Design and Fabrication of Rotating Bending Fatigue Testing Machine – A Laboratory Development Project

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Abstract - *Fatigue failures are reported to account for more than 75% of documented materials failures of which a great percent occur catastrophically. Study of fatigue life is essential in many industrial and specialized fields such as aerospace, defense, power generation etc. Fatigue life of a component can be found by various fatigue testing machines based on the loading condition. In the present study a low–cost four point loading rotating bending fatigue testing machine is designed, fabricated and tested. The design principle is based on the adaptation of the technical theory of bending of elastic beams. The machine performance was evaluated using test specimens which were machined in conformity with standard procedures. It was observed that the machine has the potentials of generating combined bending and torsional stress. Specimens of diameter varying between 6 to 8 mm where subjected to loads between 30Kgs to 90Kgs and the number of cycles to failure was found by both experimental method and theoretical calculations. It was observed that the results are under close agreement. Also the machine has the advantage of ease of operation and maintenance, and is safe for use.*

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

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 [1].Fatigue causes brittle like failures even in normally ductile materials with little gross plastic deformation occurring prior to fracture. The process occurs by the initiation and propagation of cracks. Unlike other failures, fatigue failure gives no visible warning in advance. It is sudden and totally dangerous. The technical, economic and potential human losses due to fatigue failures make its consideration during materials design. Fatigue study is important if the challenges associated with its occurrence are to be eliminated. This paper is related with study of material technology.[2]A lot of research interest has been devoted to studying the fatigue behavior of engineering materials with a view to arriving at ways to effectively design against the failure mode Over the years, there have been varied testing equipment and methods developed for fatigue evaluation . The servo – hydraulic machines are currently the fastest and most versatile with features that allow for a wide range of test variations to be performed on it[3]. The high cost of these machines is a drawback to its use. This research work thus aims at addressing this problem by venturing into the design of a low cost four point rotating bending fatigue testing machine. The theory governing the design of the fatigue machine is based on elastic beam bending principle[4] .Experimental values of fatigue life are verified using theoretical calculations.

1.1 DESIGN OBJECTIVES

This aims at designing and constructing a rotating bending fatigue testing machine that is capable of testing the fatigue life of various samples of specimen of different minimum diameters and subjected to loads varying from 30Kg to 90 Kg etc.

Also with the result of each test carried out with this machine, the numbers of cycles required to failure of specimen can be calculated. The machine is also capable of testing specimens of varying cross section.

1.2 METHODOLOGY

1. General Description

The fatigue-testing machine is of the rotating beam type. The specimen functions as a single beam symmetrically loaded at two points. When rotated one-half revolution the stress in the fibers originally above the neutral axis of the specimen are reversed from compression to tension for equal intensity [5].Upon completing the revolution, the stresses are again reversed, so that during one complete revolution the test specimen passes through a complete cycle flexural stresses i.e. the specimen is subjected to the tension and compression cycles.

2. Materials Selection And Application

I. Shaft and specimen

A high carbon alloy steel that is EN8 was selected as material for shaft. The machine design use two shafts; shaft and specimen. The principal function of the shaft is to rotate the specimen while it is under the action of bending moments from the dead weights hanged to overhang bearings. Specimen made up of mild steel is used.

II. Jaw coupling

Jaw coupling made up of grey cast iron is used to transmit power from motor shaft to the shaft. Jaw coupling is used because the spider allows the angular misalignment if any and adjust accordingly.

II. Pedestal bearing

The bearings selected for the design were self-aligning roller bearings, which have high load carrying capacity and it can accommodate misalignment and shaft deflections maximum of 0.5°. Bearings of 20 mm bore diameter were selected for the. Bearings are inserted into plummer blocks.

IV. Drill chucks

A three jaw drill chuck with taper fittings was selected as the specimen clamp for the fatigue machine. Drill chuck has taper of morse half angle $1^0 25$". The specimen clamp is expected to firmly grip the specimens without allowing for extraneous bending moments during operation of the machine. Also, the specimen must not rotate from the grip or be displaced vertically or horizontally.

V. Electric motor

The electric motor used is single phase AC 0.375kW ,1/2 horse power motor that is designed to rotate at 1440 revolutions per minute.

VI. Frame and seat of motor

The frames were cut from angle bar of dimension 35 x 35 x 5 mm alloy steel of good strength and toughness and welded together to serve as support for the whole set up. A flat flexible metallic plate was cut and attached to a part of the frame to serve as seat for the electric motor.

VII. Rubber pads and packings

A rubber pad of 8 x 8 x 0.5 inch is used as a packing below the motor to damp vibrations that are coming from the motor and isolate it from the table hence from the specimen. A wooden packing is placed below the plummer blocks so as to serve the vertical alignment.

VIII. Weight hanger and U clamps

U clamps and weight hanger arrangement is used to apply load on overhang bearings. U clamps are bolted to overhang bearings and weight hanger is hanged on it. Dead weight is added to the weight pan which is welded to hanger. These types of two separate arrangements are used for each of overhang bearings so that equal load is applied on specimen from both of its side.

