# Design and Analysis of Fatigue Testing Machine for Twist Drill

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# Design and Analysis of Fatigue Testing Machine for Twist Drill

**Major Project Report**

*Submitted in partial fulfillment of the requirements*

*for the degree of*

**Master of Technology in Mechanical Engineering**

**(CAD/CAM )**

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**MAY 2014**

# Declaration

This is to certify that

**I**. The thesis comprises my original work towards the degree of Master of Technology in Mechanical Engineering (CAD/CAM) at Nirma University and has not been submitted elsewhere for Degree.

**II**. Due Acknowledgment has been made in the text to all other material used.

**-Boghara Bipin Kantibhai**

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# Undertaking for Originality of Work

I, **Boghara Bipin Kantibhai, Roll. No. 12MMCC04,** give undertaking that the Major Project entitled **"Design and Analysis of Fatigue testing machine for twist drill"** submitted by me, towards the partial fulfillment of the requirements for the degree of **Master of Technology in Mechanical Engineering (CAD/CAM) of Nirma University, Ahmedabad,** is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary.

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**Place**: Nirma University,Ahmedabad.

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# Certificate

This is to certify that the Major Project Report entitled **"Design and Analysis of Fatigue testing machine for twist drill"** submitted by **Mr. Boghara Bipin Kantibhai (Roll No. 12MMCC04),** towards the partial fulfillment of the requirements for the award of Degree of **Master of Technology in Mechanical Engineering (CAD/CAM)** of Nirma University of Science and Technology is the record of work carried out by him under my supervision and guidance. The work submitted has in my opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of my knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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# Abstract

Fatigue is the process of progressive localized permanent structural change occuring in a materials. It occurs when a material is subjected to repeat loading and unloading. If the loads are above certain limit, microscopic cracks will begin to form at the stress concentrators such as the surface. Eventually a crack will reach a critical size, and finally the material will suddenly fracture. So the shape of the material will significantly affect the fatigue life. Fatigue testing gives much better data to predict the in-service life of materials. Drill is used to create the hole on the workpiece. While creating the hole drill has to be undergoes into compression and bending. It should be check for bending. So that the machine set-up has to be designed in CAD software and check the machine set-up for different loading condition. The aim of this thesis work is to discuss a rotating beam type set-up is designed and it is used to check the fatigue life of twist drill. The design principle of structure of fatigue test machine set-up was based on the adaptation of the technical theory of bending of beam. Components/materials selection was based on functionality, durability, cost and local availability. The major parts of the machine: the machine main frame, the bearing, the rotating shaft, the bearing housing, sensor, speed counter, dead weights, electric motor. The rotating beam type fatigue testing method can be used, because it's having simple working principle.

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# Nomenclature

d : Diameter of shaft (mm)
P : point load (N)3.1
$R_A$ : Reaction force at node A (N) 3.1
$R_B$ : Reaction force at node B (N)3.1
$M_C$ : Moment about node C (N.mm)3.1
$M_D$ : Moment about node D (N.mm)3.1
E : Modulus of elasticity (N/$mm^2$)
I : Moment of inertia of the cross section about the neutral axis ($mm^4$)
$\sigma_b$ : bending stress(N/$mm^2$)
$\sigma_t$ : Tension in shaft (N/$mm^2$)
y : distance from neutral axis to deflected axis (mm)
E : young modules of material (N/$mm^2$)
R : Radius of the curvature of the beam (mm)
C : Dynamic load rating (KN)
$C_0$ : Static load rating (KN)

# Chapter 1

# Introduction

## 1.1 Fatigue Testing Machine:

Machine is an apparatus or tool using mechanical power and having several parts, each with a certain function and together acting a particular task and that uses energy to complete a proposed action.

## 1.2 Classification:

Based on the purpose of the test, fatigue testing machine is classified into three categories:

### 1.2.1 General purpose testing machine

The general purpose testing machine can be further divided into two categories.

1. Classification based on type of stressing method:

   (a) Rotating type bending testing machine:

   In rotating type bending machine, the specimen is rotated by electric motor at constant rpm. Applying the constant force on specimen, failure is occurs on it.

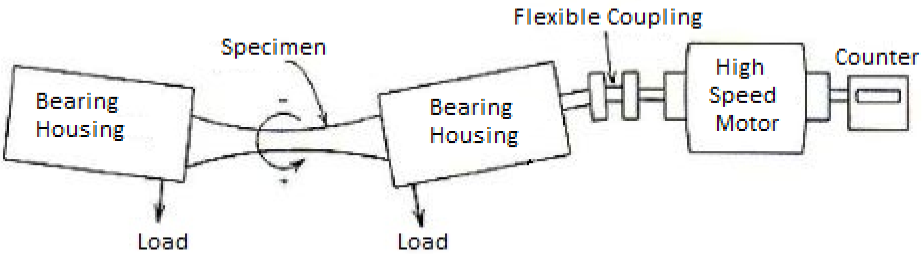



Figure 1.1: Rotating Type Bending Testing Machine
[1]

(b) Reciprocating type bending test machine:

This machine type is capable of zero mean stresses by positioning the specimen clamping vice with respect to the mean displacement position of the crank drive.

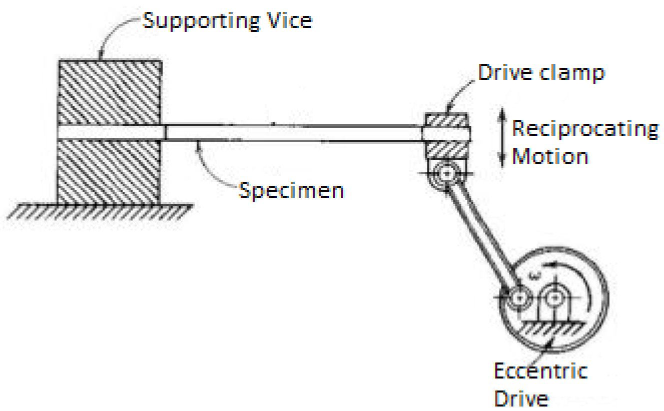



Figure 1.2: Reciprocating Type Bending Testing Machine
[1]

(c) Axial loading type fatigue tester:

In this type of tester specimen is undergoes to pure axial action during testing.

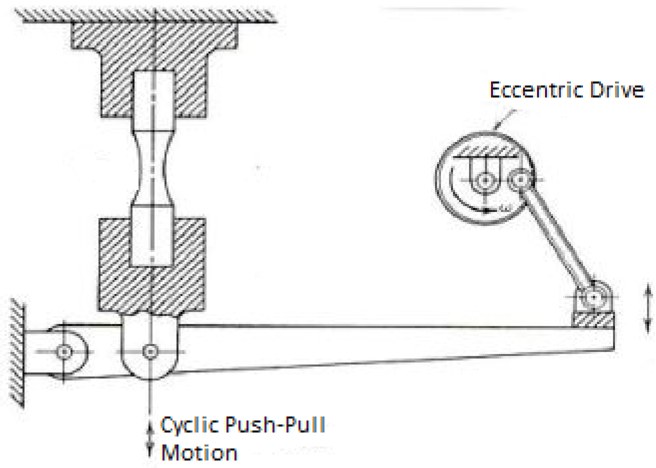



Figure 1.3: Direct-Force Fatigue Testing Machine
[1]

In this type of testing machine, bending and torsion type action is occurs on specimen. Most commercial world-wide fatigue testing machines have this features.

Other possible types, though not commonly used for simplified testing are:

- Torsion type loading fatigue tester
- Combined bending and torsion type fatigue tester
- Bi-axial and tri-axial type loading fatigue tester

2. Classification based on source of stressing:

   Based on the principle behind the source of the test-force, load is produced by:

Figure 1.4: Universal-tester
[1]

(a) Mechanical deflection

(b) Weight(Dead)

(c) Centrifugal force

The choice of load square depends on numerous factors such as the needed frequency, amount of forces required, cost, and how close the test is to be simplified to the actual working loading in service.

### 1.2.2 Special purpose fatigue testing machine:

In this type of machine, special purpose type of specimen is tested. Only one type of loading like bending, twisting and shearing can be possible in special purpose type fatigue testing machine.

### 1.2.3 Equipments for testing parts and assemblies:

In this type of machine, parts and assemblies are put in to test on this machine. This is not possible on any other machine.

## 1.3 Fatigue testing methods:

It is classified into two categories:

### 1.3.1 The sequence of stress amplitude:

- Classification based on the sequence of stress amplitude

1. Constant amplitude test:

   In this type of method, constant amplitude is applied on the test-piece. The following parameters are utilized to identify fluctuating stress cycles:

   Mean Stress, Sm

   $$S_m = \frac{S_{max} + S_{min}}{2} \tag{1.1}$$

   Stress Range, Sr

   $$S_r = S_{max} - S_{min} \tag{1.2}$$

   Stress amplitude, Sa

   $$S_a = \frac{S_{max} - S_{min}}{2} \tag{1.3}$$

   Stress Ratio, R

   $$R = \frac{S_{min}}{S_{max}} \tag{1.4}$$

   - Depending upon the choice of stress levels, constant-amplitude tests may be classified into three categories:
     - Routine test:

       In routine type test, the applied stresses are selected in such a way that all specimens are expected to fail after a moderate number of cycles around $10^4$ to $10^7$.
     - Short-life test:

       In short-life type test, the stress levels are suitable above the yield stress and some of the specimens are probable to fail statically at the application of the load.

  - Long-life test:

    In this type of testing method, the stress levels are suited below or just above the fatigue limit and a section of the specimen does not fail after a pre-assigned number of cycles around $10^6$ to $10^7$ cycles.

2. Variable amplitude test:

   More complicated sequences of amplitude are required in order to simulate the stresses to which a specimen is subjected in actual service. A realistic simulation is very complicated.In order to discover laws in relation to the accumulation of fatigue damage in a specimen subjected to stress reversals of different amplitudes, the sequence of stress amplitudes may be simplified. Independent of the pattern used, such tests is known as variable amplitude tests.

