Design and Fabrication of Low Cost Fatigue Test Rig

S.Rajesh¹ & N.Saravanan²
¹PG Scholar, Department of Manufacturing Engineering, Government college of Technology, Coimbatore, Tamilnadu, India.
²PG Scholar, Department of Engineering Design, PSG College of technology, Coimbatore, Tamilnadu, India

Abstract: “Fatigue Test Rig” is an apparatus which is used to determine the fatigue strength of material. The main idea of this project is to design and fabricate the apparatus for fatigue test. Fatigue is important in as much as it is the single largest cause of failure in metals, estimated to comprise approximately 90% of all metallic failures; polymers and ceramics (except for glasses) are also susceptible to this type of failure. Furthermore, fatigue is catastrophic and insidious; occurring very suddenly and without warning. Fabricating the apparatus of low cost fatigue test rig using an electric motor and load is given gradually to determine the fatigue strength of material.

1. Introduction
1.1 Fatigue Test

Fatigue test is a mechanical instrument used to determine the strength of the material. Fatigue is the condition where a material cracks or fails as a result of repeated (cyclic) stresses applied below the ultimate strength of the material. Fatigue failures generally involve three stages:

1.) Crack Initiation,

2.) Crack Propagation, and

3.) Fast Fracture

1.2 Fatigue Testing Machine

Most machinery and many structures do not operate under a constant load and stress. In fact, these loads and stresses are constantly changing. A good example of this is a rotating shaft such as the axle on a railroad car. The bending stresses change from tension to compression as the axle rotates. This constant change in stress can cause fatigue failure in which the material suddenly fractures. The process that leads to fatigue failure is the initiation and growth of cracks in the material.

Fracture occurs when the crack grows so large that the remaining material without crack can no longer support the applied loads. Fatigue may be defined as a cyclic (or stochastic) time-dependent loading or straining of a material.

2. Design

To design the following values are taken, the distance between the two chucks are 250mm and the outer diameter of spring is 12mm and the inner diameter of spring is 8mm.

2.1 Design Calculation for spring

To choose a required spring the following data are assumed based on the fatigue testing machine to design a spring.

No of active turns n = 36
Outer diameter of spring D = 12 mm
Wire diameter d = 2 mm
Inner diameter of spring Di =8 mm
Spring ratio = Di / d =8/2 = 4
Modulus of rigidity = 80 x 10³
Load = 10 kg = 98.1 N (approx.)

Deflection of spring y = \( \frac{PnC}{6d} \)

Where,

- P- Load acting on the spring.
- G- Modulus of rigidity
- n- Number of turns
- C- Spring index
- d- Diameter of wire.

\[ y = \frac{80 \times 10^3 \times 36}{8 \times 90.1 \times 2^2} = 11.30 \text{ mm} \]

\[ y = 11.30 \text{mm} \]

Energy stored in spring = \( \frac{1}{2} \times P_y \times \frac{1}{2} \times 98.1 \times 11.30 \)

= 554.265 N-mm
Stiffness of spring \( K = 8.68 \text{ N/mm} \)

Assume maximum shear stress \( \tau = 420 \text{ N/mm}^2 \).

(OR)

\[
\begin{align*}
\theta &= \frac{60 \times 10^5 \times \frac{1}{2}}{8 \times \frac{1}{4} \times 36} \\
&= 8.68 \text{ N/mm}
\end{align*}
\]

Between cylinder and chain

\[
\tau = K_s \frac{\theta W D}{\pi d^3}
\]

Where

\[
K_s = 1 + \frac{1}{1 + \frac{1}{4}} = 1.125
\]

\[
420 = 1.125 \times \frac{8 \times W \times D}{\pi d^3} \times \frac{12}{8}
\]

\[ W = 9.7 \text{ kg} \]

2.2 Design Calculation for Motor

To find the torque of motor, the power and speed of motor is known is given below:

Power of the motor = 0.25 hp = 0.186 kW

Speed of motor shaft = 1440 rpm

Torque of the motor = \( \frac{P \times D}{2N} \)

Where

\[
\begin{align*}
P &= \text{power of the motor} \\
T &= \text{Torque of the motor} \\
0.186 \times 10^3 \times 360 &= \frac{23 \times 1440}{3} \\
T &= 1.233 \times 10^5 \text{ N-mm}
\end{align*}
\]

2.3 Design Calculation for Bearing

To design the bearing the power transmitted to the shaft and speed of motor is known to find the outer and inner diameter of bearing.