IX. Dial Gauge

Dial indicators are important devices used in manufacturing and metal engineering among others. These devices measure small linear distances that are important in the establishment of precision and accuracy. . Graduated dial and needle are responsible for recording the minor increments that result out of the measurement procedure

2. SIMULATION

A simple setup of shaft and specimen is modelled in Solidworks as shown in fig 4. And then it is imported into ANSYS WORKBENCH[6].
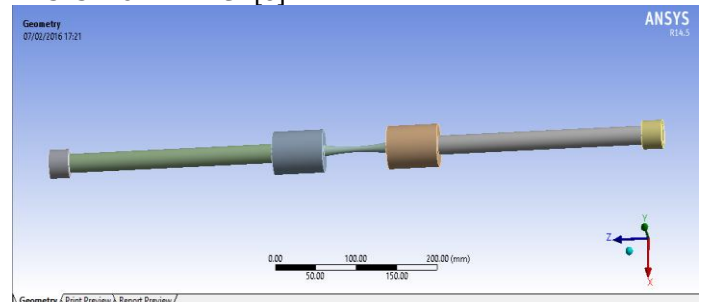

Fig 1. Setup in ANSYS

Various loading conditions like bending, torsional moments and cyclic speed are applied.
1. Cyclic Speed:- 159 rad/s
2. Bending Force: - 100 N on both sides.
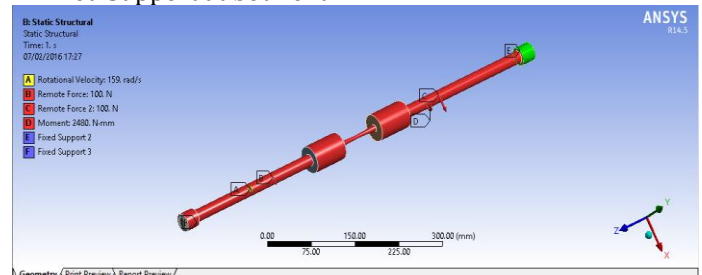3. Torque Applied: - 2480 N-mm
4. Fixed Support at both end

Fig 2. Loading Diagram

For solution following parameters are selected,

a) Total deformation-it shows that maximum deformation occurs at midpoint of specimen as shown in fig 3. And deformation is 0.2853 mm before specimen undergoes failure.
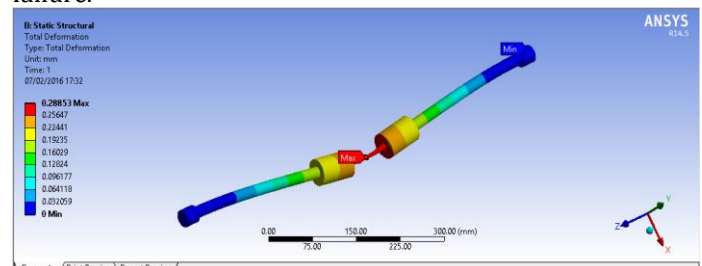

Fig 3. Toatal Deformation

b) Safety factor (in fatigue tool)-this shows that failure will occur at minimum cross-sectional area of specimen as it has zero safety factor as shown in fig 4
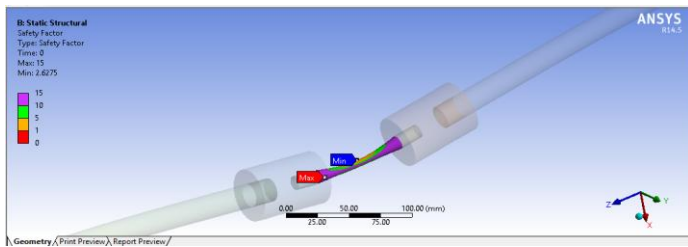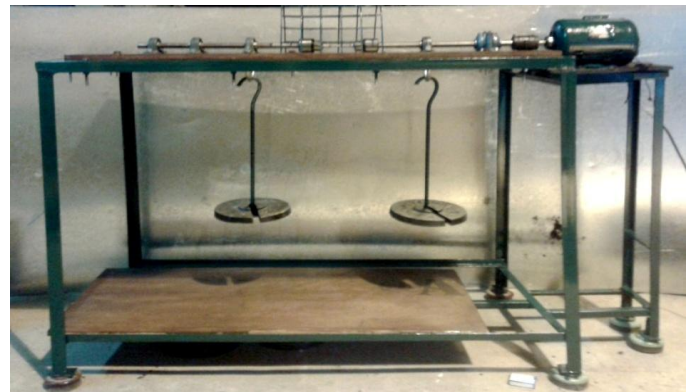
Fig 4 Safety Factor

3. FABRICATION PROCESS

After finalizing design of rotating bending testing set up materials were procured from local market and fabrication was carried out in following order.