   Variable-amplitude tests can be further divided into:

   - Cumulative damage test

     These are tests where the objective is to investigate cumulative damage theory, in which case the sequences are frequently simplified.

   - Service simulating test

     These are tests which uses a more elaborate pattern (close to real service loading) for simulating purpose.

### 1.3.2 The nature of the test-piece:

It is classified into two categories:

1. Specimens:

   The term "specimen" is generally used in the sense of a test-piece of simple shape, frequently standardized, of small size and prepared carefully and with good surface finish. The purpose of the simplification is not to make it less expensive but more to reduce the variability of the product and to keep different influential factors under control.Test-pieces of this type are generally intended for testing the material and for stating its fatigue properties; they are also used extensively for research purposes.Even if the simplified specimen may simulate many of the properties of actual machine parts, there are two factors pertaining to the component which are not represented in the specimen i.e. design and fabrication. For this reason, it is indispensable to carry out actual tests with components in exactly the same condition as used in actual service..There are different types of specimens as shown in figure no. 1.5.

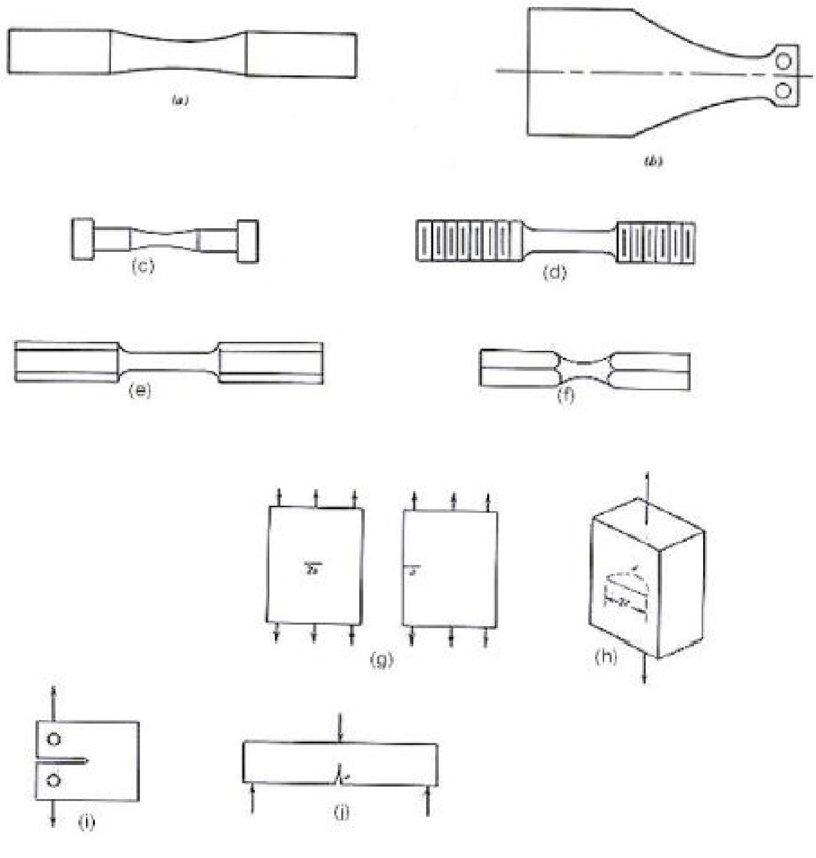



Figure 1.5: Test Specimens: (a) Rotating bending, (b) Cantilever Flat Sheet (c) Buttoned axial dog-bone, (d) Threaded axial dog-bone, (e) torsion, (f) Combined stress, (g) Axial Cracked sheet, (h) Part-through crack,(i) Compact tension and (j) Three point bend specimen

[1]

2. Component:

   It is used to signify any machine part, tool, machine, actual structure and assembly including elements simulating actual components.

## 1.4 The standard test specimen of fatigue testing as per ASTM

- Before carried out fatigue testing of any component,tool etc.,from that component's material one specimen is being prepared as per standard. After that particular component's fatigue test carried out because of checking the material properties and its behavior.

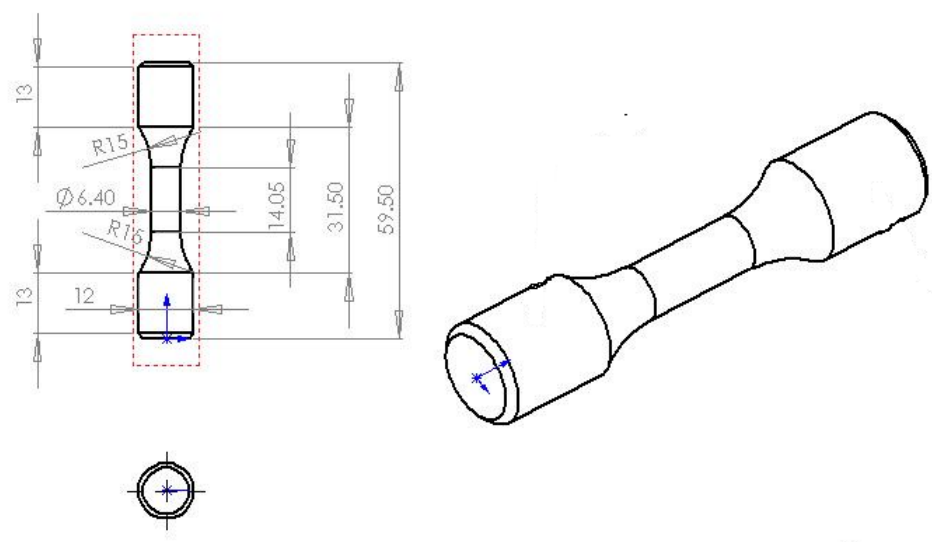



Figure 1.6: Test Specimens

## 1.5 General classification of fatigue testing:

Fatigue data are normally obtained from three general types of test. Based on objective of test, fatigue testing is divided into three categories:

1. Material type test:

   The material type of fatigue test using small specimens of various size and shape depending on the mode of stressing to be imposed. Test of the material type are useful for a comparison of the behavior materials subjected to repeated stresses, of the effects of various manufacturing processes, of the behavior of material in various environment, of various simple geometrical factors such as different sizes and shapes, of notches and different surface finishes.

   It could also be used for elaborating the effect of surface treatment such as decarburization,case-hardening, nitriding, shot-peening and plating on the fatigue properties of different materials.

2. The Structure type test:

   The structure type of fatigue test for this classification should be broadly interpreted to include machine parts and assemblies. This type of test may be useful for a comparison of components made from different materials, of different design and of structure fabricated by different procedures. They may also be used for revealing stress concentration and for developing better designs or better fabrication procedures.

3. Actual Service type test:

   Actual service type test is also called as reliability test or quality test, mainly for fault finding or verifying a new component in the machine or structure. Fatigue tests completely different in type from the above mentioned tests are those which have as an objective a study of the initiation and propagation of fatigue cracks, this requires complex knowledge of fracture mechanics and microscopic view of material structure and it is beyond the scope of this thesis work.

# Chapter 2

# Literature Review

## 2.1 Review of Published Study

1. Azeez[1] discussed the principle of fatigue failure. A comprehensive study of the underlying principle, stages and numerous factor that makes fatigue such a complex phenomenon was carried out. Different type of fatigue testing methods are described.

2. Wohler and Bauw[2] introduce the basic term of fatigue. How fatigue is relate to the material properties and causes of the fatigue failure. Different types of loading condition and mechanism had described with the help of the simple sketch and some basic formula also described.

3. Childs[3] discussed the classification of the engineering materials have been understand. Various compositions of materials have been studied. As per our requirement the material is selected as per standard on the basis of its strength. From some selection criteria from that, carbon steel material selected for various parts of fatigue testing machine.

4. Xue et al. [4] describes the design theory of machine which will adapted for required test set up. Bending theory is described and how bending stress is

produced. Some standard dimensions are also described as per some loading conditions. From this paper the design theory have been selected and it is rotating beam type bending theory. They also describes the check parameter whether the design is safe or not. According to that parameter and material properties as per standard design is proved whether it was capable of resist the acting load or not.

5. Neale[5] had done selection procedure is as per load requirement. Also life of bearing is calculated. The selection of an appropriate type of bearing, for use in a particular application, is a decision that is usually made early in a design process. It's also describes various bearing types, performance of various types of bearing, selection of a suitable bearing, and their applications. The basic function of bearings is to allow a load to be transmitted between two surfaces that are in relative motion. There are three main types of bearings: plain bearings, rolling bearings, and flexures. In plain bearings, the load is transmitted over a considerable area, while in rolling bearings the area in contact and transmitting the load is very small. As per our requirement for rotating bending type fatigue testing machine, deep groove ball bearing (C310) have been selected and bearing material as per use of bearing of Stainless steel X65Cr13 have been selected.

6. Riihimaki[6] describes the different types of fatigue testing machines. Classification of fatigue testing machines are also described. In this paper they have suggested rotating bending type fatigue testing machine was selected because it occupies low floor space and simple mechanism so it can easy to manufactured and also described design steps of fatigue testing machine.

7. Paul et al.[7] had developed rotating type bending machine for fatigue testing purpose. They carried out FEA analysis of machine set-up for applying boundary condition at different edge/face. They had also carried out static analysis of individual component for checking the design safe or not and find the critical

section in machine set-up.

8. Bijesh et al.[8] they had states that the standard for rotating beam fatigue testing has been serving industry faithfully. Over that time, the r.r.moore has been established an unsurpassed quality of machine design. The use of machine frame and heavy duty bearing housings are key components making a system built for many years of use.

## 2.2 Summary of Literature review

Bending theory is used for design the rotating type bending machine. Various component material selection is as per standard. Bearing selection is carried out based on Radial load and axil load. Components are to be designed on the basis of various loading acted on it. FEA analysis of component is used to check the possibility of failure after applying the various loading condition and check the critical section of whole assembly of machine.

