Experimental validation of fatigue life for thread rolling form tool material

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Abstract. A mechanical machine needs to be considering the effect of cyclic stress to avoid failures, the machine considered in this work is rotating beam fatigue tester to know the failure points. This machine present the fatigue strength values of different materials when it is subjected to repeated loads at different stress values. To establish the fatigue characteristics, various materials are tested with initial test, at a stress value that is under the material’s ultimate strength. Machine components are subjected to repeated varying forces or fluctuating loads of definite magnitude and stress cycles are to be measured. In this paper it has been analyse the performance EN8 and D2 steel. These materials are used for general applications of thread rolling process which experiences weariness stacking. Further, concentrates on fatigue testing machine to improve strength quality is shown. In the same way the method is repeated with the different values of load on EN8 and D2 steel specimens and the results are plotted and to represented on S-N diagram.

1. Introduction

Rotating beam fatigue tester is utilized to find out the fatigue strength or fatigue life of a metal. 90\% of the failures occur due to fatigue in a common industry. During nineteenth century, it was viewed that a fatigue fracture did not have any visible permanent deformation, this leads to a designing issue. A significant breakthrough in understanding of fatigue failure process occurred in the twentieth century with the assistance instruments like a computer, microscope by which it was not considered as a designing issue. The thought behind this work isn’t to give answers to the unanswered queries yet in addition to solve the problem from alternate point of view. This incorporates describing the whimsical idea of fatigue failure by performing tests on various examples and clarifying the known methodology of fatigue test. Basically fatigue failures are expensive due to this we perform fatigue analysis because a component failing in prototype phase is more expensive than in design phase. The component failing in service can cause a launch delays, warranty claims, recall and legal liability. In the study of materials fatigue, is the phenomenon of reducing the strength of a material occurred by load application i.e. cyclic load. It is dynamic, capricious and basic harm which happens when the specimen is subjected to cyclic stacking. Compared to yield strength or ultimate strength maximum stress of the material is less. If the applied loads are greater than a certain limit value, then microscopic cracks are occurred by applying the load up to higher limit. Due to this a crack is formed and it will expand on total structure until it is failed basically Fatigue failure occurs due to formation and propagation of cracks. It is a three stage process.
American society for testing and materials (ASTM) Committee, Murakami [3] reported that in 19th century research in the field of fatigue began and is reported in number of a range of methods for fatigue computation. It suggest the number of cycles until failure N to the cyclic loading S. The components may also fail due to low level of stress in some cases.

Gracia et al. [4] has worked on structures which are performed by using hydraulic testing machines. These are capable of applying large cyclic loads up to 100KN. The fatigue life of a structure is the number of cycles taken to break the structure. It is used for creating stress strain life curve. Wilhelm August Julius Albert [2] A German mining administrator calculated and reported on breakdown of excavation elevator cables ensuing from repetitive loadings, this is known of metal fatigue. In addition that he has developed a experiment apparatus for conveyor chains used in the mine. M.N. James and G. kang [1] studied the air worthiness Standards generally require a fatigue check performed for big aircraft previous to certification to decide their secure life. VVSH Prasad et.al (5) an attempt is being made to study the forming forces in thro feed of the component at roll as shown in figure 3.0 and work intersection and to determine the optical torque requirement using ANSYS software. To generalize the thread rolling process, software code is developed which can be used for different Work –Tool combinations to estimate the torque requirements

2. Materials

Assurance of failing attributes is basically through the stress versus no. of cycles to failure curve, which is commonly known as S-N curve. The fatigue test was directed according to IS 5075: 1975. The samples for the test were machined on a CNC lathe machine from EN8 and D2 steel bars to the shape as appeared in Figure 1.
Figure 1. Test Specimen

Table 1 give an idea about the composition of the EN 8 material and Table 2 the mechanical properties of EN8. Similarly, Table 3 and Table 4 show the composition of D2 steel, Mechanical properties of D2 steel correspondingly.