1. Angular bars were cut to form frame of length 1000mm, width 250 mm and height 990mm.Then this bars were welded using arc welding. Separate platform for motor is built.

2. Wooden ply of thickness 21 mm was cut and was press fitted& bolted into the frame which was used as base for mounting.

3. Motor was mounted on motor platform and rubber pad is used as packing below the motor.

4. Oldham's coupling was drilled and tapped so that motor shaft fixes into one of the flange and other flange holds shaft. Grub screw is used to fix both the shafts to the coupling.

5. Shafts were cut and tapered at one end according to Morse taper of drill chuck and then that tapered end is fixed and tightened into drill chuck.

6. Specimen is made according to standard specimen available for fatigue testing on lathe machine.

7. Layout of whole setup is sketched on table according to dimensions of components.

8. Plummer blocks was bolted to table at specified position and using ellen key it is tightened to shaft.

9. Then mounting is done as shown in diagram.

10. Slot was made using jigsaw machine in table for overhanging of bearings.

11. Then using dial gauge indicator alignment is checked and corrected with the insertion of suitable packing and then U clamps were bolted to overhang bearings.

12. After that weight hanger is hanged to U clamps and it is loaded with dead weights.

13. Now, set up is ready to conduct experimentation.

14. Fig. 5 shows the experimental setup.

Fig. 5 Experimental Setup

4. THEORETICAL CALCULATIONS FOR FATIGUE LIFE ESTIMATION

The setup of our rotating bending testing machine is as shown in fig. 6
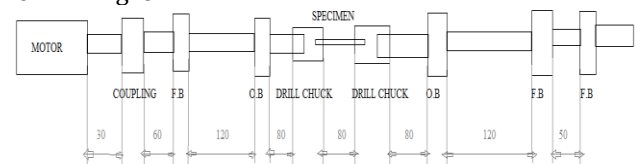

Fig 6 Schematic Diagram Of Setup

Results of theoretical calculations for fatigue life of the specimen are as follows:

Design specifications:-

Motor: - 0.5 HP, constant speed single phase A.C. motor

Speed: - 1440 RPM

Coupling: - grey cast iron Oldham's coupling

Shaft: - 20 mm diameter EN8 shafts (σ_{ut} = 800 N/mm^2)

Drill chuck: - Tool steel material

Specimen: - reducing cross section mild steel shaft (σ_{ut}= 680 N/mm^2)

Dead weights: - 20Kg - 90Kg

Problem is of completely reversed bending type loading.

Case I :-Minimum diameter of specimen is 6 mm and load applied on each fixed bearing is 15 kg. Fig. 7 shows the loading and bending moment diagram.
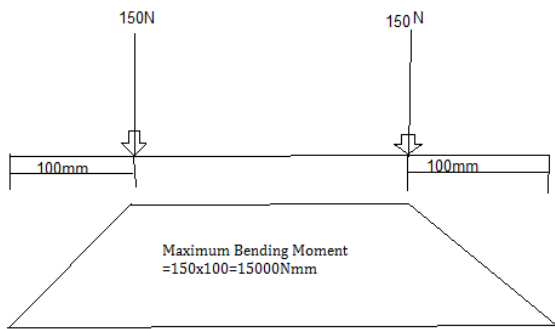
Fig. 7 Loading and Bending Moment diagram

Maximum bending moment = 15000 N-mm

Angular velocity = 150.79 rad/sec

Torque transmitted = 2.48×10^3 N-mm

According to bending theory,

Maximum bending stress induced (σ_b) = 370.90 N/mm²

According to torsion theory,

Maximum shear stress induced (τ) = 45.99 N/mm²

Equivalent shear stress = 373.74 N/mm²

Calculating fatigue by plotting S-N curve

For machined and polished surface,

Log_{10} N = 4.60

No of cycles to failure (N') = $10^{4.60}$ = 3.98×10^4 cycles

Theoretical and experimental calculations are as given in table 1.

TABLE 1 :-CALCULATION TABLE

Minimum cross sectional diameter of specimen (d in mm)	Equivalent stress developed (N/mm²)	No of cycles to failure(N')		Time required to fail(in min)	
For 15 kg load on each overhang bearing		Theoretical	experimental	Theoretical	experimental
6	373.89	39840	36850	27	25
			33120		23
7	299.23	214203	203040	148	141
			201,600		140

5. CONCLUSIONS

The testing machine is fabricated and tested. The cost of fabrication is Rs 7000.The experimental   results are compared with theoretical calculations and it was found that there is little variation in results. On completion and testing, it was observed that the machine has the potentials

of generating reliable bending stress-number of cycles data. The machine has the advantages of ease of operation and maintenance, and is safe for use. 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 by factors such as fluctuating stress, temperature, atmospheric condition, both internal and external defect on material subjected under fatigue stress. Such defect includes notch, inclusion, stress concentration and non-homogeneity.

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