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DESIGN AND FABRICATION OF FATIGUE TESTING MACHINE FOR SHEETMETAL

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Abstract - *The aim of this work is to discuss the principle of fatigue failure, research the state of the art fatigue testing methods and finally designs a verification fatigue test set-up to evaluate the performance of the newly developed standard fatigue testing machine having Indian standards.*

A comprehensive study of the underlying principle, stages and numerous factors that makes fatigue such a complex phenomenon was carried out. This was closely followed by research work on the standard fatigue testing methods and statistical analysis of fatigue test results.

Based on the knowledge from the project work stated above, a four-point fully reversed bending set-up design was developed to put into test the functionality of the dynamic testing machine once it is ready to run and also a planned fatigue test suitable for laboratory exercise in a material science or engineering design class was developed.

***Key Words*: fatigue, fatigue failure, fatigue testing machine**

1. INTRODUCTION

In the 19th century, it was considered mysterious that a fatigue fracture did not show visible plastic deformation, this lead to an erroneous believe that fatigue was merely an engineering problem. Well, they were not so wrong since the power of microscopic equipment of that time was quite limited, also during this century few fatigue tests were carried out by notable researchers; most popular was the work of August Wohler, who later come up with the idea of stress-lifetime curve (S-N Curve). A major breakthrough in the understanding of the process of fatigue failure happened in the 20th century. Thanks to more powerful tools such as computer, powerful microscopic instrument, advance numerical analysis methods and much more research work. Fatigue began to be viewed not as an engineering problem but as both material and design phenomenon. Despite the large amount of research carried out on fatigue failure, its true nature still remains unknown and damage, cracks or even complete failure due to cycling loads are constantly been reported. The problem still exists after 100 years of research in the previous century.

1.1 Fatigue

Fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit. Fatigue occurs when a material is subjected to repeated loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin, eventually crack will reach a critical size, the crack will propagate suddenly, and the structure will fracture. 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 fillets will therefore increase the fatigue strength of the structure.

1.2 Characteristics of fatigue

- In metal alloys, when there are no macroscopic or microscopic discontinuities, the process starts with dislocation movements, which eventually form persistent slip bands that become the nucleus of short cracks.
- Macroscopic and microscopic discontinuities as well as component design features which cause stress concentrations (holes, keyways, sharp changes of direction etc.) are common locations at which the fatigue process begins.
- Fatigue is a process that has a degree of randomness (stochastic), often showing considerable scatter even in well controlled environments.
- Fatigue is usually associated with tensile stresses but fatigue cracks have been reported due to compressive loads.

- The greater the applied stress range, the shorter the life.
- Fatigue life scatter tends to increase for longer fatigue lives.
- Damage is cumulative. Materials do not recover when rested.
- Fatigue life is influenced by a variety of factors, such as temperature, surface finish, metallurgical microstructure, presence of oxidizing or inert chemicals, residual stresses, scuffing contact (fretting), etc.
- Some materials (e.g., some steel and titanium alloys) exhibit a theoretical fatigue limit below which continued loading does not lead to fatigue failure.
- Low cycle fatigue (loading that typically causes failure in less than 104 cycles) is associated with localized plastic behaviour in metals; thus, a strain-based parameter should be used for fatigue life prediction in metals. Testing is conducted with constant strain amplitudes typically at 0.01–5 Hz.

1.3 Fatigue test

Different investigators have proposed different designs of fatigue tests in order to meet the intended engineering and research objectives. While the engineering objectives involve determination of fatigue properties of materials or structural elements, the research objectives are usually concerned with determination of influence of one or more variable factors, viz. composition, processing parameters, environment, load spectra etc., on the resulting fatigue properties.

The design of fatigue tests depends on the following parameters:

- Type of test: Stress based or strain based.
- Type of loading: Tensile, torsional or bending.
- Type of fatigue test piece: Actual components or standard specimens.
- Nature of load cycle: Constant amplitude (CA), variable amplitude (VA).
- Environmental conditions: Temperature, humidity, presence of corrosives etc.

1.4 Types of Fatigue Test

Two types of Fatigue Tests are available

- Low-cycle fatigue tests
- High cycle fatigue test

Low cycle fatigue: Fatigue life occurs less than 104 to 105 cycles.

High cycle fatigue: Fatigue life occurs greater than 104 to 105 cycles.

S-N curve: S-N curves are derived from tests on samples of the material to be characterized (often called *coupons*) where a regular sinusoidal stress is applied by a testing machine which also counts the number of cycles to failure. This process is sometimes known as *coupon testing*. Each coupon test generates a point on the plot though in some cases there is a run out where the time to failure exceeds that available for the test (see censoring). Analysis of fatigue data requires techniques from statistics, especially survival analysis and linear regression.

The progression of the *S-N curve* can be influenced by many factors such as corrosion, temperature, residual stresses, and the presence of notches. The Goodman-Line is a method to estimate the influence of the mean stress on the fatigue strength.