# Chapter 3

# Material selection for machine set-up

## 3.1 Design Theory

- The theory governing the design of the fatigue machine is the simply supported loading elastic beam as shown in figure 3.1 bending principle often referred to as the technical theory of bending. The theory governing the design of the fatigue machine is the simply supported loading elastic beam bending principle often referred to as the technical theory of bending. A beam is a relatively long member that can support loads perpendicular to its axis. It can also support applied moments that tend to bend it resulting in the compression of the lower layers of the beam and the extension of the upper layers of the beam.

- The stress on the beam as a result of the bending is referred to as bending stresses. The adaptation of this theory is applied in the workings of the simply supported loading type of rotating bending fatigue test which consists in the application of a known constant bending stress (due to a bending moment) to a round specimen on one end which is not hinged while the other extreme end of the specimen is fixed, combined with the rotation of the sample around the bending stress axis until failure occurs.

- The rotation and simultaneous bending on which the fatigue machine operates ensures that the bending stresses which leads to stretch the upper layers of the specimen and compress the bottom layers as is applicable in stationary beams; is evenly distributed around the entire circumference of the specimen.

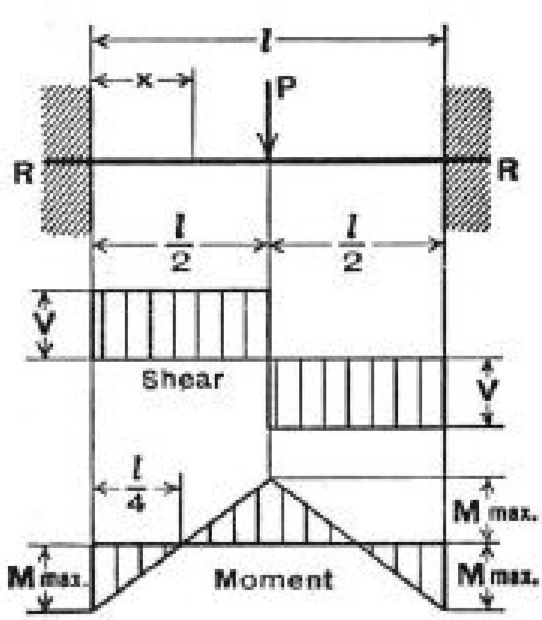



Figure 3.1: Bending Moment diagram of simply supported beam

$$TotalEquiv.uniformLoad = P \tag{3.1}$$

$$R = V = \frac{p}{2} \tag{3.2}$$

$$Mmax.(atcenterandends) = \frac{pl}{8} \tag{3.3}$$

$$M_x(whenx < l/2) = \frac{P}{8}(4x - l) \tag{3.4}$$

$$\delta max.(atcenter) = \frac{pl^2}{192EI} \tag{3.5}$$

$$\delta x(when x < l/2) = \frac{px^2}{48EI}(3l - 4x) \quad (3.6)$$

For round specimens, the moment of resistance for circular sections is applicable and is given by:

$$\frac{M}{I} = \frac{E}{R} = \frac{\sigma}{y}[?] \quad (3.7)$$

Where M = Bending moment acting at given section I = Moment of inertia of the cross section about the neutral axis $\sigma$ = Bending stress y = Distance from neutral axis to deflected axis E = Young modules of material R = Radius of the curvature of the beam

and

$$I = \frac{\pi * d^4}{64} \quad (3.8)$$

Where d = diameter of specimen in mm.

## 3.2 Components and Materials of Machine Set-up

### 3.2.1 Components of machine set-up

Different components are used in machine set-up. Block diagram of machine set-up as shown in figure 3.2

### 3.2.2 Materials

Selection of material is an important factor:

The selection of a material, for engineering purposes, is one of the most difficult problems for the designer. The best material is one which serve the desired objective at the minimum cost. The following factors should be considered while selecting the material.

1. Availability of the materials

2. Suitability of the materials for the working conditions in service

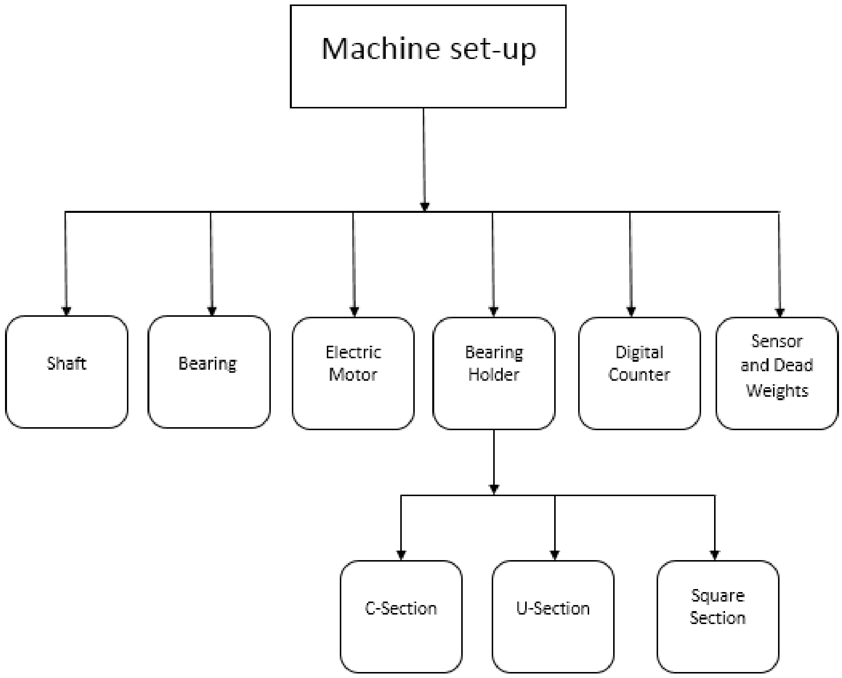



Figure 3.2: Block diagram of machine set-up

3. The cost of the materials

The various materials used for : Collets, bolts, and nuts, Ball bearing, Flate metal plate, Electric motor, Speed meter, Tachometer Rotating shaft, Automatic switch, wire and plug, switch, Dead weight etc.

**Material selection:**

Machine consists of lots of parts and the main parts of the machine set-up are: The electric motor, which gives the rotation; two main bearing, which are creating two supports; Two load bearing, where the load is applied; proximity sensor, which defects the rotation motion of the shaft and sends the signals to the counter; digital counter, which takes data from the sensor and records the number of rotation to failure of the specimen. The various parts/components of the fatigue machine were systematically coupled together through the preparation of design drawings based on the application of the theoretical principle of bending which had been thoroughly studied.

- Material selection for individual component:

Table 3.1: As per standard selection of material

| Indian Standard Designation | Composition in percentages | User as per:<br>1871 (part II) -<br>1987 (Reaffirmed 1993) |
|---|---|---|
| 40C8 | 0.35-0.45%C | It is used for shafts<br>and bolts |
| 60C4 | 0.55-0.65%C | It is used for making Screws<br>and nuts |
| High Speed Steel (M42)<br>1.5%W | 1.10%C,3.8%Cr,9.5%Mo,<br>1.2%V,8.0%Co | It is used for specimen |
| Stainless steel (X65Cr13) | 58-70%C,12.50-14.50%Cr | It is used for deep<br>groove ball bearing |

- Properties of stainless steel:-

- High oxidation-resistance in air at ambient temperature is normally achieved with additions of a minimum of 13 percent (by weight) chromium, and up to 26 percent is used for harsh environments. The chromium forms a passivation layer of chromium (III) oxide ($Cr_2O_3$) when exposed to oxygen. The layer is too thin to be visible, and the metal remains lustrous.

- The layer is impervious to water and air, protecting the metal beneath. Also, this layer quickly reforms when the surface is scratched.

- This phenomenon is called passivation and is seen in other metals, such as aluminium and titanium. Corrosion-resistance can be adversely affected if the component is used in a non-oxygenated environment, a typical example being underwater keel bolts buried in timber.

- When stainless steel parts such as nuts and bolts are forced together, the oxide layer can be scraped off, causing the parts to weld together. When disassembled, the welded material may be torn and pitted, an effect known as galling. This destructive galling can be best avoided by the use of dissimilar materials for the parts forced together, for example bronze and stainless steel, or even different types of stainless steels (martens tic against austenitic), when metal-to-metal wear is a concern, but two different alloys electrically linked in humid environment work as pile and corrode faster.

- Nitronic alloys reduce the tendency to gall through selective alloying with manganese and nitrogen. Additionally, threaded joints may be lubricated to prevent galling. Similarly to steel, stainless steel is not a very good conductor of electricity, with about a few percent of the electrical conductivity of copper.

- Ferritic and Martenstic stainless steels are magnetic. Austenitic stainless steels are non-magnetic.

# Chapter 4

# Machine Design

## 4.1 Introduction

- The testing machine is a rotating bending type machine which can be used for fatigue testing. In this type of machine the specimen is gripped in between two shaft and rotation can be given by electric motor and then dead weights are hanging with the help of rod so that some bending action can be occurs after some revolution the cracks are produced in specimen.
- One sensor mechanism is connected to the specimen. So it is helping us to automatic switch off the motor.
- Then tachometer takes a reading of rpm of motor or revolution of motor then plot that result into S-N diagram. So we can find the life of specimen's material with the help of the S-N diagram.
- We can derive the conclusion that there is a some parameter it relates to the fatigue life of the any component.
- We carried out structural analysis with the use of beam theory to predict the reaction and bending moment of the rotating member at some particular point at which the supports have situated.

