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Performance Testing Of Torque Limiter Timer Belt Spindle Drive for Overload Protection

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Abstract *-Power is transmitted from motor to output shaft without any interference when no excessive load acting on the machine. But major problem is faced by industry on the machine that is when excessive load will act on the output shaft then problem of overloading make the driving motor or engine to stall; which will lead to burnout of the electric motor. In extreme cases this overload will lead to the breakage of drive elements or the clutch itself. In order to avoid the damage of the transmission elements it is necessary that the input and output shafts be disconnected in case of sudden overloads. The isolation of the input driver member i.e.; motor from the output member is absolutely necessary to avoid damage itself.*
Such serious problem which face by the industry can be avoided by use of Torque limiter timer belt spindle drive for overload protection and this can be achieved by the overload slipping ball clutch which is an safety device used in the transmission line to connect the driving and driven elements such that in case of occasional overload the clutch will slip there by disconnecting the input and output members. This protects the transmission elements from any breakage or damage and to cope up with this situation static structural analysis is done on the different parts of Torque limiter such as Base flange, Test rig, output shaft, plunger etc. In this case according to the discussion with company person we will decide to done the static analysis of various parts such as base flange, test rig, output shaft etc.

Key Words:*Timer belt, Torque limiter, FEA, Static structural Analysis, Overload protection, Ball clutch.*

I. INTRODUCTION

The present work aims for a correct, safe and economical machine working it is necessary that the component elements of this to be designed and accomplished properly. It is important that, still from the conceiving stage, to work both on the machines and equipment's gauge and on their reliability (so implicitly on the materials and energy consumptions). Taking into consideration all of these, one of the solution is represented by the use of some safety clutches. In this way, the designers can decrease the value of the safety coefficient for the dimensioning of the mechanical transmissions of equipment's.

The safety clutches fulfill – besides the main function of the torque transmission and rotational motion transmission between two consecutive elements of a kinematic chain - the function of transmitted torque limitation, in the case of some overloads occurrence, during the performance. In this way it is avoided the kinematic chain elements overstressing and their deterioration. The overloads – that occur in transmission thanks to some causes like machine starting or stopping, the passing through resonance zone, too high overloads of the driven mechanism – can be dynamic (with shocks), with very short duration or quasi-static with long duration. Indifferently of the overloads type, these can lead to the machine deterioration and its retirement. Taking into consideration all overloads, for the transmission calculus, it can lead to an excessive over-measure of this, situation that cannot be accepted. If a safety clutch is assembled in the kinematic chain of the mechanical transmission, then the mechanical properties of the materials, for the transmission component elements can be used to maximum.

The clutches are used largely in machine buildings, and by the correct selection of these depends to a great extent – the safe and long working, both of these and of the kinematic chain equipped with them. The guarantee of these demands, for the mechanical power transmission between shafts, represents a ticklish problem for all areas and engineering applications that require compact, simple and reliable systems. By their advantages, the safety clutches are preferred in different top techniques areas like cars, naval industry and so on.

The main function of the clutches is characteristic to all of them and is the function of transmitting the motion and the torque moment. The other functions, specific to each clutch type are: the motion commanding, the load limitation (with or without interrupting the kinematic flux), the protection against shocks and loads; the compensation of assembling errors; the compensation of the errors which can appear during working; the limiting of revolution; the one-sense transmission of the motion. All of these functions can appear singularly or concomitantly. Clutch is a mechanism which enables the rotary motion of one shaft to be transmitted, when desired to a second shaft the axis of which is coincident with that of the first.

