# DESIGN AND DEVELOPMENT OF THREAD TESTING RIG FOR SUSPENSION ROD

A Final Year Project Report

Presented to

**SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING**

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In Partial Fulfillment

of the Requirements for the Degree of

Bachelors of Mechanical Engineering

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First and foremost, we thank Allah for given us strength to undertake and carry out this project.

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Last but not the least, we are indebted to our parents, without whom we would not have been able to achieve our goal.

# ABSTRACT

Threaded fastening is widely used in the automotive industry as quick means to assemble two or more parts. It is, however, necessary to make sure that the quality of the threads manufactured is according to the required standards. Manual testing does not suffice the aforementioned need. The aim of this project, therefore, is to automate the very process of checking the thread quality of suspension rods. Since rods with properly manufactured threads would have a specified tightening torque, an apparatus would be both designed and manufactured that checks these values of torque against some pre-defined values.

The test rig is to include two parts, one fixed and the other moving. The fixed part is to essentially be comprised of a gauge, a motor to rotate the gauge, bearings, and a load cell. The moving part consists of the specimen to be tested, pneumatic actuators, linear guides (as sliders), v-blocks and mechanism to clamp the work-piece. Finally, Data acquisition is to be employed to create an output regarding the quality of threads of suspension rods.

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# ABBREVIATIONS

| | |
|---|---|
| DC | Direct Current |
| CAD | Computer Aided Design |
| AC | Alternating Current |
| FCV | Flow Control Valve |
| DVCs | Directional control valves |

# NOMENCLATURE

| | |
|---|---|
| T | Torque |
| d | Major Diameter of the Threads |
| F | Force acting on the Threads |
| $d_r$ | Minor Diameter of Threads |
| l | Lead of Threads |
| p | Pitch of Threads |
| $\tau$ | Shear Stress |
| $\sigma$ | Tensile Stress |
| $\sigma_b$ | Root Bending Stress |
| $\sigma'$ | Von Mises Stress |

# CHAPTER 1: INTRODUCTION

## Motivation

Threaded fastening, despite its ubiquity in industry, is of complex nature. Many factors play a role in determining its quality. Internal and outer diameters of threads, thread pitch and the number of threads are among the parameters that dictate how effectively two threaded components mate.

It is, therefore, necessary that the thread on the components are tested against some standard. This testing almost becomes inevitable when threaded fastening mates critical parts of an assembly, which in the given case was the shock-absorber assembly of a motorbike.

The thread tightening torque is a useful indication of the thread quality since threads with a particular pitch, number, internal and outer diameter would have a certain value of tightening torque. Therefore, following mating with a standard (gage), determination of this very value of torque, and comparison with the standard, would enable to evaluate the thread quality.

## Problem Statement

The specimen tested herein in manufactured in Karachi and assembled in Sheikupura, where it manifests a high rejection rate. The specimen is much like a hollow rod, with internal threads on one side used for the connection.

At present, the testing is manual. Not only is there an absence of any standard, but also likely chances that many parts go untested. Manual testing is largely susceptible to the amount of tightening torque that the testing personnel applies on the gage. It is not only necessary to standardize that but also to have a quantitative measurement of the tightening torque to comment on the thread quality.

**Figure 1: Manual Testing**

## Objectives

The requirement is to test 4 work-pieces/minute to match the production rate. Failure to do so in the recent times has made it a bottleneck process in the entire assembly procedure.

It is also necessary to quantify the torque attained at the end of the tightening process. Comparison of the value with the standard would allow commenting on the thread quality.

Yet another parameter that is aimed to be checked is the number of revolution of the gage shaft into the specimen. This would allow quantifying the number of threads that were properly manufactured and/or the number of threads that were able to be engaged in the tightening process.

**Figure 2: Specimen**

# CHAPTER 2: LITERATURE REVIEW

## Methods to measure torque in real time

The force applied to threads can be calculated by measuring the torque applied during the fastening and unfastening of threads. There are two basic methods to measure torque in real time:

## OPTION 1: Using AC Motor

One way to measure torque is by coupling an AC motor with the fitting end (gage). Inserting the specimen into the fitting end (gage). Measure the variations in current that is drawn by the motor during the fastening of specimen in standard size gage. The abnormal changes will correspond to improper thread quality.  Determine the condition of thread by these current variation. [1]

**Figure 4:** AC Motor

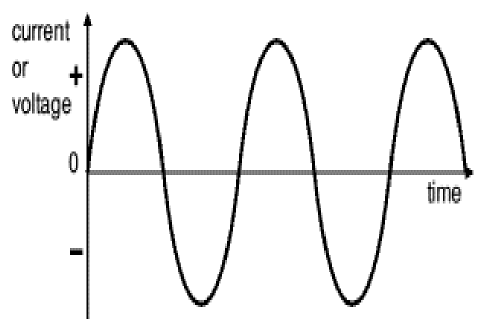


**Figure 3: Current variation**

## OPTION 2: Using Load Cell

Another way to measure torque is achieved by using a Load cell. First measure the break torque through load cell and then calibrate the current signals given by load cell output due to torque variations during threaded fastening. The abnormal changes will correspond to improper thread quality. Determining the condition of the specimen by the current signals.

**Figure 5: Load Cell**

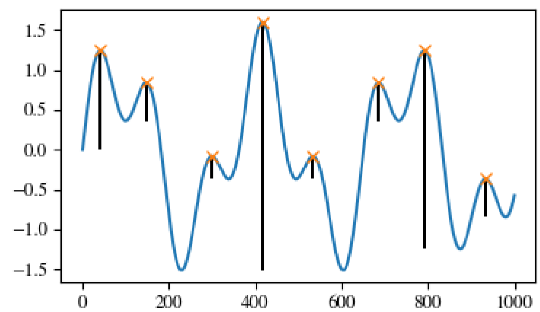


**Figure 6: Output Variations**

## Load Cells

A load cell is highly accurate transducer that converts applied weight into a measurable electrical signal as an output. Although there are many varieties of load cells, strain gage based load cells are the most commonly used type. [1]

## Measurement Principle

The load is made of a Spring Material and a Strain Gage. The spring element develops a strain directly proportional to the applied force. The strain gage then changes its resistance corresponding to the strain caused by spring element. This change in resistance is then calibrated to use the load cell as a weight measuring device.

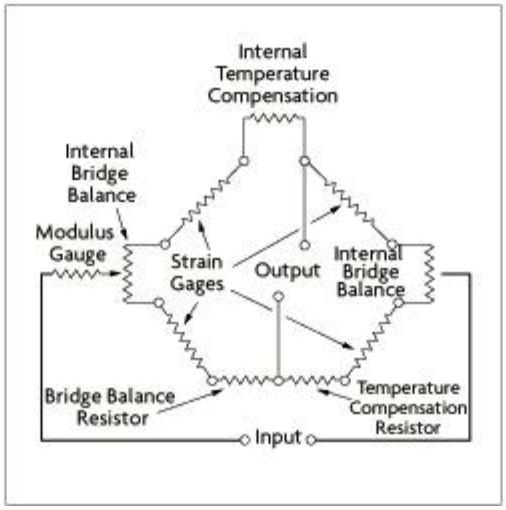


**Figure 7: Load Cell Circuit Schematic**

## Classification of load cells [2]

There are various parameters that help classify the load cells

- On basis of Sensor Type:
  - Resistive
  - Capacitive
- On basis of Loading:
  - Tension
  - Compression
  - Universal / Alternating
  - Bending

- Based on Outer Shape:
    - Beam Type
    - Canister Type
    - S Type
    - Washer Type / diaphragm-type

- Based on Shapes of Spring Material:
    - Column Type
    - Shear Type
    - Roberval Type (Parallel-beam Type; Double-beam Type)
    - Ring Type
    - Diaphragm Type

- Based on Air Tightness:
    - Hermetically Sealed
    - Open
    - Explosion Proof

- Based on Precision:
    - Ultra Precision
    - Precision
    - Standard
    - General-purpose

- Other Classifications:
    - Single Point and Multi Point Type
    - Miniature Type
    - Ring Torsion (RTN) Load Cell

## DC Motors

The different types of DC motors and their applications are:

### Shunt motors

It has a steady speed however its initial torque isn't high. Consequently, it is appropriate for systems with constant speeds, where large torque in start isn't required, for example, fan, blowers, lathe machines, belt, tools or conveyor chains and so on.