## 4.2 Components of a Machine set-up

All types of fatigue testing machine consist of the following structural components:

1. Load producing mechanism

   This generates the alternating load (displacement) to which in some cases a steady load is added. Ex. Electric motor

2. Load transmitting member

   This includes grip, guide fixture, flexure joints etc. by which the load produced is transmitted n such way as to produce the desired stress distribution within the specimen. Ex. Shaft

3. Measuring devices

   This permits the setting of the nominal upper and lower load limits. Ex. Tachometer

4. Control devices

   This component controls the load throughout the test and sometimes automatically corrects changes in force or displacement arising during the test using feedback techniques.

5. 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.

6. Framework

   It supports the various parts of the machine and if necessary is arranged to reduce the vibratory energy transmitted to the foundation.

## 4.3 Description of individual component

1. Shaft:

   - A medium carbon law alloy steel material was selected for design of shafts of the machine. The fatigue resistance of the steel was taken into consideration before selection. The stress at a point in the shaft is equal to the torque times the radial position of that point, divided by the torsion constant. Stress = $(Torque \times Radialposition)/J_T$. That equation show you that the stress is concentrated in the only most material of the shaft, and the material in the center of the shaft can be removed and applied to the outside of the shaft, increasing the strength and stiffness.

   - Torsion constant of a solid shaft is $\pi/2$ times the radius of the shaft raised to the further power, while the torsion constant of a hollow shaft is $\pi/2$ times the difference of the outer radius to the further minus the inner radius raised to the fourth. Whenever things are proportional to something raised to an exponent like this, it's something that can be taken advantage of. Due to this, a hollow tube can be both stiffer and lighter. On the basis of this solid shaft can be selected for testing because shaft's displacement is important to this type of application of failure of specimen due to displacement of shaft in downward direction.

   - The machine design require the uses of two shafts - the first is connected to the electric motor and links the motor to second shaft that contains the specimen.The function of the shaft attached to the electric motor is to transmit torque from the motor to be second shaft that contains the bearing, bearing housing, specimen at the end of the shaft

- The principle function of the second shaft is to rotate the specimen while it is under the action of bending moments from the dead weight. The shaft is threaded to allow collet for clamping the specimen.

Design of shaft is carried out based on two criteria:-

- Shaft subjected to tension only :
  Shaft has a circular cross section.

$$A = \frac{\pi}{4}(d^2) \tag{4.1}$$

$$A = 0.78 \times d^2 \tag{4.2}$$

Now

$$P = \sigma_t \times A \tag{4.3}$$

Where
A = Cross sectional area of shaft
d= Diameter of shaft
P= Load acting upon the shaft= 1500 N
$\sigma_t$ = Tensile strength of the shaft material and it is 58 $N/mm^2$ as per standard
From equation no. (4.2) and (4.3)
d = 5.75 ≅ 6 mm

As per above calculation shaft diameter will be selected in between 6 mm < d < 30 mm for safe design.

- Shaft subjected to bending moment only :
  Our experiment set up is purely under bending condition so that diameter of the shaft is selected based on this criteria.From fig no.5.2 We can draw the bending moment diagram as shown below :

From fig no.4.1 reaction force acted upward at node A($R_A$) and B($R_B$)

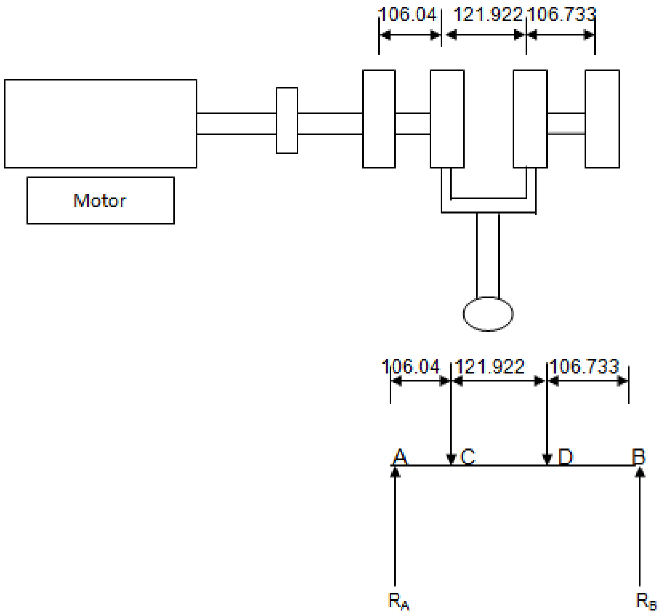



Figure 4.1: Beam analysis of machine set up

can be found with the help of the fig no.3.1. At node C and D 1500 N load is acting.
Taking node A as a reference,

$$R_B \times 334.66 = 1500 \times 106.004 + 1500 \times (106.004 + 121.922) \quad (4.4)$$

$$R_B = 1496.70N \quad (4.5)$$

$$R_A = 3000 - R_B \quad (4.6)$$

$$R_A = 1503.29N \quad (4.7)$$

Taking moment about at node A and B,

$$M_C = R_A \times 106.004 \quad (4.8)$$

$$M_C = 159354.75 N.mm \tag{4.9}$$

$$M_D = R_B \times 106.733 \tag{4.10}$$

$$M_D = 159747.28 N.mm \tag{4.11}$$

Now,

$$Z = \frac{\pi}{32}(d^3) \tag{4.12}$$

$$Z = 0.0982 \times d^3 \tag{4.13}$$

$$\sigma_b = \frac{M}{Z} \tag{4.14}$$

$\sigma_b = 100\ N/mm^2$ $\tau = 60\ N/mm^2$

M= maximum bending moment at node.So M = 159747.28 $N/mm^2$. With the help of the equation no. (4.13) and (4.14)

$$d = 25.33 mm \tag{4.15}$$

We consider equivalent twisting moment,

$$P = \frac{2\pi NT}{60} \tag{4.16}$$

Where

P = power of motor in W

= 1 HP

= 0.74 KW

= $0.74 \times 10^3$ W

N = RPM of motor

= 2500 rpm (Maximum rpm of motor is 2880)

$$T = 2.82 N.m \tag{4.17}$$

Equivalent twisting moment,

$$(T_e) = \sqrt(M^2 + T^2) \tag{4.18}$$

$$(T_e) = \sqrt(159747.28^2 + 2820^2) \tag{4.19}$$

$$(T_e) = 159747.52 N.mm \tag{4.20}$$

Torque produced on the shaft,

$$T = \frac{\pi \times \tau \times d^3}{16} \tag{4.21}$$

from equation no. (4.21),

$$d = 23.84 mm \tag{4.22}$$

From result (4.22) and (4.15),
Shaft diameter taken as 26 mm.

2. Bearing and bearing housing:

- The bearing selected for this design were deep grove ball bearing which have high load carrying capacity and it can accommodate misalignment and shaft deflection of 0.50. It was ensured that the bearing would allow for the mounting of all components onto the shaft physically and that the mass of all components including the bearings was minimized.
- Bearing selection procedure[5] describes as shown below :
- Bearing have two loads :

(a) Radial load : It is acting along vertical direction or perpendicular to the bearing rotation axis. It is denoted by $W_R$.

(b) Axial load : It is acting along horizontal direction or along with bearing rotation axis. It is denoted by $W_A$.

From figure no. 3.1,

$$W_R = 1503.29N \tag{4.23}$$

And,

$$W_A = 0.25 \times W_R \tag{4.24}$$

$$W_A = 375.82N \tag{4.25}$$

Maximum RPM of the motor is 2880. So N = 2880 rpm. Life in hours, Since the average life of the bearing is 5 year at 5 hours per day, therefor lief of bearing in hours is (Assuming 300 working days per year),

$$L_H = 5 \times 300 \times 5 \tag{4.26}$$

$$L_H = 7500 \tag{4.27}$$

and life of the bearing in revolutions,

$$L = 60 \times N \times L_H \tag{4.28}$$

$$L = 1296000000rev \tag{4.29}$$

Basic dynamic equivalent radial load,

$$W = (X \times V \times W_R) + (Y \times W_A) \tag{4.30}$$

In order to determine the radial load factors (X) and axial load factor (Y), We require $\frac{W_A}{W_R}$ and $\frac{W_A}{C_o}$. Since the value of basic static load capacity ($C_o$) is taken from standard and it is 0.5. Now from Table no. 4.1 $\frac{W_A}{C_o}$ = 0.5 , X = 0.56, Y =

1.0.

[5]

Table 4.1: Value of X and Y for dynamically loaded bearing

| Type of Bearing | Specification | $\frac{W_A}{W_R} \leq e$ | $\frac{W_A}{W_R} \leq e$ | $\frac{W_A}{W_R} > e$ | $\frac{W_A}{W_R} \leq e$ | e |
|---|---|---|---|---|---|---|
| Deep groove ball bearing | $\frac{W_A}{C_O} = 0.25$ | X=1 | Y=0 | X=0.56 | Y=2 | 0.22 |
| | =0.04 | X=1 | Y=0 | X=0.56 | Y=1.8 | 0.24 |
| | =0.07 | X=1 | Y=0 | X=0.56 | Y=1.6 | 0.27 |
| | =0.13 | X=1 | Y=0 | X=0.56 | Y=1.4 | 0.31 |
| | =0.25 | X=1 | Y=0 | X=0.56 | Y=1.2 | 0.37 |
| | =0.50 | X=1 | Y=0 | X=0.56 | Y=1.2 | 0.44 |

$$W = (0.56 \times 1 \times 1503.29) + (1 \times 3 \times 75.82) \tag{4.31}$$

$$W = 2217.6624N \tag{4.32}$$

We find that for uniform and steady load service factor $K_s$ for ball bearing is 1.

Basic dynamic load rating,

$$C = \frac{w \times l^{\frac{1}{k}}}{10^{6\,\frac{1}{k}}} \tag{4.33}$$

k = 3 for ball bearing,

$$C = 24178.56N \tag{4.34}$$

$$C = 24.178KN \tag{4.35}$$

Where,

BC = Basic Capacities in KN.

SRDG = Single row deep groove ball bearing.

SRAC = Single row angular contact bearing.

DRAC = Double row angular contact ball bearing.

SA = Self aligning ball bearing.