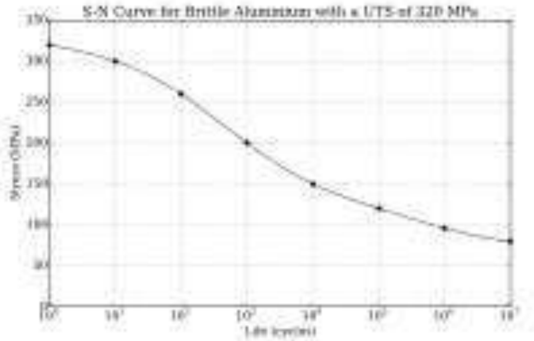

Chart-1: S-N Curve for a Brittle Aluminum with an

Ultimate Tensile strength of 320 MPa.

1.5 Fatigue Testing Machine

A fatigue testing machine may be classified from different viewpoints such as purpose of the test, type of stressing, means of producing the load, operation characteristics, type of load etc.

1.6 Classification of Fatigue Testing Machine

Based on the purpose of the test, the fatigue testing machine can be divided into the following types,

1. General purpose fatigue testing machine
2. Special purpose fatigue testing machine
3. Equipment for testing parts and assemblies

1.7 Components of a General Fatigue Testing Machine

All the type of fatigue testing machine is composed of the following structural components:

1. Load-producing mechanism: This generates the alternating load (displacement) to which in some cases a study state is added.
2. Load-transmitting member: This includes grips guide fixtures, flexure joints etc. by which the load produced is transmitted in such a way as to produce the desired stress distribution within the specimen
3. Controlled devices: This component controls the load throughout the test.
4. Counter and shut-off apparatus: This counts the number of stress reversals imposed on the specimen and stop the testing machine after a given number of cycles, at complete fracture of the specimen or at some pre-assigned change in deformation or frequency.

1.8 Sheet Metal

Sheet metal is metal formed by an industrial process into thin, flat pieces. It is one of the fundamental forms used in metal working and it can be cut and bent into a variety of shapes. Countless everyday objects are constructed with sheet metal. Thickness can vary significantly; extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6mm (0.25 inch) are considered plate.

2.1 Problem definitions

To calculate the fatigue strength of the materials, high cycle fatigue machines are available. High cycle fatigue strength (about 104 to 108 cycles) can be calculated by the machine, such as load-controlled servo-hydraulic test rig is commonly used in these tests, with frequencies of around 20–50 Hz. Other sorts of machines—like resonant magnetic machines— can also be used, to achieve frequencies up to 250 Hz. There are no machines available in the market to calculate the fatigue strength below 104 cycles. For calculating the fatigue strength of the newly prepared composite sheet metals or any sheet metals one have to pay huge amount. To overcome this problem low cycle fatigue testing machine is developed.

2.2 Objective

- To build the low cycle fatigue testing machine with low price.
- To get the desired fatigue strength of the sheet metals or any fibre sheets.
- To get the fatigue strength of the sheet metal with lower cost or negligible cost.
- To get the fatigue strength of the sheet metal for research people in their lab itself.
- To fulfil the aim with desired properties.

3. METHODOLOGY

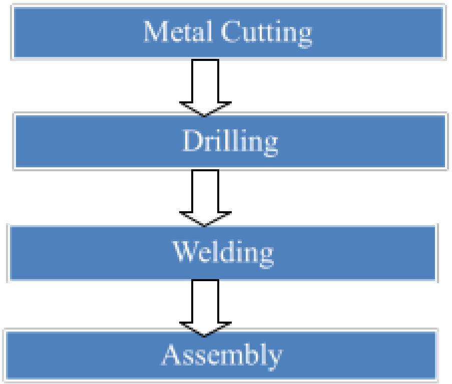

Chart-2: Flow chart of Methodology

4. Design of Fatigue Test RIG

By design, a material is selected to meet or exceed service loads that are anticipated in fatigue testing applications. Fatigue tests are commonly loaded in tension-tension, compression to compression and tension into compression and reverse. In our design cyclic fatigue test produce repeated loading and unloading in tension.

The new fatigue testing rig is developed in a simpler design. Here the rotational motion is transmitted to reciprocating motion in order to apply continuous load. The rotational motion is enabled by the help of a motor and a pulley setup. The core portion of a rig is made using mild steel angles, the rotating disc and pulley is made of cast iron. The load is transmitted to the leaf blade through a load head (hammer) which is also made of cast iron, a rail mechanism is designed for the proper movement of the load head.