Power transmit to the shaft = 0.186 kW.

Speed of the motor = 1440 r.p.m.

Expected life for 90% of bearing is 5000hrs.

Radial load acting on the bearing \( P_1 = 695 \text{ N} \).

Axial load acting on the bearing \( P_2 = 400 \text{ N} \).

Radial factor \( X = 1 \), thrust factor \( Y = 0 \).

Load \( P = X \times P_1 + Y \times P_2 = 695 \text{ N} \).

Load factor = 1.4

Life of bearing in million revolution \( L_R = \frac{60 \times 10^6}{60 \times 1440 \times 5 \times 5000} = \frac{60 \times 10^6}{10^9} \)

= 432 million revolution.

Dynamic load capacities of bearing \( C = P \times L^{(1/3)} \)

X load factor \( C = 7350 \text{ N} \)

Hence for \( C = 7350 \text{ N} \) and the bearing no.6304 having outer diameter of \( D = 42 \text{ mm} \), inner diameter \( d = 21 \text{ mm} \) and thickness \( t = 12 \text{ mm} \) and the bearing is chosen as ball bearing since it as less wear and long life time.

3. Assembly Model

Fig 1 Isometric view of Fatigue Testing Machine

3.1 Common Fatigue Test Specimens

(a) Rotating bending,

(b) Axial uniform,

(c) Axial hourglass

The figure 2 shows rotational bending, axial uniform and axial hourglass of the common test specimen.

3.2 S-N Curves

S-N curves obtained under torsion or bending load-control test conditions often do not have data at the shorter fatigue lives (say \( 10^3 \) or \( 10^4 \) cycles and less) due to significant plastic deformation.
- **Fatigue life, $N$:** The number of cycles of stress or strain that a specimen sustains before failure occurs.

- **Fatigue strength:** A hypothetical value of stress at failure for exactly Number of cycles determined from an S-N diagram.

- **Fatigue limit, $S$:** The limiting value of the median fatigue strength as Number of cycles becomes very large. Endurance limit is often implied as being analogous to the fatigue limit.

### 4. Fabrication

#### 4.1 Material Selection Process

#### 4.1.1 Frame Construction:

First the material for frame had been chosen as mild steel (hollow square rod) with dimensions (length 1210mm and depth 30mm). As per the dimensions of cylinder, motor, test specimen and C-channel the frame was welded by Arc welding technique. Drilling operation was carried out in the frame in order to connect the cylinder, motor and C-channel with the frame.

The frame is connected to the legs to hold frame by using nuts and bolts, the distance between the frame and floor level is 7650mm and then motor is mounted on the frame is shown in fig 4.

#### 4.1.2 C-Channel Construction:

The material for C-channel had been chosen as mild steel of dimensions (length 80mm and width 4mm). Drilling operation was carried out for a diameter of 10mm for fixing of cylinder.

The C-channel is welded to the frame and the cylinder is fixed by using nuts and bolts and drilling operation is carried out.

#### 4.1.3 Welding of Spring with Bush:

The power from the motor is transmitted to the shaft which connects the chuck, where the spring is gas welded to the bush. One end of the bush is drilled to a diameter of about 6mm and tapping operation is carried to connect the two shafts using bolt.

The spring with two bushes is used to connect the motor shaft and the shaft which connects bearing by using bolts the bush is tightly connected to the shafts.