[5]

Table 4.2: Selection of bearing no.according to the dynamic load rating

| Bearing no. | BC in KN | BC in KN | BC in KN | BC in KN | BC in KN | BC in KN | BC in KN | BC in KN |
|---|---|---|---|---|---|---|---|---|
| | SRDG | SRDG | SRAC | SRAC | DRAC | DRAC | SA | SA |
| | Static | Dynamic | Static | Dynamic | Static | dynamic | Static | Dynamic |
| | $C_O$ | C | $C_O$ | C | $C_O$ | C | $C_O$ | C |
| 200 | 2.24 | 4 | - | - | 4.55 | 7.35 | 1.80 | 5.70 |
| 300 | 3.60 | 6.3 | - | - | - | - | - | - |
| 201 | 3 | 5.4 | - | - | 5.6 | 8.3 | 2.0 | 5.85 |
| 301 | 4.3 | 7.65 | - | - | - | - | 3.0 | 9.15 |
| 202 | 3.55 | 6.10 | 3.75 | 6.30 | 5.6 | 8.3 | 2.16 | 6 |
| 302 | 5.20 | 8.80 | - | - | 9.3 | 14 | 3.35 | 9.3 |
| 203 | 4.4 | 7.5 | 4.75 | 7.8 | 8.15 | 11.6 | 2.8 | 7.65 |
| 303 | 6.3 | 10.6 | 7.2 | 11.6 | 12.9 | 19.3 | 4.15 | 11.2 |
| 403 | 11 | 18 | - | - | - | - | - | - |
| 204 | 6.55 | 10 | 6.55 | 10.4 | 11 | 16 | 3.9 | 9.8 |
| 304 | 7.65 | 12.5 | 8.3 | 13.7 | 14 | 19.3 | 5.5 | 14 |
| 404 | 15.6 | 24 | - | - | - | - | - | - |
| 205 | 7.1 | 11 | 7.8 | 11.6 | 13.7 | 17.3 | 4.25 | 9.8 |
| 305 | 10.4 | 16.6 | 12.5 | 19.3 | 20 | 26.5 | 7.65 | 19 |
| 405 | 19 | 28 | - | - | - | - | - | - |
| 206 | 10 | 15.3 | 11.2 | 16 | 20.4 | 25 | 5.6 | 12 |
| 306 | 14.6 | 22 | 17 | 24.5 | 27.5 | 35.5 | 10.2 | 24.5 |
| 406 | 23.2 | 33.5 | - | - | - | - | - | - |
| 207 | 13.7 | 20 | 15.3 | 21.2 | 28 | 34 | 8 | 17 |
| 307 | 17.6 | 26 | 20.4 | 28.5 | 36 | 45 | 13.2 | 30.5 |
| 407 | 3.05 | 43 | - | - | - | - | - | - |

- From Table no.4.2 Bearing no. 307 (Deep groove ball bearing) selected for machine.
- The bearing housing is a bearing shaped. It has good strength and toughness. The housing was bored to the size of the external diameter of the collet. Two bearing were forcefully inserted into the housing at both ends and at remaining two bearing the specimen has supported. The specimen has supported with the use of collet which has expand mechanism.

3. Proximity sensor:

- The proximity sensor utilized in the design is presented in Figure no. 4.2. The sensor is utilized to detect the oscillation of nearby objects without having any physical contact with the object; so far the objects are not more than a distance of 15mm from it.

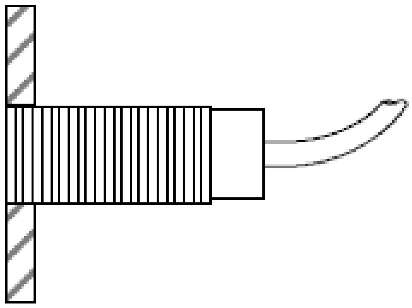


Figure 4.2: Side view of Proximity sensor

- A proximity sensor often emits an electromagnetic or electrostatic field, or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. For material (High speed steel) detection, inductive type proximity sensor is used.
- It has been found suitable for detecting the number of revolutions of rotating materials hence it was selected to detect the number of revolutions of the shaft under the applied bending moments leading to fatigue failure. The sensor was placed on the end of the shaft which is connected to the specimen at the left arm of the main frame of the machine to detect every cycle the shaft rotates. The rotating motion of the shaft and sends signal to the counter.

- Longer sensing distance can be obtained by using an unshielded sensor. Unshielded proximity sensors require a metal-free zone around the sensing face. Metal immediately opposite the sensing face should be no closer than three times the rated nominal sensing distance of the sensor. Here no. of sensor is depend upon length of specimen which will sense the surface of the specimen. For longer specimen two pair of sensor can be used as shown in figure 4.3.

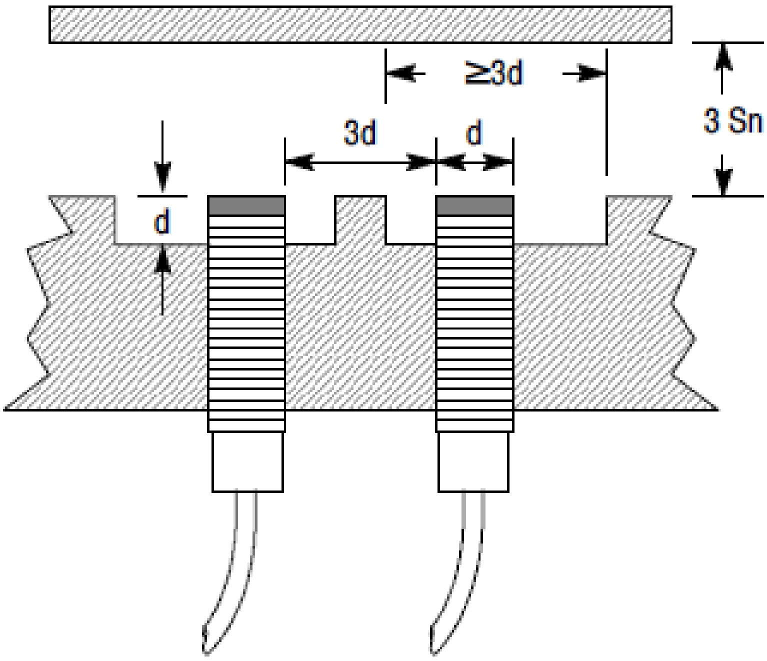



Figure 4.3: Two inductive proximity sensor for long specimen

Where,

d = Diameter or width of active sensing face

$S_n$ = Nominal sensing distance

4. Digital Counter:

- A 6 digit digital counter was selected for recording the number of stress cycles a specimen undergoes during testing.

- It was ensured that the digital counter was compatible with the proximity sensor selected, that is, it should be able to translate the signals from the sensor to a numerical output.


Figure 4.4: Digital counter

- The digital counter utilized can relay digital outputs, but can be programmed to run for a specified number of cyclic revolutions utilizing an analogy input bottom incorporated into the counter. It can also be programmed to evaluate rate in a given time. Conventionally, an 8 - digit counter is utilized for the design of rotating bending fatigue machines. The unavailability of the 8 - digit counter led to the use of the 6 - digit counter which was readily available within the country.

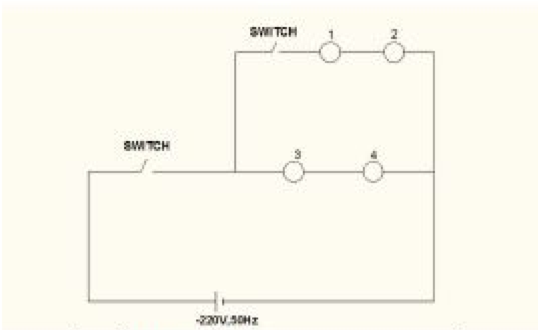
5. Electric motor:

- An electric motor uses electrical energy to produce mechanical energy, very typically through the interaction of magnetic fields and current-carrying conductors. Based on calculation carried out, maximum load is 3000KN so based on this, motor is selected which having 2880 rpm and power consuming capacity is 0.74 KW (1HP). The electric motor used in machine set-up as shown in figure no. 4.5.

Figure 4.5: Electric motor

6. Electric connections and circuit diagrams:

   - The electrical connection is done in such a way that when the whole machine is put on, the counter comes on and is indicated by the lighting of a bulb but the whole machine doesn't come on not until the second switch is put on, this is to ensure safety and to be able to control the whole machine.




| No | Component |
|---|---|
| 1 | Bulb Indicator for Electric Motor |
| 2 | Electric Motor |
| 3 | Bulb Indicator for Speed Counter |
| 4 | Speed Counter |

Figure 4.6: Electric circuit diagram

# Chapter 5

# CAD Model and FEA Analysis

## 5.1 CAD Model

- On the basis of design carried out in previous chapter, CAD Model of machine set up is developed in CAD Software as shown in figure 5.1. Detailed drawing of machine set-up as shown in figure 5.2.