### Service motors

It has large initial torque and its speed is decreases with increase in applied load for example at the low loading conditions, the speed is high and for heavy loading, it is low. So, this motor has applications in lifts, footing work, cranes, coal cutting and loading in coal mines and so forth.

### Compound motors

This type of motor has also large initial torque and variable speed. Its benefit is that it can keep running at NO load conditions with no hazards. This type of motor in this manner is used for loads with large inertia or applications with high irregular torque, for example, lifts, transport, roller mills, presses, planes, shears, coal cutting and winding machines and so on. [2]

## Pneumatic Actuators

The pneumatic actuator is a gadget that converts the energy of compressed air into mechanical energy to perform useful work. The pressurized air coming from source is supplied to a reservoir. Now, this pressurized air from reservoir is supplied to pneumatic actuator to perform useful work. The actuators normally represents the operating end of any pneumatic system, that helps to perform certain operations such as clamping, filling, picking and placing, ejecting and tool changing - are carried out.

The pneumatic actuator is a basic and effective gadget for giving directional push or straight line movements with a quick reaction. Losses due to friction are low, only sometimes surpasses 5 % with a cylinder in great condition, and chambers are especially appropriate when used for only one purpose applications or where quick response is required. They are likewise appropriate for use under conditions which block the work of pressure driven chambers that is at high encompassing temperature of up to 200$^{o}$C to 250$^{o}$C.

Their main constraint is that the compressibility of compact air makes them unsatisfactory for fueling development where totally enduring powers or movements are required connected against a fluctuating burden, or where extraordinary precision of feed is important. The air barrel is additionally constrained in output thrust by the generally low supply weight with the goal that creation of high yield powers must be accomplished by a greater chamber size. [3]

**Figure 8: Pneumatic Actuator**

## Classification of Pneumatic Actuators

- Pneumatic actuators are able to provide linear, oscillatory and circular motions. Three basic types of pneumatic actuators based on movement of head are:
    - Linear Actuator (Pneumatic cylinders)
    - Rotary Actuator (Air motors)
    - Limited angle Actuators

- On the basis of cylinder designs:
    - Diaphragm cylinder
    - Rolling-diaphragm cylinder
    - Spring return single acting cylinder
    - Gravity return single acting cylinder

- On the basis of cylinder movement:
    - Rotating type air cylinder
    - Non rotating type air cylinder

- On the basis of action of cylinder:
    - Single acting cylinder
    - Double acting cylinder

## Solenoid Valve

Electro-Pneumatic control incorporates pneumatic and electrical advancements and it is broadly utilized for bigger scale applications. In Electro-Pneumatics, either AC or a DC source is utilized as a signal. Operating fluid is compact air. Working voltages ranges between 12 to 220 Volts. The last control valve is excited by solenoid actuation.

Electrically controlled directional control valves frame the interface between the two sections of an electro pneumatic control. [4] The most imperative errands of electrically excited DCVs incorporate:

- Switching the supply air between OFF and ON
- Movement of cylinder heads

Solenoids are used for the switching of electrically actuated DVCs. These are categorized into two groups:

- Spring return valves; they remain in the actuated position only as far as the solenoid is excited by the current
- Double solenoid valves; they retain the latest actuated position even when solenoid has no flowing current.

## Solenoid Actuation

The solenoid incitation is otherwise called electrical activation. The block diagram of solenoid incitation is appeared in Figure below. The invigorated solenoid curl makes an attractive power which maneuvers the armature into the loop. This development of armature controls the spool position. The basic advantage of solenoid actuation is its quick response time. [4]

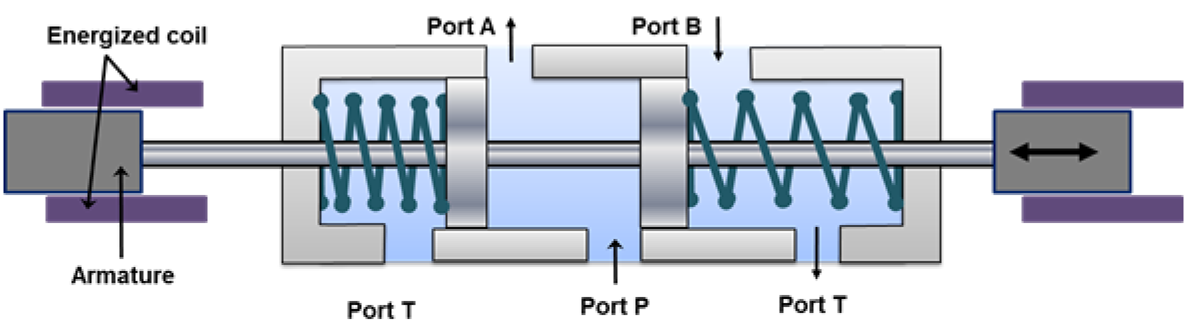


**Figure 9: Schematic of solenoid Actuation**

## Classification of Solenoid Valves:

- Based on construction:
    - Poppet valve
    - Spool valve

- Based on count of ports:
    - Two way valve
    - Three way valve
    - Four way valve

- Based on count of switching positions:
    - Two position
    - Three position

## Bearings

Bearing is a machine component that constraints relative movements and are used to decreases grating between moving components of machine to achieve required movement or we can define as the machine components which support the pivoting parts of a machine and decrease frictional force are known as bearings. For instance to avoid any misalignment in the rotating shaft of a machine, a bearing is employed. [5]

Bearings are mostly used for:

- Decrease friction among components with rotational motion.
- Provide support rotating machine components.
- To absorb radial and axial loads.

## Types of Rolling Bearings

- Ball Bearings
    - Deep-Groove Ball Bearing
    - Self-Aligning Ball Bearing

    - Angular-Contact Ball Bearing
    - Thrust Ball Bearing

- Roller Bearings
    - Tapered Roller Bearings
    - Spherical Roller Bearings
    - Cylindrical Roller Bearings
    - Needle Roller Bearings

## Self-Aligning Ball Bearings

Self-Aligning Bearings are perfect when the alignment between the rotating shaft and bearing housing is critical and the shaft is prone to bending. The external ring has a circular cavity with its focal point aligned with that of bearing. This permits the pivot of the internal ring, balls and shell to bend to some degree around the center. The axial thrust limit is low because there is a very little point of contact. Under ordinary loads, the reasonable powerful misalignment is around 4 to 7 degrees (0.07 to 0.12 radians). [3]

**Figure 10:** Self Aligning Ball Bearing

## Shaft / Gage

The gage is the component which has outer threads which will be used to test the internal thread of the suspension rod. The thread is a ridge of uniform section in the form of helix in the external or internal of the cylinder or it could be explained as a sloping plane curled around a cylinder. The gage we are using in our design has the major diameter of 18 mm and the pitch is 1 mm.