**Table 1. Chemical composition of EN31 Material**

| Element  | Min  | Max  |
|----------|------|------|
| Carbon   | 0.35 | 0.45%|
| Manganese| 0.60 | 1.0% |
| Silicon  | 0.5  | 0.35%|
| Sulphur  | -    | 0.6  |
| Phosphorus| -   | 0.6  |

**Table 2. Mechanical properties of EN8**

| Property         | Value                  |
|------------------|------------------------|
| Maximum Stress   | 700 to 850 N/mm²       |
| Yield Stress     | 465 N/mm²              |
| 0.2% Proof Stress| 450 N/mm²              |
| Elongation       | 16%                    |
| Impact KCV       | 28 Joules              |
| Hardness         | 201 to 255 Brinell     |

**Table 3 Chemical composition of D2 Steel**

| Element      | Min | Max  |
|--------------|-----|------|
| Carbon       | 1.4 | 1.6  |
| Manganese    | -   | 0.6  |
| Silicon      | -   | 0.6  |
| Sulphur      | -   | 0.03 |
| Phosphorus   | -   | 0.03 |
| Chromium     | 11  | 13   |
| Molybdenum   | -   | 0.6  |
| Iron         |     | Remaining |
Table 4. Mechanical properties of D2 Steel

| Property                                      | Value           |
|-----------------------------------------------|-----------------|
| Hardness, knoop (converted from Rockwell C hardness) | 769             |
| Hardness, Vickers                            | 748             |
| Izod impact unnotched                         | 77.0J           |
| Poisson’s ratio                               | 0.27 to 0.30    |
| Elastic Modulus                               | 190 a to 210 GPa|

3. Fatigue testing machine

Generally fatigue test is to decide the life expectancy that might be normal from a material exposed to cyclic stacking. The fatigue life of material is the absolute number of cycles that a material can be exposed to a solitary stacking condition. To carry out fatigue test, a sample is loaded into a fatigue testing machine. This cycle of loading and unloading is then repeated until the end of the test is reached. The test may run to a predetermined number of cycles or until the sample has failed depending on the parameters of the test. The type of fatigue testing machine using is Rotating beam type. The specimen function is as a single beam symmetrically loaded at two points. Fatigue testing machine details and rolling process as shown in fig.2 and fig.3 respectively.

Figure 2. Fatigue testing machine   Figure 3. Rolling

4. Mechanical and Test Specifications

Specimen material and size: Non heat treated ∅12.7 and 101.6 mm long
Collect size: ∅ 13mm
Load: 50 to 1000N (load applied with dead weights)
Loading ratio: 1:5
Specimen speed: Min 1000 rpm, Max 5000 rpm
Bending moment: 3 to 55Nm
Bending Stress: 110 to 2190Mpa
Setting block length: 40mm
Centre of profile: 19.05mm
Bending moment distance: Bending distance = loading distance + middle of profile centre
Loading distance = Loading point + Housing Covering plate + Collect length (9.9+9+17) = 35.95mm
Bending distance = 35.95+19.05 i.e. 55mm
Counters (counts): 1 to 999999
5. Procedure

The testing sample is held on machine toward one side to give rotational movement though the opposite end is connected to a heading and furthermore exposed to a heap or stress. At the point when the sample stacked between the grasps is turned about longitudinal pivot, the upper and lower portions of the sample measure length are exposed to ductile and compressive stresses. Accordingly, stress varies at the same time anytime in sample surface. The test continues until sample failure happens. The upset counter is utilized to acquire the quantity of cycles to failure relating to the stress applied. Increasing the load applied to the sample brings about a decrease in number of cycles to failure. It is essential to preparation of the samples as per the IS standard geometry. This includes cylindrical grinding up to surface roughness of 0.4 microns RA. That specimen is subjected to fatigue loading under normal ambient conditions from 5 to 1000N varying from up to 5000rpm cycles. The fatigue strength of the specimen is experimentally determining the S-N (Endurance strength-No. Of cycles) plots are drawn. Similar procedure has been adopted and subjected to thermal boundaries varying between 5000-9000c. And S-N curves are plotted and comparative studies are carried out for different materials EN8 and D2 steel. Table 5 and Table 6 shows the fatigue life calculations of EN8 and D2 steel materials.