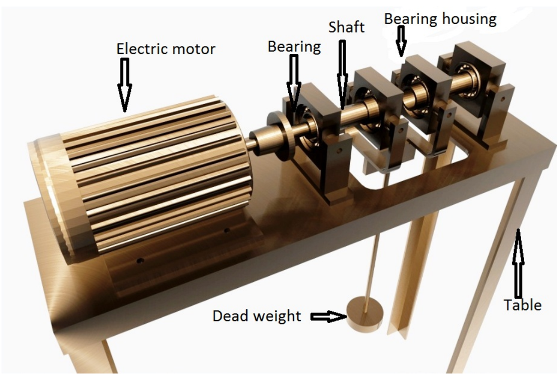



Figure 5.1: CAD model of machine set-up

- Different loading condition are applied on the individual components or assembly of two components to check the design aspects whether it is safe or not

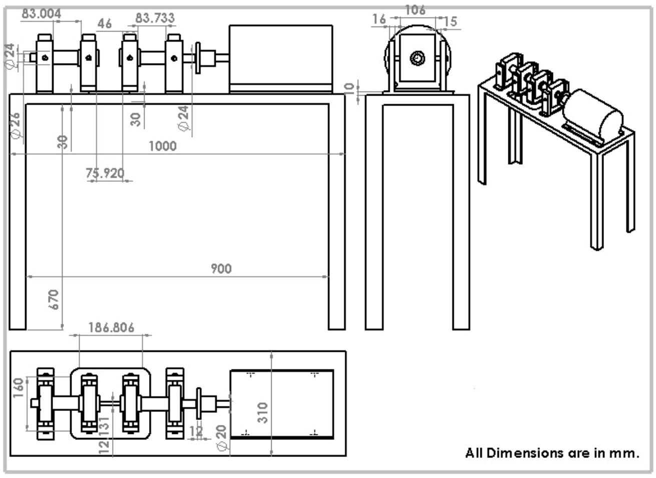



Figure 5.2: Detail drawing of machine set-up

under loading condition. So that FEA simulation is carried out discussed in section 5.2.

## 5.2 FEA Analysis

### 5.2.1 Introduction

- This chapter contain FEA simulation of the machine part. Static analysis of the part is carried to see the effect of different loading condition.

### 5.2.2 Steps for FEA Analysis

- Following steps are carried out for Static(Stress)Analysis of a part:

1. Import CAD Model
2. Assigning material to the part creating a static analysis study
3. Applying a fixed restraint and a pressure load
4. Setting meshing options and meshing the part

5. Running the study

6. Viewing basic results of static analysis

7. Assessing the safety of the design

8. Generating a study report

- General guidelines to creating the static analysis:

1. Opening the part and Assigning Material:
   First opening the part in which to create the static analysis then assign the material which required. Verify all the parameters like ultimate strength, yield strength, von mises stresses of the part.

2. Creating static analysis Study:
   Select the which type of study required.

3. Applying Fixed Restraints:
   Applying fixed restraints at edge, face of the part.

4. Applying Pressure:
   If part is under pressured at some edge or face then apply the pressure at that face or edge.

5. Set meshing Options:
   Meshing options contain mesh control. There are different type of Meshing like Solid mesh,Shell mesh,Beam mesh and Mixed mesh.

6. Meshing the part and Running the Analysis:
   After creating meshing, run the study.

7. Displaying Mesh Information:
   Check the information of Mesh whether it is right or wrong.

8. Viewing von Mises (Equivalent) Stresses:

   Viewing the von mises stresses in form of scale of stress.

9. Viewing Resultant Displacement:

   This step contains displacement of point,edge and face can be shown with the help of colour as shown in displacement scale.

10. Animating a plot:

    This is used for animate the plot. How stresses can be distributed.

11. Viewing Equivalent Element Strains:

    Viewing the strain in form of scale of strain.

12. Assessing the Safety of the Design:

    Compared the maximum stress with material's ultimate strength. If maximum stress can be grater than ultimate strength then design not to be safe

13. Plotting the critical Regions of the Part:

    Critical section can be shown in result. That can't be subjected to fail.

14. Generating a Study Report:

    In this step report is generated which contains all the above results.

### 5.2.3 Analysis

- By applying different loading condition, analysis of different parts is carried out with help of above steps.There are three parts namely C-Section,U-Section and Square section are required to simulate individually. There are two no. of C-Section, four no. of square section and two no. of U-section in machine set up.

- Different Loading condition applied on different Parts assemblies as shown in below.

1. Analysis of Assembly of C-Section and Square Section:

   - In this section material properties, various loading condition, Meshing information, Meshing, Von-mises stress plot, Displacement plot, Strain plot of assembly of C-section and Square section is described. Comparison of all stress, displacement and strain of assembly with it's material properties whether it is safe or not in form of table as shown in Table no. 5.1. In this type of analysis all joints, types of loading, material properties can be consider. Detailed drawing of individual component is shown in figure no. 5.3.

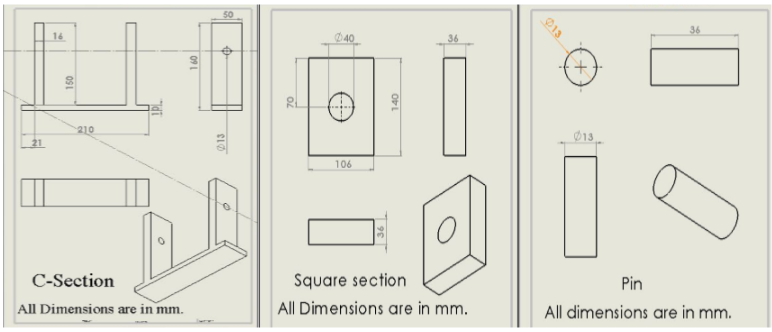



Figure 5.3: Detailed drawing of C-Section, Square Section and Pin

   - Material properties of C-section and Square section:

     (a) Modulus of Elasticity = 2.0X10$^{11}$ $N/m^2$
     (b) Poisson ratio = 0.28
     (c) Mass density = 7700 $kg/m^3$
     (d) Tensile strength = 7.23X10$^{8}$ $N/m^2$
     (e) Yield strength = 6.20X10$^{8}$ $N/m^2$

   - Material properties of pin:

     (a) Modulus of Elasticity = 2.1X10$^{11}$ $N/m^2$

(b) Poisson ratio = 0.3

(c) Mass density = 7300 $kg/m^3$

(d) Tensile strength = 6.6X$10^8$ $N/m^2$

(e) Yield strength = 5.6X$10^8$ $N/m^2$

- Loading Condition:

  Force is acting on the Upper face of square section is 1503.29 N in upward direction and torque at shaft upper face is 2820 N.mm as shown in figure no. 5.4.

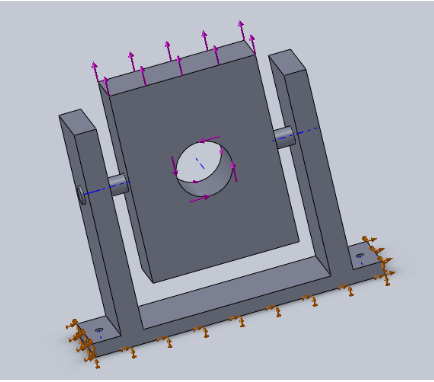


Figure 5.4: Loading condition

- Mesh Information :

(a) Mesh Type: Solid Mesh

(b) Meshed Used: Standard mesh

(c) Jacobian Check: 4 Points

(d) Element Size: 7.87 mm

(e) Tolerance: 0.3935 mm

(f) Number of elements: 24079

(g) Number of nodes: 14781

As shown in Figure no. 5.5, Meshing is carried out.

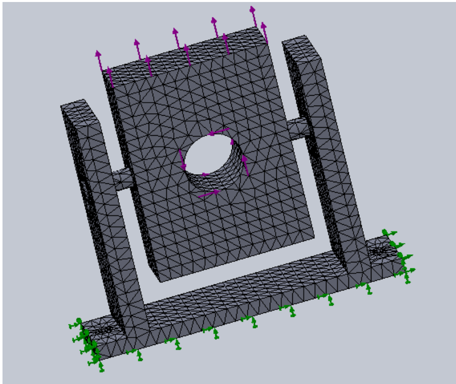


Figure 5.5: Meshing Model

- Study result :

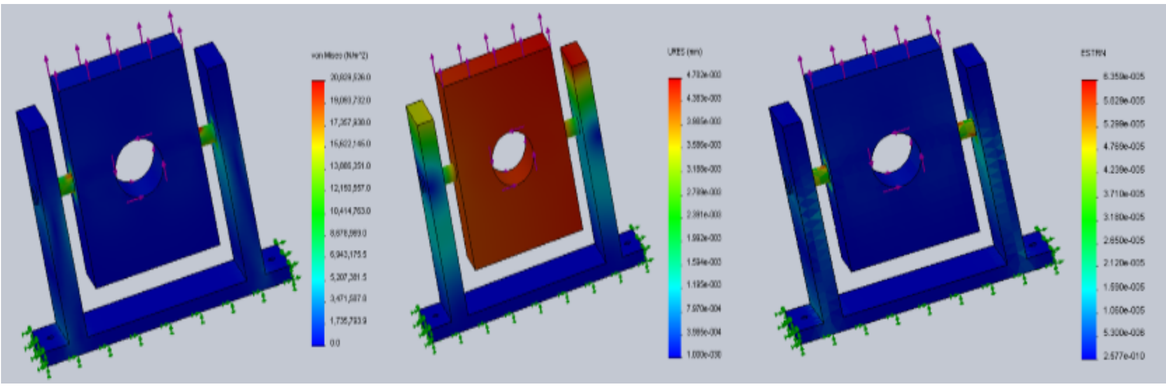


Figure 5.6: Von-mises stress, Displacement and Strain of C-Section and square section

- Von mises stress : As shown in Figure no. 5.6 maximum value of von mises stress is 20.82 $N/mm^2$ and it is below yield strength so that design is safe based on given boundary and loading conditions.
- Displacement : As shown in Figure no. 5.6 maximum value of displacements is 4.782X$10^{-3}$mm. In fig red color portion indicates maximum displaced area.

- Strain :

  As shown in Figure no. 5.6 maximum value of strain is $6.359X10^{-5}$.

- Representation of analysis data of stress, displacement and strain of individual component in form of table as shown in table no. 5.1.