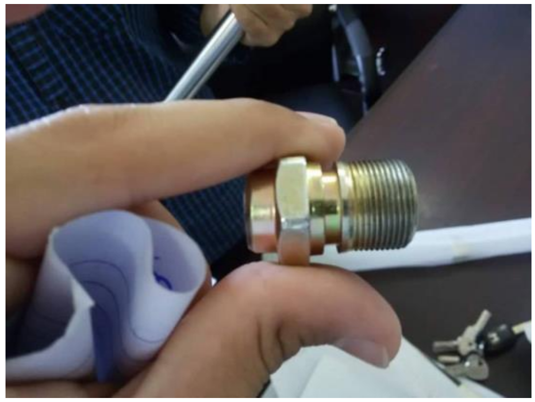

**Figure 11: Gage**

There are two types of threads based on the position of the threads:

- Internal threads
- External threads

Basic Features stated below are explained in figure 12:

- Major Diameter
- Effective Diameter
- Pitch
- Flank
- Crest

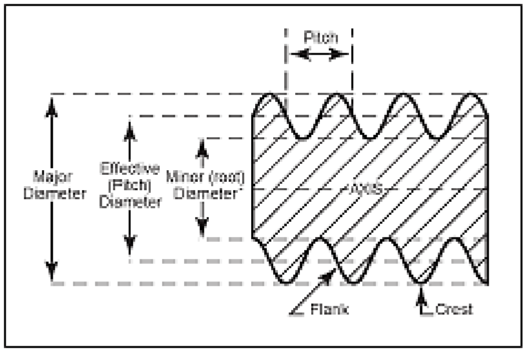


**Figure 12: Threads**

There are several types of cuts which are present in the threads and some of these are described here. [3]

Types of threads based on the cut:

- Sharp V
- Unified
- Whitworth
- Modified square
- ACME
- B&S worm
- Modified buttress
- Knuckle
- Dardelet

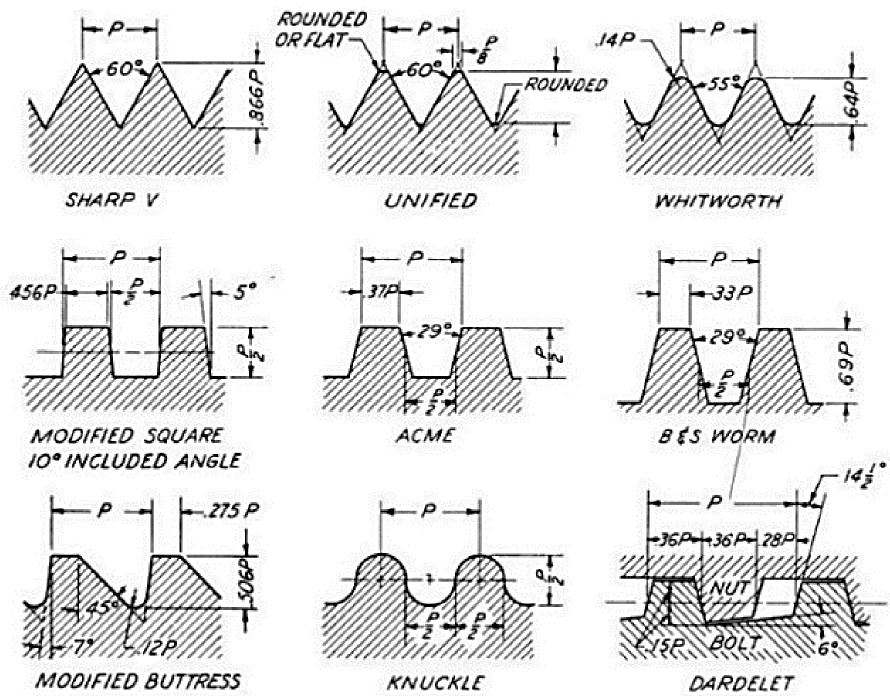


**Figure 13: Thread Types**

# CHAPTER 3: METHODOLOGY

## CAD Model

The overall assembly is essentially divided into two parts:

- Fixed Part
- Moving Part

## Fixed Part

This part contains:

- DC motor
- Load cell
- Bearings with housings
- Connecting rod
- Clamps

## Moving Part

This part contains:

- Linear guides (sliders)
- Moving plate
- V-blocks
- Pneumatic actuators
- Clamping units
- Specimen

Both the fixed part and the moving part of the overall assembly would be placed on one common base plate.

## Overall Assembly

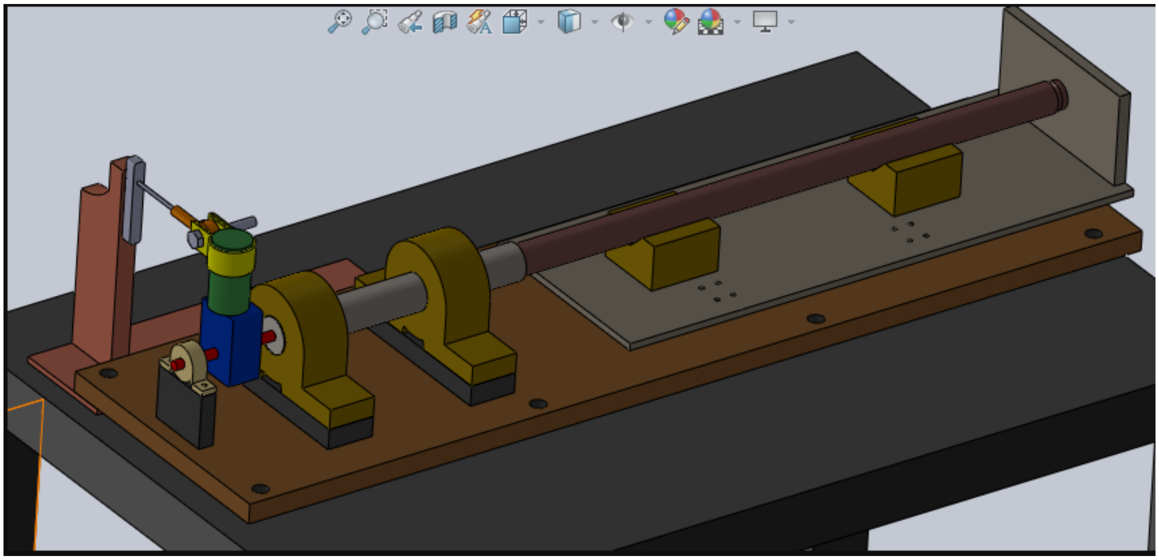

**Figure 14: CAD Model**

## Selection of motor

To determine the required motor of specific torque and rpm, the torque required to distort the threads of the specimen had to be calculated that would define the upper threshold value of the motor. This torque is the maximum limit and any torque above this value should not be applied on the threads  On the basis of the torque calculation, a motor of specific characteristics is to be selected which has the power to deliver the required torque

## Torque calculations

The torque evaluation could be done through two techniques these are

- Theoretical
- Experimental

## Theoretical torque calculation

The theoretical calculation includes the measurement of torque by considering the suspension rod threads as a system similar to that of a threaded fastener. Calculating the torque at the point of distortion due to the shear force acting on the threads we can specify the upper limit of torque for the motor which defines the specifications of the motor.

For a threaded fastener, the torque acting on the threads is given as [7]

$$T = \frac{Fd}{2} * (\frac{l + \pi f d}{\pi d - f l})$$

Where d is the diameter of the threads, f is the friction coefficients (0.15-0.20 for stainless steel), l is the lead of the threads the shear stress acting on the threads is

$$\tau = \frac{16T}{\pi d_r^3}$$

Where $d_r$ is the minor diameter of the threads, T being the torque.

The tensile stress is calculated as

$$\tau = \frac{4F}{\pi d_r^2}$$

And the bending stress is calculated as [7]

$$\tau = \frac{6F}{\pi d_r p}$$

Where F=0.38F as one thread is under analysis at a time, p is the pitch of the threads

Substituting the values in the equations of the suspension, we get [7]

$$T = 1.51 * 10^{-3}F$$

$$\tau = 1244028T$$

$$\sigma = 4976F$$

$$\sigma_b = 45382F$$

Substituting in the Von Mises equation by equating it equal to the shear stress value (for stainless steel=110MPA)

$$\sigma_{ss} = \frac{1}{\sqrt{2}} * \{(\sigma_b)^2 + (\sigma)^2 + (\sigma_b - \sigma)^2 + 6(\tau)^2\}$$

We get

$$F = 2.84KN$$

Substituting in equation (4)

$$T = 1.51 * 10^{-3} F$$

$$T_{Theoretical} = 4.23Nm$$

## Experimental calculation

To validate the result of the calculation, the torque limit was also measured through experimental means. A torque wrench was fitted within the threads of the suspension rod. At the point where the torque wrench slipped indicating that maximum value of torque has been reached, the torque was measured through a gage

The experimental torque came out to be

$$T_{Experimental} = 4\ Nm$$

**Figure 15: Torque Wrench**

The preciseness between theoretical and experimental values provides validation to our torque calculations.

