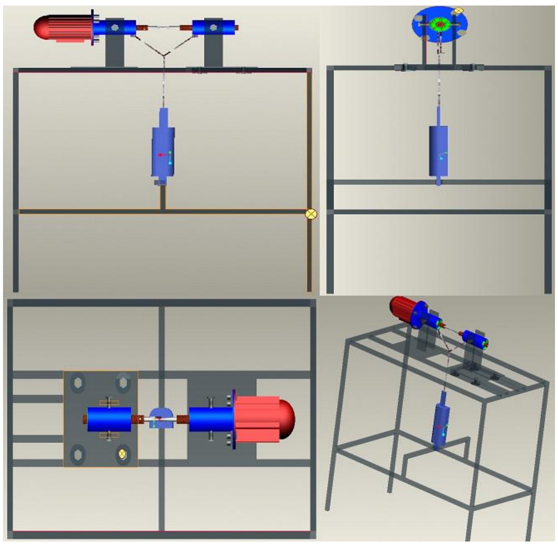

Figure: 3.2 PROE sketch of experimental setup

IV. WORKING

The supply to the machine is turned OFF and the spring load is reduced to zero. Then the bolts in the clamping mechanism are loosened and the specimen is loaded in to it. The bolts are then tightened to ensure that the specimen does not loosen during the operation of the machine. The required load is set on the spring load by adjusting the nut below the spring load mechanism and the supply is turned ON. The digital counter is reset to zero and the machine is turned ON. After a certain period of time the specimen will fail and the digital counter will stop, then the machine is turned OFF. And the failed specimen is removed and a new specimen is loaded and the test is repeated for different values of spring load.

V. TESTING AND RESULTS

Trial no.	Load (N)	Stress (MPa)	Number of cycles
1	300	530.51	528
2	260	459.78	1586
3	220	389.04	2286
4	180	318.3	10824
5	140	247.57	55869
6	120	212.22	639847
7	100	176.83	858628
8	80	141.47	∞
9	60	106.1	∞
10	20	35.36	∞

Table: 5.1 observations for stainless steel 302

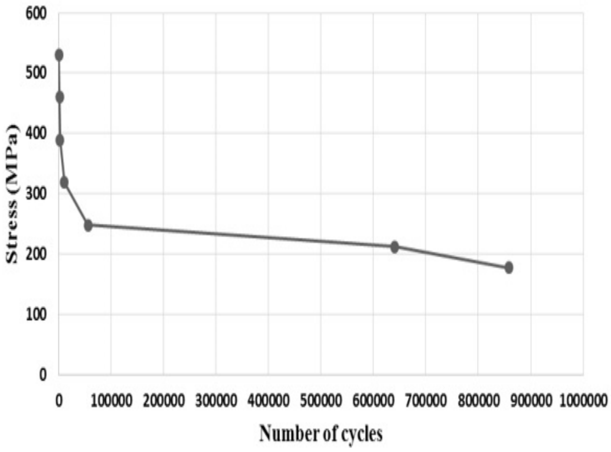

Figure: 5.1 S-N Curve for stainless steel grade 302

From the values obtained TABLE: 5.1 during the testing of the specimen of stainless steel grade 302, S-N graph is plotted with stress (MPa) on y-axis and number of cycles to failure on x-axis. From the graph it can be noted that with decrease in load the number of cycles to failure increases. Below a particular load limit the number of cycles to failure increases and approaches infinity, this limit is known as endurance limit. From the graph Fig: 5.1, the endurance limit of stainless steel grade 302 from the obtained S-N curve is 176.83MPa.
The actual value of endurance limit of stainless steel grade 302 is 220 MPa.

Trial no.	Load (N)	Stress (MPa)	Number of cycles
1	300	530.51	617
2	260	459.78	1837
3	220	389.04	3003
4	180	318.3	8096
5	140	247.57	41295
6	120	212.22	59632
7	100	176.83	72153
8	80	141.47	90892
9	60	106.1	99856
10	20	35.36	∞

Table: 5.2 observations for mild steel 1080

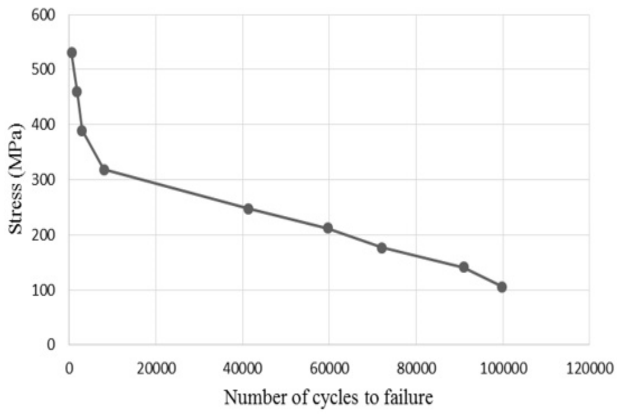

Fig: 5.2 S-N curve for mild steel 1080

From the values obtained TABLE: 5.2 during the testing of the specimen of mild steel 1080, S-N graph is plotted with stress (MPa) on y-axis and number of cycles to failure on x-axis. From the above graph Fig: 5.2, the endurance limit of mild steel from the obtained S-N curve is 106.1 MPa
The actual value of endurance limit of mild steel 1080 is 145 MPa.
From the testes conducted on the two different materials it can be concluded that the stainless steel of grade 302 has better fatigue strength than the mild steel of grade 1080
The rotating specimen can be modeled as a simply supported beam. The maximum bending stress of a beam can be expressed as

$$\sigma = \frac{Me}{I} \quad (1)$$

Simplifying;

$$\sigma = \frac{8*WL}{\pi*D^3} \quad (2)$$

$$= \frac{8*100*0.15}{\pi*0.006^3}$$

$$= 176.83 \text{ MPa}$$

W - the load acting on the specimen
L - the length of the specimen
D - the diameter of the neck

The actual endurance limit of stainless steel grade 302 is 220Mpa and the result obtained from the experiment is 176.83 MPa. The percentage error between the obtained value and the actual value is 19.62%.
The actual endurance limit of mild steel 1080 is 145 MPa and the result obtained from the experiment is 106.1 MPa. The percentage error between the obtained value and the actual value is 26.82%.

VI. CONCLUSION

The benefit of the present design is the simplicity of its modeling and ease of understanding. The rotating specimen can be modeled as a simply supported beam. The machine enables the evaluation of the stress life fatigue characteristics of the material analyzed by plotting a graph of bending stress against number of cycles from which the fatigue limit/fatigue strength of the material analyzed can be determined. An affordable and a fully functional educational version of the R. R. Moore Fatigue Testing apparatus that produces dependable results is proposed. The difference between the theoretical and experimental endurance limit maybe due to the additional vibration, size or temperature effects. The study and test conducted so far shows that fatigue failure cannot be predicted accurately since material failure under fatigue are affected not by just reversal loading alone but also the number of revolution (cycle per minute) and fluctuating stress and other factors such as temperature, atmospheric condition, both internal and external defect on material subjected under fatigue stress. Such defect includes notch, inclusion, stress concentration and non-homogeneity.
This approach is beneficial for all parties involved including; the researching/collaborating student(s), underclassmen who would benefit from such experiments, and the enthusiastic instructors/ laboratory coordinators who may be fighting with budgetary issues. However, although we have not yet achieved an impressive level of "accuracy", we can clearly conclude that the results are approximately correct as the fatigue properties depend on several other factors such as temperature, surface finish, endurance limit, size factor etc.

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