6. Calculations

Bending Moment, \( M = \) Load applied \( \times \) Bending distance
Bending Stress, \( \sigma_b = \frac{32M}{\pi d^3} \)
Endurance Stress, \( \sigma_e = Ka.Kb.Kc.\sigma_1 \)
Where \( Ka = a (\sigma_{out}) b, \) Surface Finish Factor
\( Kb = 1.24d^{-0.107}, \) Size Factor
\( Kc = \) Reliability Factor
\( \log_{10}N-3 = EF \)
Where \( EF = \) Fatigue strength corresponding to the \( N \) cycles

### EN8

| Load in N | Speed in RPM | Bending Moment in Nm | Cycles |
|-----------|--------------|----------------------|--------|
| 50        | 1000         | 2.75                 | 7.61   |
| 100       | 1000         | 5.5                  | 12336  |
| 200       | 1000         | 11                   | 25515  |
| 250       | 1000         | 13.75                | 37436  |

### D2 STEEL

| Load in N | Speed in RPM | Bending Moment in Nm | Cycles |
|-----------|--------------|----------------------|--------|
| 50        | 1000         | 2.75                 | 23555  |
| 100       | 1000         | 5.5                  | 30394  |
| 200       | 1000         | 11                   | 42766  |
| 250       | 1000         | 13.75                | 51368  |
7. Results and discussion:

The S-N curvature is utilized to plot the extent of a rotating stress and the number of cycles to failure for a given case material. Both stress and the quantity of cycles are shown on logarithmic scales. The exhaustion qualities of a given material are taken by its S-N graph, a case of which is appeared in fig. 7. The representation of fatigue test in which an example of material is trying to failure by applying a alternate stress of extent S comprises of spots. It is rehashed for various estimations of S and number of cycles to failure then N is plotted against S. For various materials the plot of log S against log N is shown to in straight line.

S-N Curve

S-N curvature is drawn with logarithm of number of cycles for failure by the side of x axis and yielding stress by the side of y axis. The yielding stress was calculated by means of the equation =\[ L \times P \times 32/\pi \times d^3 \]

Where, \( L \) = Distance from predetermined end of the specimen to specimen’s contact point with load arrangement (mm)
\( d \) = Diameter at the narrow measurement of the sample (mm)
\( P \) = Applied load (N)

The magnitude of bending stresses (in this case alternating fully reverse alternating bending stresses are concerned therefore bending stress is indicated on y-axis different stress in axial loaded fatigue testing) and the equivalent fatigue life \( N \) (log10) i.e. on a logarithmic scale for which the graph is plotted and shown in figure 4.

EN8/C40

Figure 4. Bending moment and load curves of EN8 steel specimen.

D2 Steel

Figure 5. Bending moment and load curves of D2 steel specimen

Comparison

Figure 6. Curves of EN8 and D2Steel specimens
Figure 4, 5 and figure 6 shows the bending moment and load curve of the two circumstances. One clear observable fact that can be experiential during all the curves is that, whereas the stress increase, the number of cycles for rupture reduces. Despite the fact that it very well may be notice that for the stress esteems the examples withstand higher the number of cycles before fracture. Furthermore, the D2 steel test withstands more occasions the number of cycles before fracture when contrasted with the EN8 example. Regardless of whether we think about a plan for a fixed number of cycles, state 105 cycles, while EN8 tests can withstand of 512 N/mm2, the D2 steel tests can withstand 744.3 N/mm2. Improving the fatigue life of D2 steel as it displays a higher failing life when contrasted with different cases. The results are plotted from reports with the observation of S-N curve as shown in Figure 6. During fatigue test we observed the stages of failure over the specimen materials and obtained the fatigue life by number of cycles. The components which are subjected to load changes with time can undergo failure at stresses below the material’s maximum strength. This is referred to as Fatigue Failure. It accounts big majority of mechanical test.

8. Conclusions

- D2 steel specimen has considerably advanced UTS than that of the specimen of EN8 steel.
- Although D2 steel specimen endure advanced fatigue cycles prior to failure when compare to EN8 steel, the sample has extra fatigue existence than other specimen as lower bending stresses are concerned.
- At higher levels of stresses D2 steel specimen have two times the life of EN8 specimens.
- As D2 steel, steels show a advanced fatigue existence compare in the direction of others and have a enhanced extent for application concerning fatigue load
- The interest in studying and analysing of EN8 and D2 steel materials fatigue life have made an impact on us.
- For designing and dimensioning, the predictable load is compared with the capability to resist loads (fatigue strength). It means that the theoretical calculations and expressions were understood earlier than the realistic approach.
- The equipment used in this project for the fatigue characteristics of various metals is limited to standard shapes for above mentioned report.
- In future this obstacle can be overcome by introducing various shapes of metals used, which results in greater favourable results for withstanding the fatigue loads.
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