## Selection of load cell

The next process comes to the selection of the load cell.To ensure all the required values being measured are to be measured by the load cell, the specific load conditions had to be calculated by measuring the force the acting on the load cell

Knowing that the force on the load cell would be caused by the bottom part of motor. Measuring the distance from the shaft axis to that point where the load cell is connected with the motor, it comes out to be

$$R=80.79mm$$

Torque divided by this value gives us the force acting on the load cell .to calculate the force for the upper limit which defines the specifications of the load cell, the value of force is 52.29 N

This force is measured in terms of kilograms is given as

Force in terms of kilograms = 5.32 kg

Considering a range of the torque as a safe sight the load cell selected as

**Table 1: Load Cell Specifications**

| | |
|---|---|
| Brand name | HYXC |
| Load cell type | S type |
| Load specification | 3 Kg |
| Sensitivity | 2mv/V |

## Sensors

The auxiliary utilization of the sensors is to fulfill the following purposes:

- To measure the number of rotations
- To detect the contact of the specimen with the gage

## Sensor to measure the number of rotations

The basic concept of the design demands the number of threads to be measured which will indicate which thread is according to standard .if the number of rotations are measured correspondingly to the torque measurement, then a torque value for each thread can be specified. This can be accomplished through a

- Hall effect magnetic sensor
- Infrared-based tachometer

## Hall Effect magnetic sensor

It works on the principle of change in the magnetic induction with the change in the surrounding magnetic field.

Depending on the rotations speed, the current produced due to the changed magnetic induction will be obtained .this current would specify the rpm of the rotating bodies.to find the number of rotations of the shaft or the number of the threads the rpm is divided by the starting time from which the sensor has started measuring the rotations this would enable us to measure the number of rotations or the threads of the suspension rod.

## Infrared Tachometer

The infrared tachometer is used in a similar manner with the utilization of an infrared sensor instead of the Hall Effect principle.

## Sensor selected

**Table 2: Sensor Selection**

| | |
|---|---|
| Brand name | Autoleader |
| Working power supply | 8-24 V |
| Range | 1-9999Rpm |
| Detected objects | Metal |


Figure 16**:** MI Proximity Sensor

## Selection of Bearings

There are a total of three bearings in use for the project. Two shall be used for the motor shaft and one would be used for the gage shaft. The motor shaft would be coupled with the gage shaft.

Bearings are not only responsible to hold the shafts, but along with the v-blocks, are also in charge to align the specimen with the gage shaft.

The bore diameters for the motor and gage shaft are 8mm and 20 mm respectively. All the bearings used herein are self-aligning.

Self-aligning bearings, along with the housings, essentially come in two arrangements. In the first case, the bearing itself is of self-aligning nature; its inner ring can change its axis relative to the outer ring. The outer ring, which is not spherical, has then to be attached to the housing. Usually, this provides less dimensional control over the shaft height.

In the second possible arrangement, the bearing itself is not of self-aligning nature. However, the outer ring of the bearing is spherical, along with the inner surface of the housing. Since bearing and its housing can be attained as a single unit off-the-shelf, this also provides greater dimensional control over the shaft height, whilst also countering the issue of shaft misalignment.

UC bearings were chosen in compliance for the aforementioned requirements. These bearings are single-row deep groove ball bearings. Hence the bearing can also sustain a certain degree of axial load. They also provide less friction torque, which prolongs the life span of bearings. The housing type was Pillow Block. [7]

The engineering drawing of the bearing, along with the housing is as below:

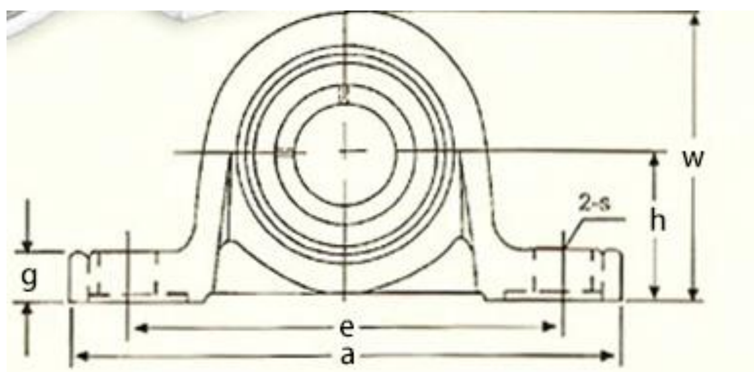


**Figure 17: Bearing Dimension**

The values of the dimensions for bearings, both 8mm and 20mm bore diameter ones, are stated below:

**Table 3: Bearing Dimensions**

| Dimension | Bearing with 8mm bore diameter (mm) | Bearing with 20 mm bore diameter (mm) |
|---|---|---|
| a | 55 | 127 |
| e | 42 | 95 |
| g | 5 | 16 |
| h | 15 | 33.30 |
| w | 29 | 65 |

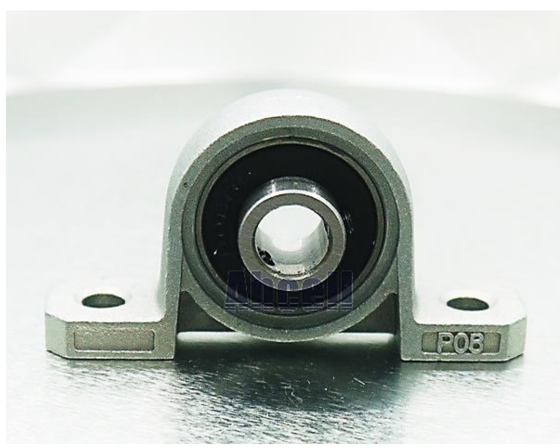


**Figure 18: UCP 08 – Bearing along with Pillow-Block Housing**

## Placement of bearings on the base plate

The motor shaft has a length of 102mm, amongst which 27 mm is already used by the motor body. The bearing with 8mm bore diameter is placed at a distance of 17.5 mm from the motor. 12.5 mm from the other end is devoted to the coupling of the 8mm motor shaft with the gage shaft. The gage shaft, whose length is 20mm is rested on two bearings with a bore diameter of 20mm. Both the bearings are at distance of about 90mm from each other. The last 15mm of the gage shaft are devoted for threading, with an overall thread length of 10mm and a pitch of 1mm.

## V Blocks

V-blocks are not only responsible to hold the specimen, but along with the bearings, are also in charge to align the specimen with the gage shaft.

The manufacturing of the v-block was critical. It was necessary that parallelism between v-edge and bottom face is attained lest alignment is compromised. Techniques like shaping or milling do not suffice the need. Even CNC cannot be used since it could not provide the entire cut in one go, whilst making sure that bottom face is parallel at all the times.

Therefore, Electrical Discharge Machining (EDM) was used. The input to the system were the dimensions of the v-block required and blocks of polished mild steel. The v-block dimensions used are depicted below as in engineering drawing:

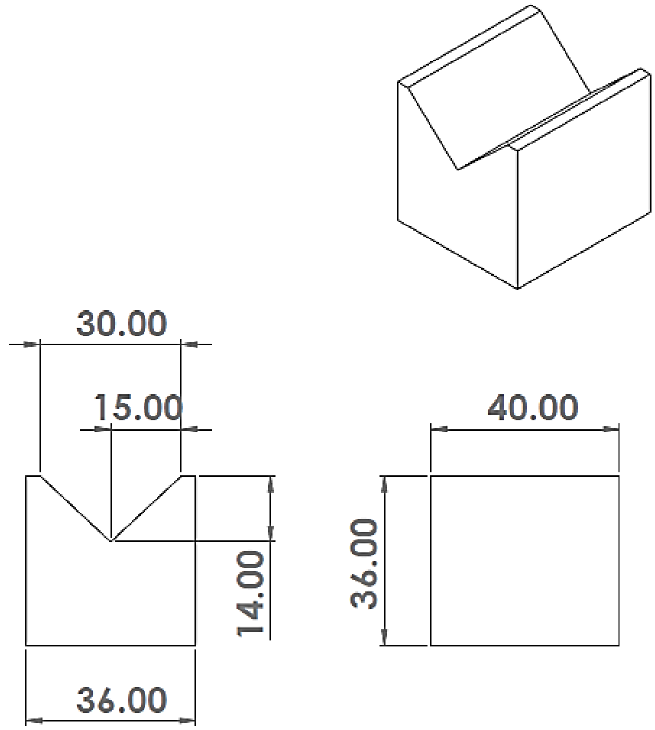


**Figure 19: V-Block Dimensions**

The choice of polished mild steel provided a good compromise with a number of factors namely cost, machinability, and availability. Moreover, the coefficient of friction was good enough to grip the specimen onto itself.