<table>
<thead>
<tr>
<th>S No</th>
<th>LOAD (kg)</th>
<th>LOAD (N)</th>
<th>STRESS ($\sigma$) N/m$^2$ $\times 10^6$</th>
<th>No of Cycles (N) $\times 10^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>4</td>
<td>39.24</td>
<td>0.78</td>
<td>65.328</td>
</tr>
<tr>
<td>2.</td>
<td>8</td>
<td>78.48</td>
<td>1.56</td>
<td>27.072</td>
</tr>
<tr>
<td>3.</td>
<td>12</td>
<td>117.72</td>
<td>2.34</td>
<td>2.236</td>
</tr>
</tbody>
</table>

### 4.1.4 Construction of Cylinder:

The material for cylinder making is chosen as mild steel of length 245mm and diameter 50mm where the two bearings are inserted in the cylinder to hold the bearings tightly ply is made the rod of diameter 22mm is inserted in the inner diameter of the bearings is shown in fig 6.
Chain is connected to the two cylinders by using nuts and bolts the distance between the chain and the ground level is 700mm.

The test specimen is connected to the chuck where the dimension of the specimen is 250mm length and diameter of 8mm in the middle and diameter at each edge is 12mm.

5. Result and Discussions

Once the fabrication process is completed the testing of specimen is carried out to find the fatigue strength by gradually increasing load. We know that the rpm of the motor and by calculating the time taken for breaking of specimen we get number of cycles and by plotting graph between the number of cycles and stress the fatigue curve is obtained.

Rpm of motor = 1440 rpm

Therefore,

\[
1 \text{ minute (i.e. 60 sec) } = 1440 \text{ rev} \\
1 \text{ sec} = \frac{1440}{60} = 24 \text{ rev=24 rps}
\]

No of cycles = time taken (s) × 24 rps

<table>
<thead>
<tr>
<th>S No</th>
<th>LOAD kg</th>
<th>TIME TAKEN sec</th>
<th>No of Cycles(N) ×10^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>2722</td>
<td>65.328</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>1128</td>
<td>27.072</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>94</td>
<td>2.236</td>
</tr>
</tbody>
</table>

Table 1

The table 1 shows load applied and corresponding time taken for the specimen to break.

5.1 Stress calculation

Stress developed = Load/ (cross sectional area of specimen)

Diameter of the specimen = 8 mm = .008m

Cross sectional area of specimen = \( A = \pi r^2 \)

\[ = \pi (.004)^2 \]

\[ = 5.026 \times 10^{-5} \text{ m}^2 \]

Table 2

The table 2 shows the Stress amplitude and the corresponding no of cycles taken for the specimen (aluminium) to break.

5.2 Stress – No Of Cycles Curve

The S-N curve for the aluminium specimen from the results obtained shown in the figure 8.

![S-N Curve plotted from the results obtained](image1)

Fig 7 S-N Curve plotted from the results obtained

The fatigue limit, fatigue life and fatigue strength are obtained from the above figure 7.

5.3 Fatigue limit

Since the curve does not become horizontal for all values of N, therefore it tends to meet the X axis at some point, so fatigue limit for the selected aluminium specimen could not be determined.

5.4 Fatigue Life

Fatigue life of the selected specimen for the given stress level can be found out by extending the line from the S-N curve towards the abscissa as shown in figure 8.

![Fatigue life corresponding to the stress (S₁)](image2)

Fig 8 Fatigue life corresponding to the stress (S₁)
5.5 Fatigue Strength

Fatigue strength of the selected specimen the stress level at which the specimen breaks can be found out for given number of cycles can be found out by extending the line from the S-N curve towards the ordinate as shown in figure 9.

![Stress Vs No of cycles graph](image)

Fig 9 Fatigue strength corresponding to N₁ no of cycles.

The broken specimen of aluminium during the fatigue failure occurs is shown in figure 10.

![Broken Specimen](image)

Fig 10 Broken Specimen

6. Conclusion

- This fabrication process gave good knowledge regarding the development of the LOW COST FATIGUE TEST RIG, as on new to proceed and make a successful project.
- Thus the low cost fatigue test rig will be 95% efficiency to the existing one has been developed.

7. References