Table 5.1: Comparison of stress, strain and displacement with it's material property of assembly of C-section and Square section

| Component name | Von-mises in $N/mm^2$ | Displacement in $mm$ | Strain | Material Property in $N/mm^2$ | Design Safe Yes/No. |
|---|---|---|---|---|---|
| C-Section | 21.1 | $4.782X10^{-3}$ | $4.769X10^{-5}$ | TS=723<br>YS=620 | Yes |
| Square Section | 5.2 | $4.79X10^{-3}$ | $6.36X10^{-5}$ | TS=723<br>YS=620 | Yes |
| Pin | 17.3 | $3.58X10^{-3}$ | $5.82X10^{-5}$ | TS=560<br>YS=560 | Yes |

Where,

TS=Tensile strength

YS=Yield strength

2. Analysis of Assembly of U-Section and Square Section:

   - In this section material properties, various loading condition, Meshing information, Meshing, Von-mises stress plot, Displacement plot, Strain plot of assembly of U-section and Square section is described. Comparison of all stress, displacement and strain of assembly with it's material properties whether it is safe or not in form of table as shown in Table no. 5.2. In this type of analysis all joints, types of loading, material properties can be consider. Detailed drawing of individual component is shown in figure no. 5.7.

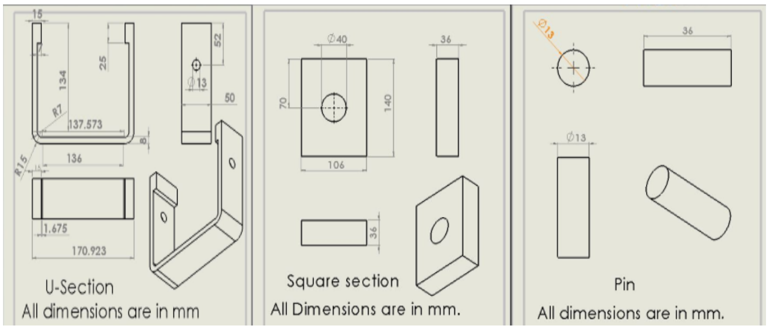



Figure 5.7: Detailed drawing of U-Section, Square Section and Pin

- Material properties of U-section and Square section:

  (a) Modulus of Elasticity = $2.0X10^{11}\ N/m^2$
  (b) Poisson ratio = 0.28
  (c) Mass density = 7700 $kg/m^3$
  (d) Tensile strength = $7.23X10^{8}\ N/m^2$
  (e) Yield strength = $6.20X10^{8}\ N/m^2$

- Material properties of pin:

  (a) Modulus of Elasticity = $2.1X10^{11}\ N/m^2$
  (b) Poisson ratio = 0.3
  (c) Mass density = 7300 $kg/m^3$
  (d) Tensile strength = $6.6X10^{8}\ N/m^2$
  (e) Yield strength = $5.6X10^{8}\ N/m^2$

- Loading Condition:

  Force is acting on the Upper face of square section is 1500 N in downward direction and torque at shaft upper face is 2820 N.mm as shown in figure no. 5.8

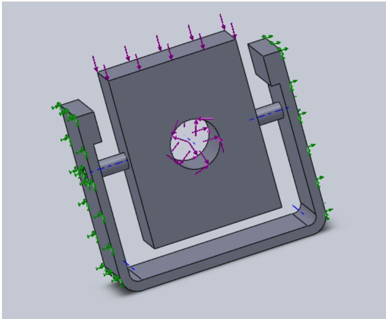


Figure 5.8: Loading condition

- Mesh Information :

  (a) Mesh Type: Solid Mesh

  (b) Meshed Used: Standard mesh

  (c) Jacobian Check: 4 Points

  (d) Element Size: 7.87 mm

  (e) Tolerance: 0.3935 mm

  (f) Number of elements: 24079

  (g) Number of nodes: 14781

  As shown in Figure no. 5.9, Meshing is carried out.

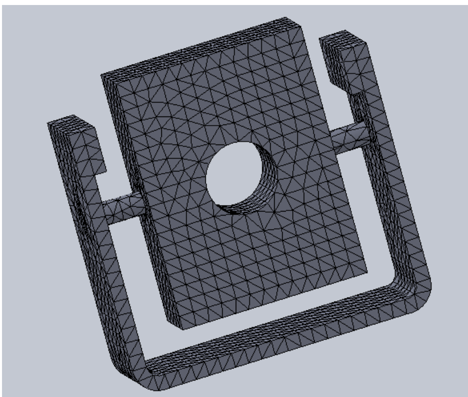


Figure 5.9: Meshing Model

- Study result :

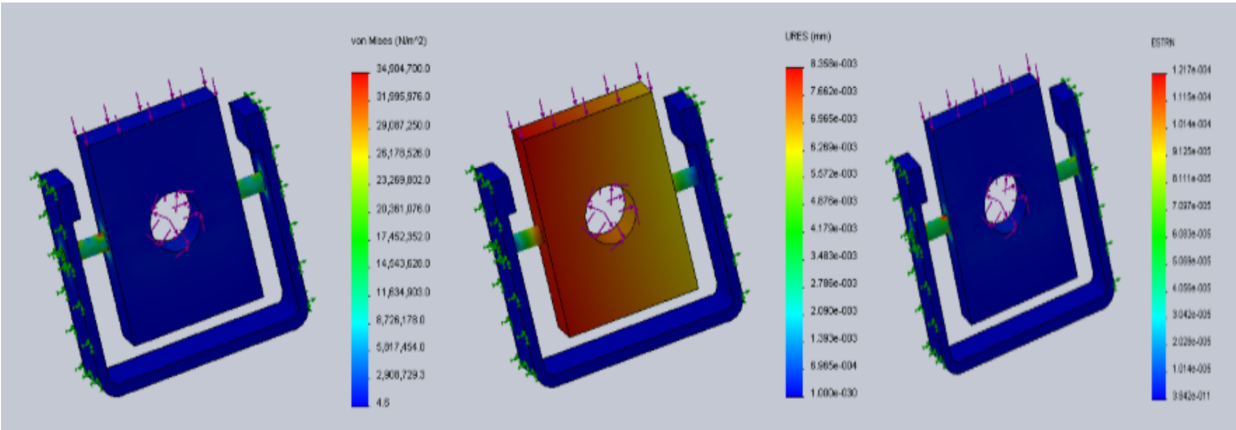



Figure 5.10: Von-mises stress, Displacement and Strain of U-Section and square section

- Von mises stress : As shown in Figure no. 5.10 maximum value of von mises stress is 34.9 $N/mm^2$ and it is below yield strength so that design is safe based on given boundary and loading conditions.
- Displacement : As shown in Figure no. 5.10 maximum value of displacements is 8.35X$10^{-3}$mm. In fig red color portion indicates maximum displaced area.
- Strain :

  As shown in Figure no. 5.10 maximum value of strain is 1.21X$10^{-5}$.
- Representation of analysis data of stress, displacement and strain of individual component in form of table as shown in table no. 5.2.

Table 5.2: Comparison of stress, strain and displacement with it's material property of assembly of U-Section and Square section

| Component name | Von-mises in $N/mm^2$ | Displacement in $mm$ | Strain | Material Property in $N/mm^2$ | Design Safe Yes/No. |
|---|---|---|---|---|---|
| U-Section | 24 | 2.09X$10^{-3}$ | 5.06X$10^{-5}$ | TS=723<br>YS=620 | Yes |
| Square Section | 9.2 | 8.1X$10^{-3}$ | 8.92X$10^{-5}$ | TS=723<br>YS=620 | Yes |
| Pin | 23.9 | 6.0X$10^{-3}$ | 1.2X$10^{-4}$ | TS=560<br>YS=560 | Yes |

Where,

TS=Tensile strength

YS=Yield strength

3. Analysis of shaft:

    - Study result :

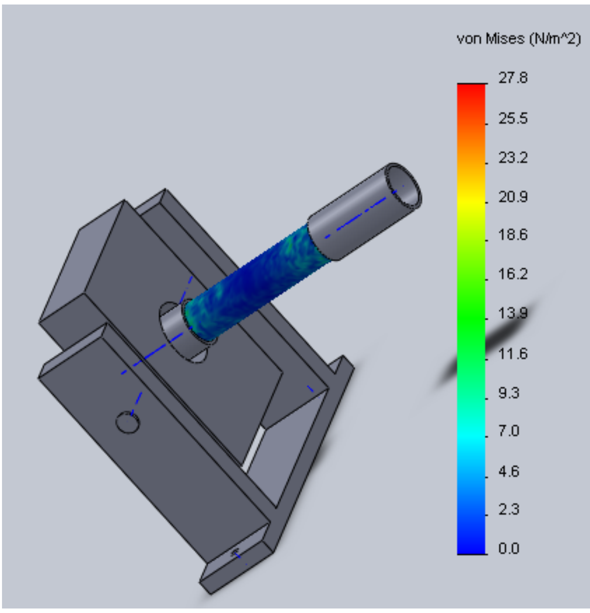



Figure 5.11: Von-mises stress of shaft

- Von mises stress : As shown in Figure no. 5.11 maximum value of von mises stress is $27.8X10^{-6}\ N/mm^2$ and it is below yield strength so that design is safe based on given boundary and loading conditions.

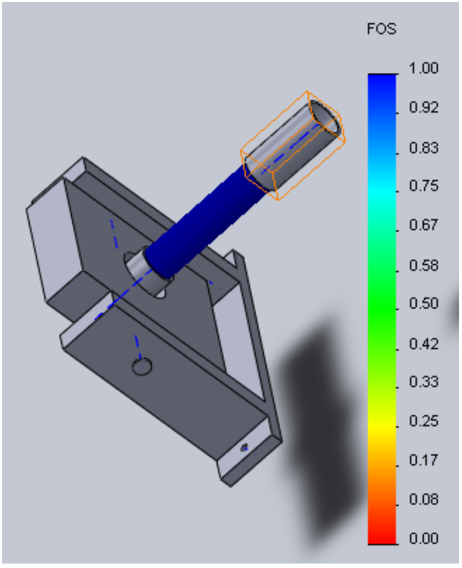



Figure 5.12: Factor of safety of whole machine set-up

- Factor of safety: As shown in Figure no. 5.12 maximum value of factor safety is 1.