**Figure 20: V-Blocks**

## Measurement and Instrumentation

The National Instruments USB-6009 was used integrate all the sensors readings and hardware control. It provides eight single ended analog input (AI) channels, two analog output (AO) channels, 12 DIO channels, and a 32-bit counter with a full-speed USB interface.

The program to control the running of entire system was developed in LabView 2016.

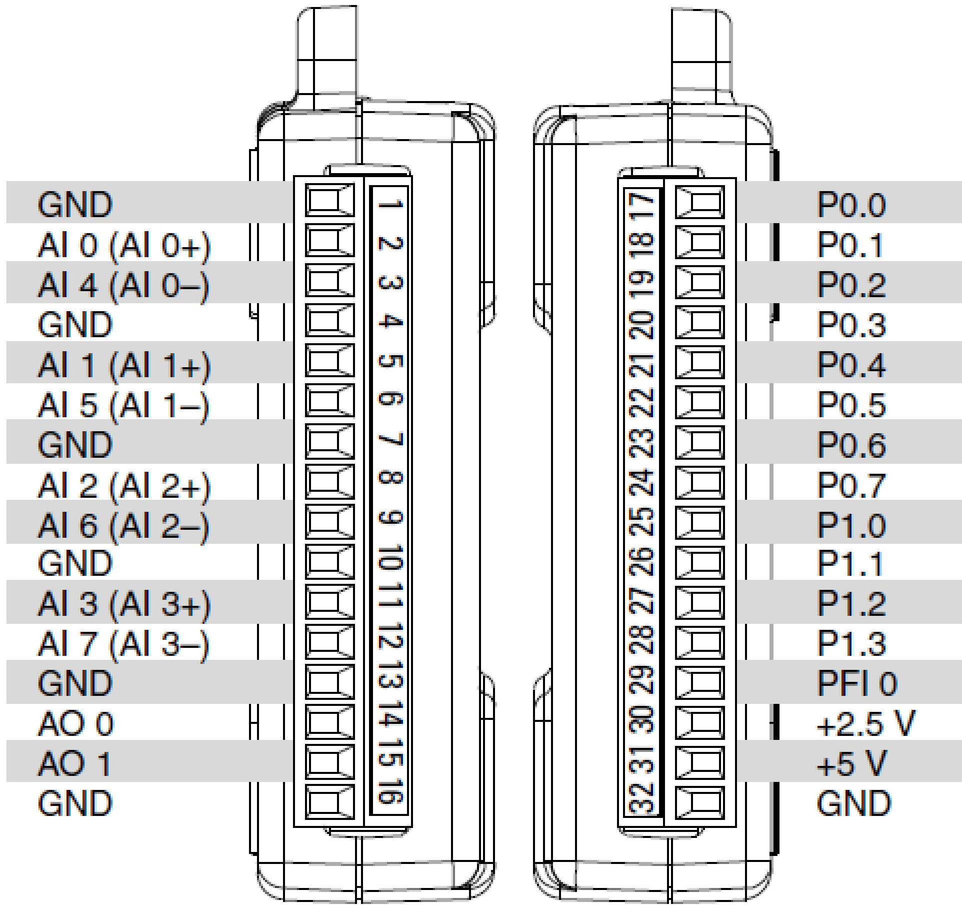


**Figure 21: USB 6009 Pinout**

**Table 4: USB 6009 Catalog**

| Pin Name | Signal Type | Description |
|---|---|---|
| 1(AI 0) | Analog Input (RSE) | It receives input from load cell amplifier |
| 5(AI 1) | Analog Input (RSE) | It receives input from Inductive Sensor |
| 1,4,7,32 (GND) | Ground | It provides common ground for all hardware |
| 18(P0.1) | Digital Output | It provides digital output to control DPDT relay for motor direction |
| 19(P0.2) | Digital Output | It provides digital output to control SPDT relay for actuator on/off |
| 20(P0.3) | Digital Output | It provides digital output to control SPDT relay for system on/off |
| 31 (+5V) | Power Source | It provides power to relays |

The Referenced Single-Ended (RSE) signals were essentially used for three reasons:

- The input signal can share a common reference point, GND, with other signals that use RSE.
- It allows the input range of the ±10 V (as in the case of load cell amplifier).
- The leads connecting the signal to the device were less than 3 m (10 feet).

## LabView Interface

The user interface of LabView front panel is shown in the figure 22.

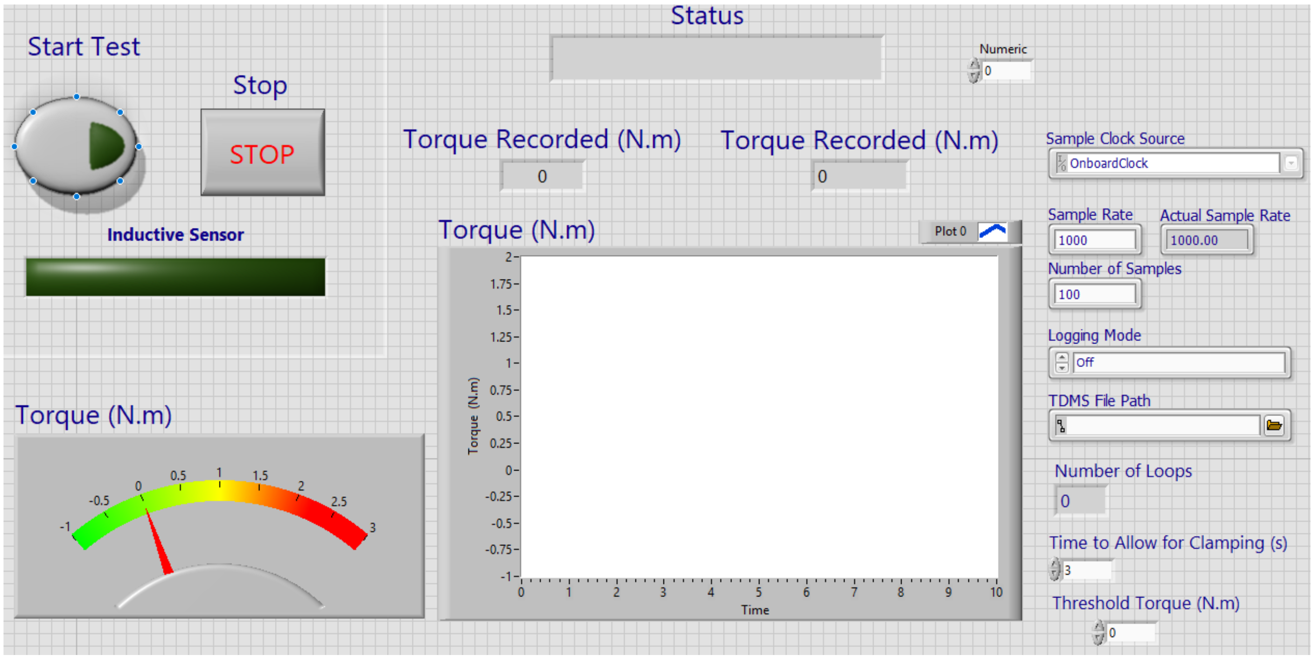


**Figure 22: Lab View Interface**

## Load Cell Amplifier

Since the output of load cell is usually in millivolts, Load cell amplifier RW-GT01A was used. It can adjust, filter and amplify electrical signal from the load cell and output 0-5V and 4-20mA standard industrial control signal to support PLC or other measuring control system acquisition.


**Figure 23: Load Cell Amplifier**

**Table 5: Load cell Amplifier Catalog**

| **Terminal** | **Definition** |
|---|---|
| 1 | Power Supply (+24 V) |
| 2 | Ground (0 V) |
| 3 | Current Output |
| 4 | Voltage Output (V+) |
| 5 | Output Common |
| 6 | Excitation Voltage (E+) |
| 7 | Signal (S+) |
| 8 | Signal (S-) |
| 9 | Excitation Voltage (E-) |
| 10 | Shield |

## Load Cell Calibration

Procedure:

Weights were added in intervals of 200 grams (0.2 kg) and the reading obtained via load cell amplifier (in volts) was noted.