The design of the rig is made after studying about possible mechanism and designs. There are manly three types of Classification based on type of stressing method which are,

- **Rotating bending testing machine**
- **Reciprocating bending test machine**
- **Axial loading (push-pull) type fatigue tester**

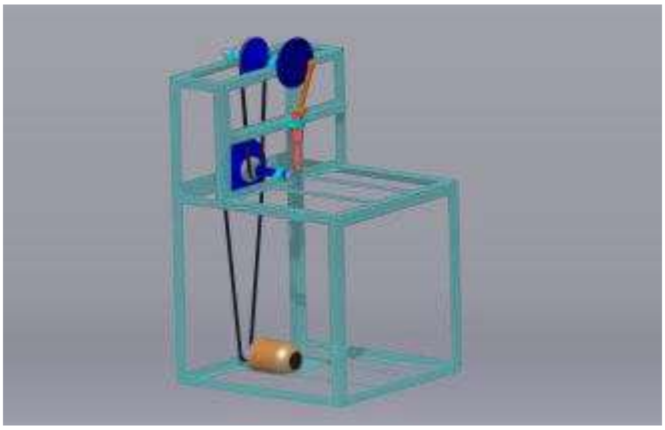

Fig -1: 3D Model of Fatigue Rig

Table -1: Specification of Pulleys

Position	Diameter in meter	Speed in rpm
Motor pulley	0.04	1475
Middle shaft pulley	0.21	280
Middle shaft stepped-pulleys	0.03, 0.06, 0.09	280
Upper shaft stepped-pulley	0.12, 0.10, 0.08	70, 168, 315
Crank	0.14	

5. Load acting on the Work Piece

Load is the weight acting on the sheet metal by the ball indented hammer of Low Cycle Fatigue testing machine when it is working condition.

It can be calculated by 3 methods

- Using Load Cell
- Using deflection calculation method

5.1 Using Load Cell

One can calculate the load acting by keeping the load cell below the hammer when the hammer is in working. Load cell measures the load acting on it and gives the convenient values.

- This method gives very accurate value.
- This is less time consuming process.

The Load acting on the sheet metal in Low Cycle Fatigue testing machine when it is working condition is 12.

5.2 Using deflection calculation method

By taking the slow motion working video of Low Cycle Fatigue testing machine on standard gauze and fixed size sheet metal. Calculate the deflection of the sheet metal by placing the scale on the monitor from initial position to deflected position. Note down the deflection of sheet metal.

Once again fix the sheet metal in the clamp and keep-on adding load on hook which is hanged exactly at the ball indentation happening. Simultaneously calculate the deflection, stop adding the load, once the deflection is matched with the calculated value.

Note down the total load added, and it is the load acting on the sheet metal by the Low Cycle Fatigue testing machine.

6. Result and discussion

6.1 Specimen

For evaluating the designed and fabricated Low Cycle Fatigue Testing Machine, have to determine the fatigue strength of standard sheet metal by this Low Cycle Fatigue Testing Machine and compare with the fatigue strength of same sheet metal which is calculated with the standard fatigue testing machine. For calculating the fatigue strength, testing is done by using standard sheet metal (Mild-Steel sheet gauge 19, its thickness is 1.06mm). For testing standard Steel sheet metal specimen is prepared by rectangular shape (6mm by 24mm), as shown below.

Fig -2: Specimen

Dimensions of Prepared Specimen Length of Specimen: 0.24m Width of Specimen: 0.06 m Thickness of Specimen: 0.01m

6.2 Fatigue Strength on Steel Sheet Metal

Four specimen are used to evaluate the fatigue strength, different cycles of strokes are applied on the each different specimen except one specimen which is kept for calculating the tensile strength of gauge 19 original steel sheet.

Different cycles such as 50,000, 75,000, 1, 00,000 cycles of strokes are applied on three specimens of same material and gauge.

Specimen worked with the different cycles of strokes are shown below,

Fig -2.a: Original specimen

Fig -2.b: Sample specimen work with 50,000 cycle stroke

Fig -2.c: Sample specimen work with 75.000 cycle stroke

Fig -2.d: Sample specimen work with 1,00,000 cycle stroke

7. CONCLUSIONS

The fatigue test rig is designed and effectively used to study the fatigue behavior of the sheet metal. Three gauze of GI sheet were tested.

Following were the conclusions drawn from the experimental study;

- Sheet metals were satisfactorily working under the applied fatigue load and number of cycles.
- The designed fatigue test machine performs better in testing the sheet metal.
- The operating speed of the fatigue test machine is quite satisfactory and no damages were observed even after working for 10 hours continuously.
- Though the project, it is shown that the sheets of any specification such as, composite, metal, fiber can be tested.

7.1 SCOPE OF FUTURE WORK

Due to the wealth of materials on fatigue available on fatigue for research works, it was quite challenging to sieve through these useful materials and come up with the most relevant ones to the task at hand. Despite this fact, tremendous effort was put into this work to select the most relevant information necessary for designers and researcher. Following are some of the further scopes.

- Fatigue cycles can be increased and tested.
- Test can be done for varied speeds.
- Composite sheet can be investigated.
- By modifying the specimen holder arrangement other sheet metal can be tested.

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BIOGRAPHIES

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