4. Analysis of Assembly of machine set-up with specimen:

   - In this section material properties, various loading condition, Meshing information, Meshing, Von-mises stress plot, Displacement plot, Strain plot of assembly of U-section and Square section is described. Comparison of all stress, displacement and strain of assembly with it's material properties whether it is safe or not. In this type of analysis all joints, types of loading, material properties can be consider.

   - Material properties of U-section, C-section and square section:

     (a) Modulus of Elasticity = $2.0X10^{11}\ N/m^2$

(b) Poisson ratio = 0.28

(c) Mass density = 7700 $kg/m^3$

(d) Tensile strength = 7.23X10$^8$ $N/m^2$

(e) Yield strength = 6.20X10$^8$ $N/m^2$

- Material properties of pin:

(a) Modulus of Elasticity = 2.1X10$^{11}$ $N/m^2$

(b) Poisson ratio = 0.3

(c) Mass density = 7300 $kg/m^3$

(d) Tensile strength = 6.6X10$^8$ $N/m^2$

(e) Yield strength = 5.6X10$^8$ $N/m^2$

- Loading Condition:

  Force is acting on the Upper face of first square section is 1503.29 N in upward direction direction, On the upper face of second and third square section is 1500 N in downward direction, On the upper face of fourth square section is 1496.70 N and torque at shaft upper face is 2820 N.mm as shown in figure no. 5.13

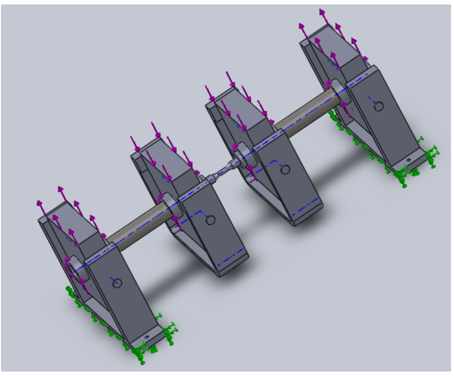


Figure 5.13: Loading condition

- Mesh Information :

  (a) Mesh Type: Solid Mesh

  (b) Meshed Used: Standard mesh

  (c) Jacobian Check: 4 Points

  (d) Element Size: 7.50 mm

  (e) Tolerance: 0.393 mm

  (f) Number of elements: 107856

  (g) Number of nodes: 66266

  As shown in Figure no. 5.14, Meshing is carried out.

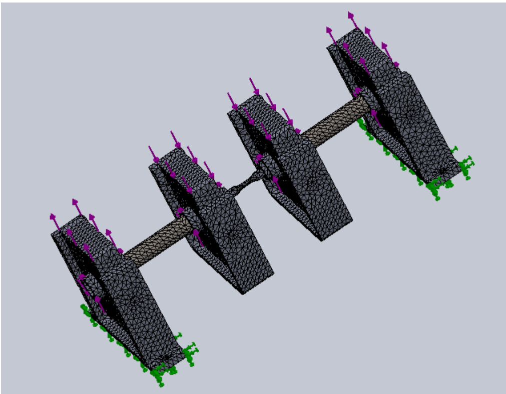


Figure 5.14: Meshing Model

- Study result :

- Von mises stress : As shown in Figure no. 5.15 maximum value of von mises stress is 528.5 $N/mm^2$ and it is below yield strength so that design is safe based on given boundary and loading conditions.

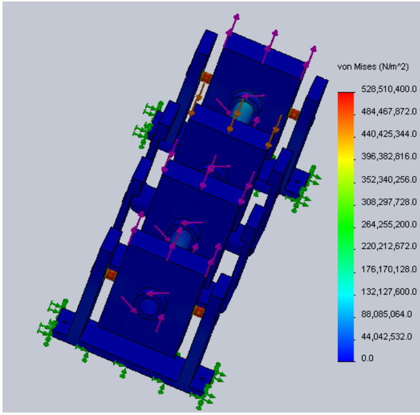



Figure 5.15: Von mises stress

- Displacement : As shown in Figure no. 5.16 maximum value of displacements is 3.182 mm. In fig red color portion indicates maximum displaced area.

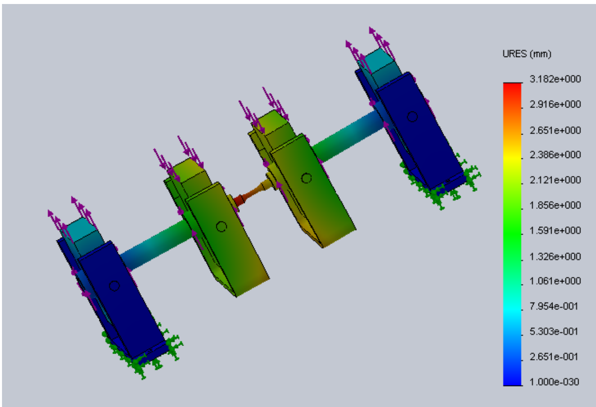



Figure 5.16: Displacement

- Strain :

  As shown in Figure no. 5.17 maximum value of strain is $1.814X10^{-3}$.

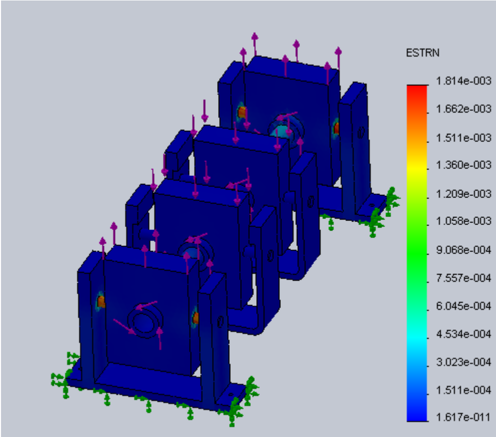



Figure 5.17: Strain

5. Analysis of Assembly of machine set-up:

- Mesh Information :

    (a) Mesh Type: Solid Mesh
    (b) Meshed Used: Standard mesh
    (c) Jacobian Check: 4 Points
    (d) Element Size: 28.59 mm
    (e) Tolerance: 1.42 mm
    (f) Number of elements: 29876
    (g) Number of nodes: 16465

- Study result :

- Von mises stress : As shown in Figure no. 5.18 maximum value of von mises stress is 255.3 $N/mm^2$ and it is below yield strength so that design is safe based on given boundary and loading conditions.

- Displacement : As shown in Figure no. 5.18 maximum value of displacements is $8.21X10^{-1}$mm. In fig red color portion indicates maximum dis-

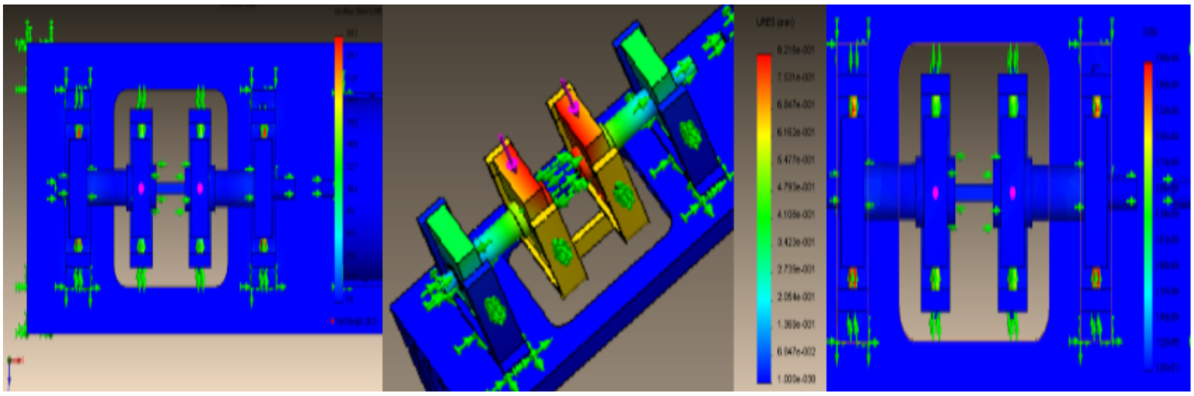


Figure 5.18: Von-mises stress, Displacement and Strain of whole machine set-up

placed area.

- Strain :

  As shown in Figure no. 5.18 maximum value of strain is $8.66X10^{-4}$.

# Chapter 6

# Conclusions & Future Work

## 6.1 Conclusions

The following conclusions drawn from above study.

- The Beam analysis for bending stress has been carried out.
- Static analysis of Machine set-up is carried out.
- The rotating beam type approach can be used as a fatigue life estimation for any component using this method for testing. It is easiest to find fatigue life of any material or component. This can help for industry for checking fatigue life for twist drill.
- FEA analysis of Machine set-up is carried out with the help of CAD software. Results of FEA analysis is discussed below:

  1. Design stress value of C-Section is 21.1 $N/mm^2$ and, yield stress and tensile stress of material of C-Section is 620 and 723 $N/mm^2$ respectively. Design value is less than the yield stress and tensile stress.
  2. Design stress value of U-Section is 24 $N/mm^2$ and, yield stress and tensile stress of material of U-section is 620 and 723 $N/mm^2$ respectively. Design value is less than the yield stress and tensile stress.

3. Design stress value of Square section is 9.2 $N/mm^2$ and, yield stress and tensile stress of material of U-section is 620 and 723 $N/mm^2$ respectively. Design value is less than the yield stress and tensile stress.

4. Design stress value of pin is 23.9 $N/mm^2$ and, yield stress and tensile stress of material of pin is 560 and 560 $N/mm^2$ respectively. Design value is less than the yield stress and tensile stress. So all the design is to be safe.

5. Design stress value of shaft is 27.8X$10^6$ $N/mm^2$ and, yield stress and tensile stress of material of pin is 552 and 620 $N/mm^2$ respectively. Design value is less than the yield stress and tensile stress. So all the design is to be safe.

## 6.2 Scope of Project

The Future work will be carried as per following steps:

- Perform a test with standard specimen and next to the drill.
- Data representation in the form of S-N Curve.
- Comparison of this result with computer simulation.

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