The loading curve was followed by unloading curve in which weights were removed gradually. This was to check for any hysteresis. There was not much appreciable discrepancy in the values during loading and unloading, which showed that there was not any hysteresis in the measurement.

A graph was then plotted, using load cell amplifier reading as ordinate and weight added as abscissa. A straight line was attained which manifested a linear relation the two variables in consideration.

**Figure 24: Load Cell Callibration**

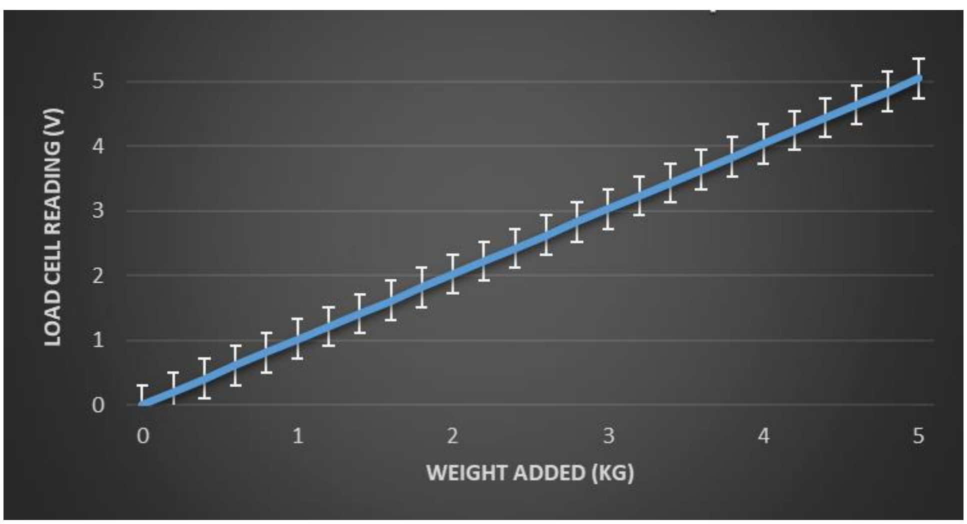


**Figure 25: Load Cell Calibration Graph**

## Inductive Proximity Sensor Detection Switch

Model:

LJ12A3-4-Z/BY

Features:

- DC type
- PNP
- NO (Normally open)
- Non-screen shield
- Detection distance: 8 mm

As the metal objects get within the detection distance, the voltage reading between output (black wire) and ground (blue wire changes). This change would then be read by NI DAQ.

## Three wires

a) Blue: Ground
b) Brown: VCC
c) Black: Output

**Figure 26: Proximity Sensor**

## Relays

## SPDT Relay

Single Pole Double Throw (SPDT) relays are used to simply switch the current on or off. They cannot be used to change the direction of current.

Two SPDT relays were used.

1. One was used to start/stop the entire program
2. The second was used to control the movement of pneumatic actuator via solenoid valve. Since solenoid valve either needs voltage or ground to reverse the direction of actuator, a SPDT relay was sufficient to fulfill that purpose.

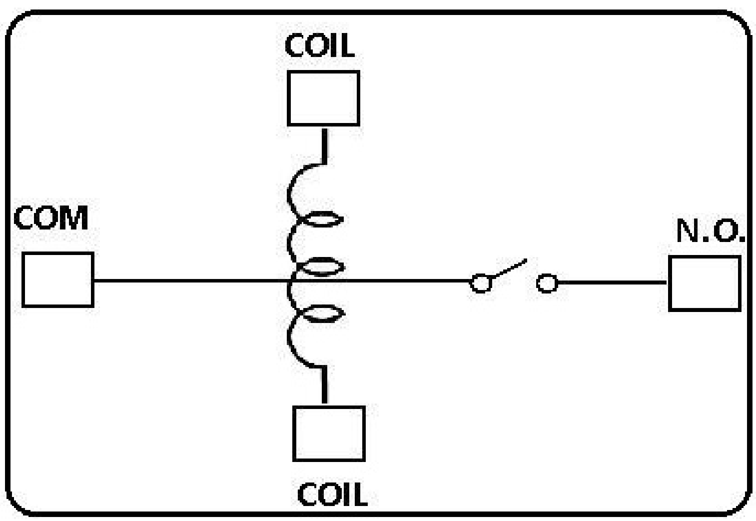


**Figure 27: SPDT Relay Terminals**

## DPDT Relay

Double Pole Double Throw (DPDT) relays are used when they are is a need to switch the directions of current. It is essentially a combination of two SPDT relay.

DPDT relay was used to switch in the direction of DC motor to allow motor to perform both tightening and untightening operations on the specimen.

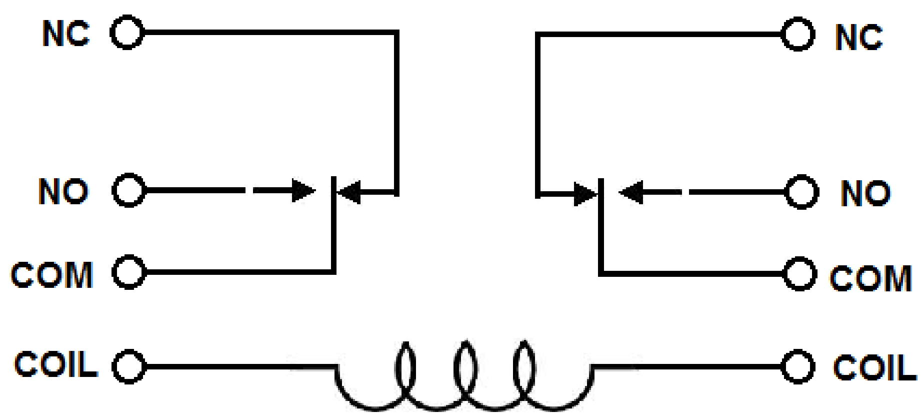


**Figure 28: DPDT Relay Terminals**

# CHAPTER 4: RESULTS AND DISCUSSIONS

## Motor

Based on the calculations which yield a tightening torque of about 4 Nm the motor selected was a worm gear dual-shaft DC motor

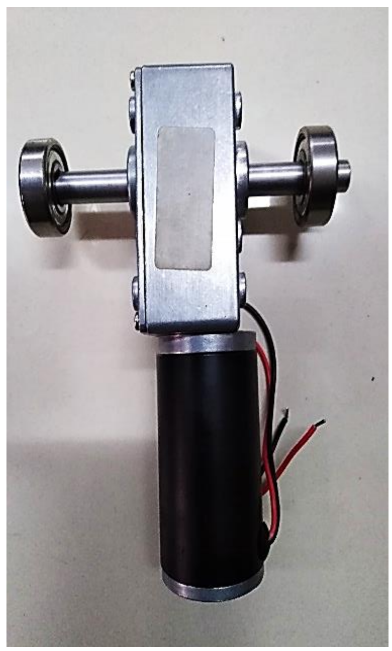

**Figure 29: Motor**

Its specifications are as follows

**Table 6: Motor Specifications**

| | |
|---|---|
| Brand name | BRINGSMART(Ali express) |
| Type | Gear motor |
| Work voltage | 6-24V |
| Rated voltage | 24V |
| Load torque | 8 Nm |
| Rpm | 80 |
| Shaft diameter | 8mm |

## Load Cell

The force of 52.29 N acting on load cell being measured in terms of kilograms is given as

Force in terms of kilograms=5.32 kg

Considering a range of the torque as a safe sight the load cell selected as

**Table 7: Load Cell Specifications**

| | |
|---|---|
| Brand name | HYXC |
| Load cell type | S type |
| Load specification | 3 Kg |
| Sensitivity | 2mv/V |

## Contact Sensor

The design specification includes that the motor should start rotating only when the specimen is in contact with the gage. This is accomplished through a

- Magnetic proximity sensor

## Working principle

As the workpiece approaches the gage the distance between them decreases. With the change in the distance, the magnetic induction corresponding to the distance changes.at the instant where the suspension rod touches the gage, the magnetic induction gives a specific value in the form of electric current. The electric current measured will give an indication that the suspension rod is in contact with the gage.

Sensor specifications:

**Table 8: Sensor Specifications**

| | |
|---|---|
| Brand Name | WAVGAT |
| Output | Switching Transducer |
| Type | Biosensor |
| Output Current | 300mA |
| Voltage | 6-12V |

**Figure 30: Magnetic Proximity Sensor**

## Finite Element Analysis

The base plate and the clamping arm are the most critical elements of the overall assembly. Finite Element Analysis helps to predict the structural response of these two under the given conditions. FEA is utilized since failure is likely to exist as a result of stress concentrations in slots and/or fillets and theoretical computation could have not else been possible.

The machine is to be placed in the factory so it must be accurate, reliable and most importantly it must be durable. For this great care had to be taken in designing to keep the stress values well below the alarming rate. The machine was designed keeping the stresses as minimum as possible. In this report the analysis if the most critical parts of the machine are shown for instance the most critical part in the machine are the component we have specified as the 'Base Plate' and the second one is the component named 'Clamping Arm'.

The software used for the analysis was ANSYS. ANSYS is basically a structural analysis software that enables you to solve the complex engineering problems and make design improvements. It is widely used in the industry to optimize the engineering design and reduce the extra cost for the physical testing.

## Base Plate

One of the most critical components of the machine is the base plate since the whole assembly will be set on it. It was designed keeping in mind the load it will have to bear moreover the machine had to be cost-efficient. The base plate selected for the design had thickness of 20 mm and the equivalent stress values it gave were in the range of 909.34 Pa to 4368.3 Pa which was quite under the safe limits and the design accepted since the tests gave positive results after the load equivalent to all the components was applied and the stresses were calculated. The design was safe and could be proceeded for the fabrication.

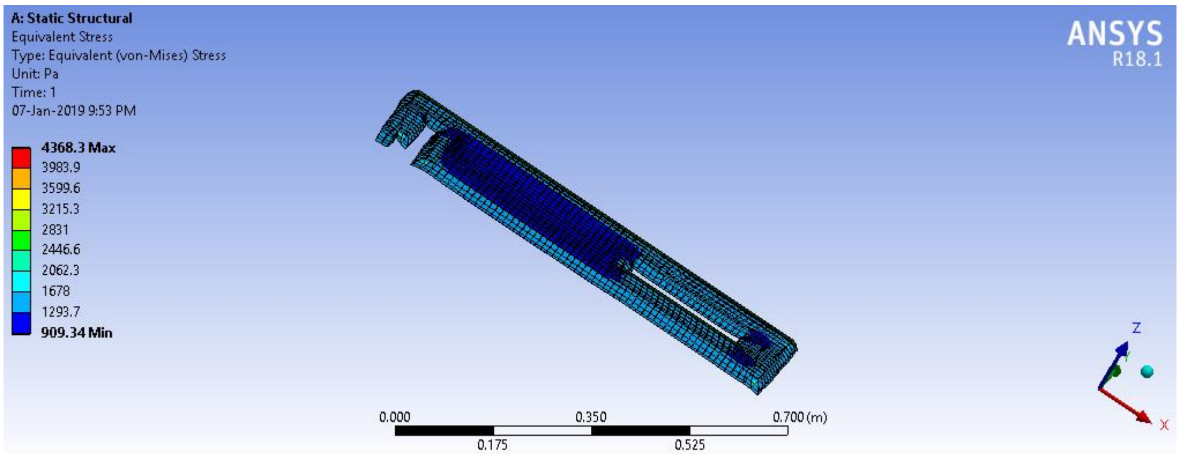


**Figure 31: Base Plate Stress**

The second deciding factor was the bending which was a very crucial factor since it was a long plate and the load was not uniformly distributed on it. The deformations due to a load of all the components placed on it were calculated using the same software that is ANSYS and the maximum value of the total deformation came out to be 2.8603e-10 m. which was very acceptable since such small deformation will not affect our readings or compromise the safety of the machine.

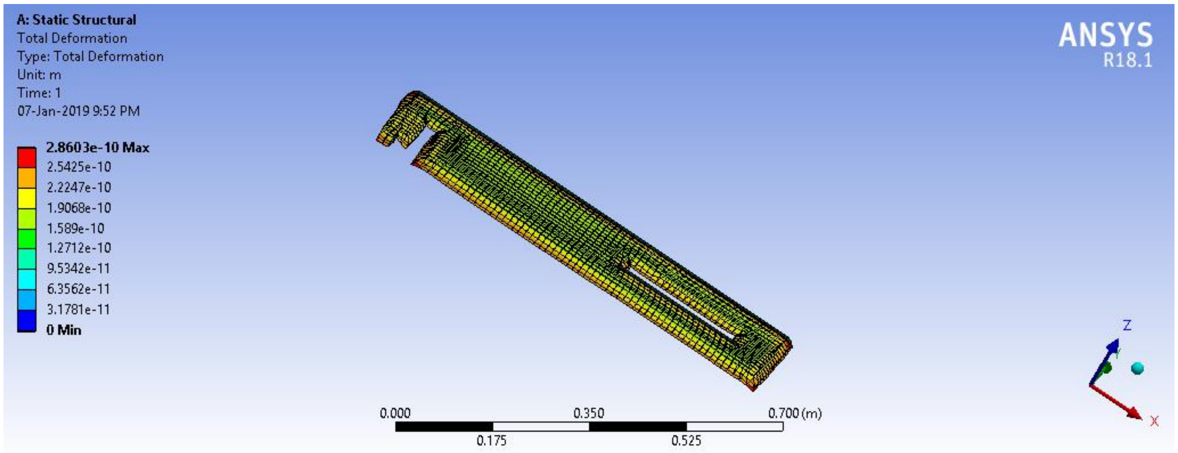


**Figure 32: Base Plate Deformation**

The ANSYS results were quite promising since the total deformations were minimum moreover the equivalent results were well under the safe limit hence the design of the base plate was accepted.

## Clamping Arm

The second most critical component on the load basis is the clamping arm since the load placed on it was far away from its center of gravity. The design was finalized keeping in mind that the whole load will be placed on the tip. The cross-sectional area selected for the clamping arm was 15 mm x 20 mm and the material is mild steel. The equivalent stresses came out to be in the range of 164.79 Pa to 1.3514e6 Pa which was well under the safe limit. The design was accepted and could be proceeded for the fabrication

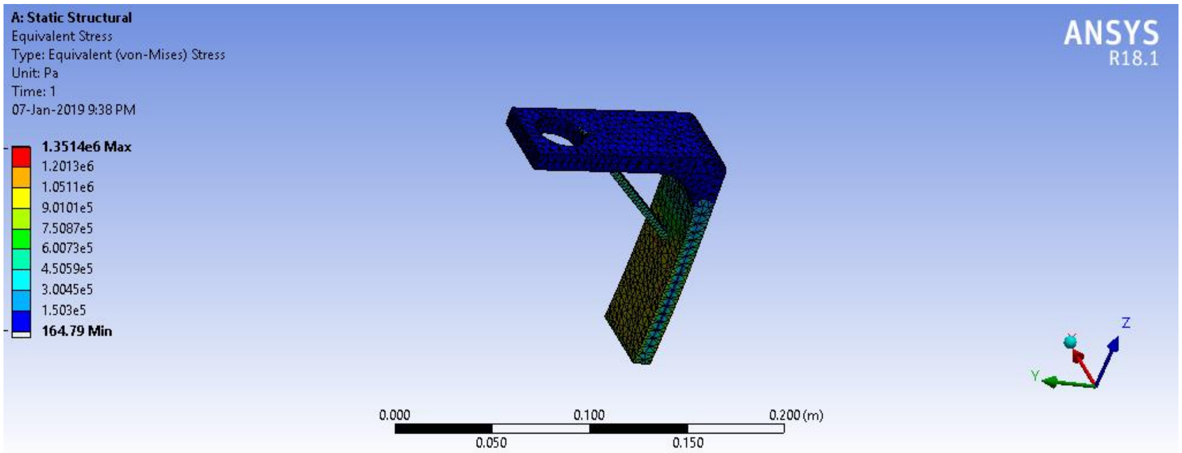


**Figure 33: Clamping Arm Stress**

The other deciding factor was the total bending since all the load was applied at the tip and the bending was expected to maximum in this component. The total deformations in the component in the presence of the total load applied were calculated and the maximum value came out to be 1.1412e-5 m. This value as acceptable since such minute value will not alter the results and the design was accepted.

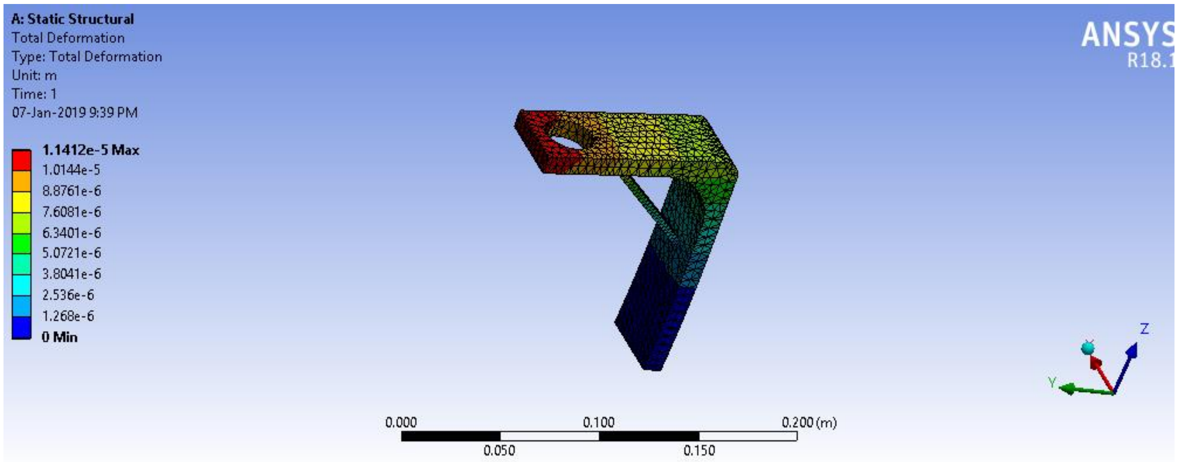


**Figure 34: Clamping Arm Deformation**

The ANSYS results were quite promising since the total deformations were minimum moreover the equivalent results were well under the safe limit hence the design of the clamping arm was accepted.

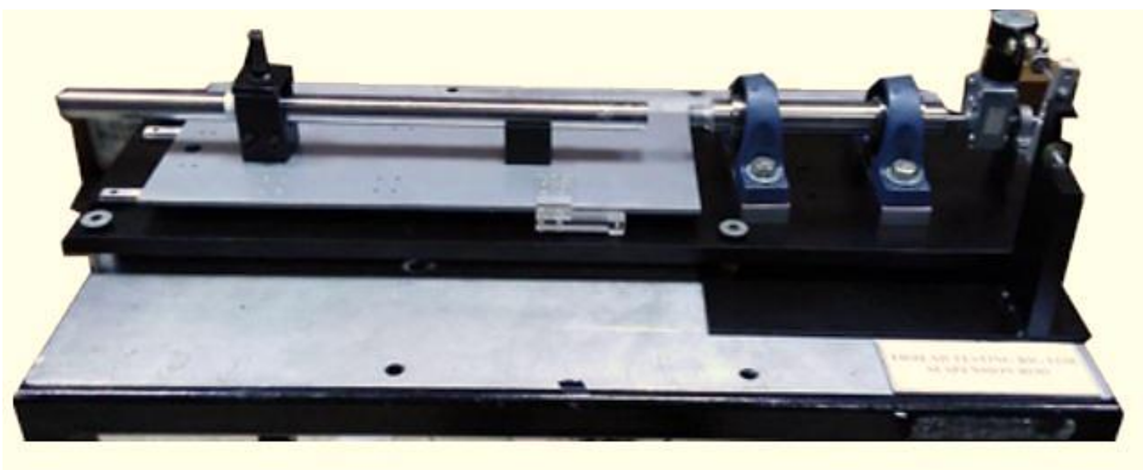

**Figure 35: Final Assembly**

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

Our project was to design and develop a thread testing rig for the suspension rod. The issue at hand was that the suspension or as we are calling it suspension rod was manufactured in Agriauto Industries Limited in Karachi while the bikes were assembled in Atlas Honda Shekhupura Factory. The problem at hand was the high rejection rate due to improper testing of the specimen. So our task was to automate the process of testing according to the standards.

The first step was to select the standard for the testing and after consulting the industry the number of threads inserted at the specified value of torque was selected. The value of the torque according to the company standard came out to be 4 Nm, which was also verified before designing the testing rig. The net task was to select the torque measurement method and after comparing different methods the load cell was selected since it was appropriate for our project requirement. The proof of concept of the design was also done and the design was continued since it gave promising results.

The next task was to design the complete assembly of the testing rig in which all the components used were incorporated. The CAD model of the complete assembly was made using SOLIDWORKS and simultaneously the market survey was carried both local and online to check the availability as well as the cost of the components. The complete design was approved and then the assembly of the machine was started which is in process. The design was made mainly using the pneumatic equipment since it is lightweight, cost-efficient and most importantly the continuous supply of 7 bar compressed air is available in the industry so we did not have to make the separate arrangements for its working.

SOLIDWORKS

The ultimate goal of the machine is to first of all test each and every suspension rod which comes out of the assembly line since during previous testing techniques many parts went untested which created an issue at the assembly line and hence had rejection rate. In this way, the defected parts could be repaired at the factory and could save the transport cost since both the factories are quite far apart. The goal is that the each and every part which leaves the factory must be QC PASSED otherwise the part must be declared Failed and should be sent to the repair shop of the factory.

The second thing is testing the parts on some standards since previously in the manual testing there were no standards specified and a person was provided with the gage for the testing and he performed the tests. There was a huge possibility of the human error since he might apply greater torque in testing than required and in some cases, he might apply lower torque than required. In both the cases, the part was rejected when it came to the assembly line. Hence the standard was set that the thread should be fastened at the constant torque of 4 Nm and the parts that fail to fasten at this value of torque should be rejected. The second standard was that by applying 4 Nm torque all the 10 threads should be inserted which proved that the threads are according to the standard. If the part failed to fulfill any one of the two standards it should be rejected at the factory and sent for repairs.

The speed was one the most important design factor since the parts were manufactured at the speed of 4 pieces per minute while the testing rate was too slow as compared to it so we had to meet the production speed of 4 pieces per minute by testing the speed of 4 pieces per minute. The design was made according to the requirements and the motor and the actuators were selected which will fulfill our requirements. Time is one of the most crucial factors in the assembly and in the concerned factory parts were manufactured at the required rate were not tested that fast and the orders were delayed just because if the poor testing rate which definitely affects both the industries. The challenge of the speed was overcome by using the appropriate design and the perfect components available for the job. The product was designed by making no compromise in the quality.

The thread testing rig was designed by keeping in mind that it must be reliable, durable and most importantly cost effective. The testing rig will reduce human labor and hence will reduce the chances of human error. It will reduce the time of testing and will match it with the production rate of the factory. All parts that come out of the factory will tested and last but not the least all the parts will be tested according to the specified standard and under same conditions. Only the QC PASSED parts will be shipped to the factory for the assembly by going through the testing. The testing process is hence simplified and standardized and most importantly fulfills the time constraint.

Although the testing itself is automatic, the placement of the specimen on the test rig is something which is carried out manually. Moreover, following the completion of testing, the process of placing the specimen back on the assembly line or rejected part is human-dependent. An addition to the project would be a design of a robotic arm which would not only pick up the specimen but also place it back on either assembly line or rejected parts.

The project, being an industrial one, asks for testing of a specimen with specified dimensions. The idea could be extended to other parts with different dimensions; all that would need is to change the gage shaft and re-calibrate the Data Acquisition according to the new requirements. Hence the proof of concept attained herein can be effectively carried out on a much larger scale, with only slight modifications in the present design.

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