II. PROBLEM IDENTIFICATION AND PROBLEM DEFINITION

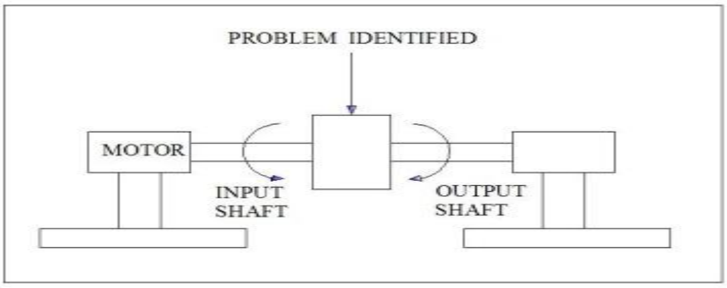


Fig-1: Problem Identification in the Torque Limiter

Above diagram shows that power is transmitted from motor to output shaft without any interference when no excessive load acting on the machine. But major problem is faced by industry on the machine that is when excessive load will act on the output shaft then problem of overloading make the driving motor or engine to stall; which will lead to burnout of the electric motor. In extreme cases this overload will lead to the breakage of drive elements or the clutch itself. In order to avoid the damage of the transmission elements it is necessary that the input and output shafts be disconnected in case of sudden overloads. The isolation of the input driver member i.e.; motor from the output member is absolutely necessary to avoid damage itself.

Such serious problem which face by the industry can be avoided by use of Torque limiter timer belt spindle drive for overload protection and this can be achieved by the overload slipping ball clutch which is an safety device used in the transmission line to connect the driving and driven elements such that in case of occasional overload the clutch will slip there by disconnecting the input and output members. This protects the transmission elements from any breakage or damage and to cope up with this situation static structural analysis is done on the different parts of Torque limiter such as Base flange, Test rig, output shaft, plunger etc. With this I have defined following problems regards with torque tender.

- Excess load on output shaft.
- Incomplete constrained motion.
- Excessive load on the motor.
- Less power transmission by output shaft.
- More power consumption.

III. SCOPE OF WORK

1. In many cases pump shaft drives either electrical or engine drives are normally furnished with the overload slipping ball clutch to avoid the breakage or damages arising due to pump clogging or blockage Compressor drives, especially in many mining applications are equipped with the over load slipping ball clutch.
2. Compact size: The size of the Torque limiter is very compact; which makes it low weight and occupies less space in any drive.
3. Ease of operation: The changing of torques gradual one hence no calculations of speed ratio required for change torque .Merely by rotating adjuster lock nut torque can be changed.
4. Machine tool slides are driven by electrical drives connected to lead screw. The over load slipping ball clutch isolates the electrical drive from the output in case of overload.

IV. OBJECTIVES OF PROJECT

- To design a Test rig and plunger which easily avoid the excess load acting on the output shaft.
- To prevent the Motor from stalling or burning which cause due to overloading on output shaft by doing static structural analysis.
- To vary Torque carrying capacity by Varying number of Ball & spring sets.
- Integration of the timer pulley set and torque limiter to form final drive system.

V. METHODOLOGY

5.1 Preparation of CAD model. Following are the various object of include in the projects which are listed below.

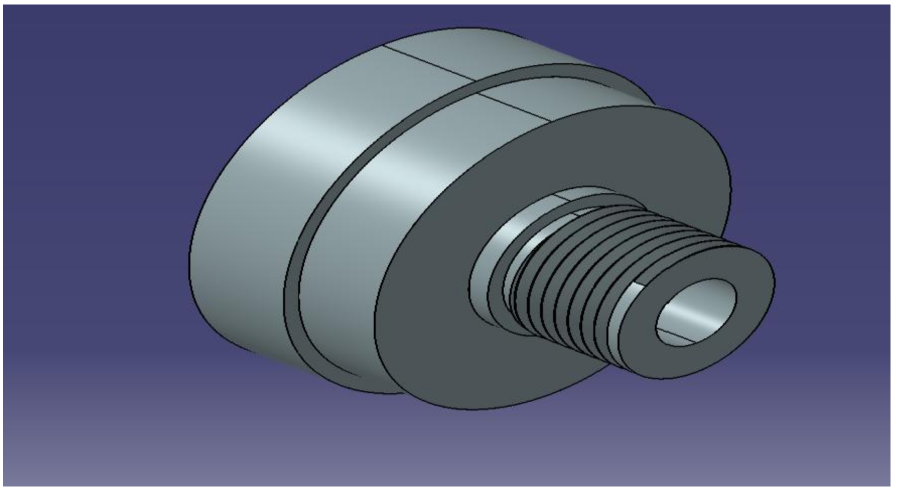


Fig 2 Clutch body

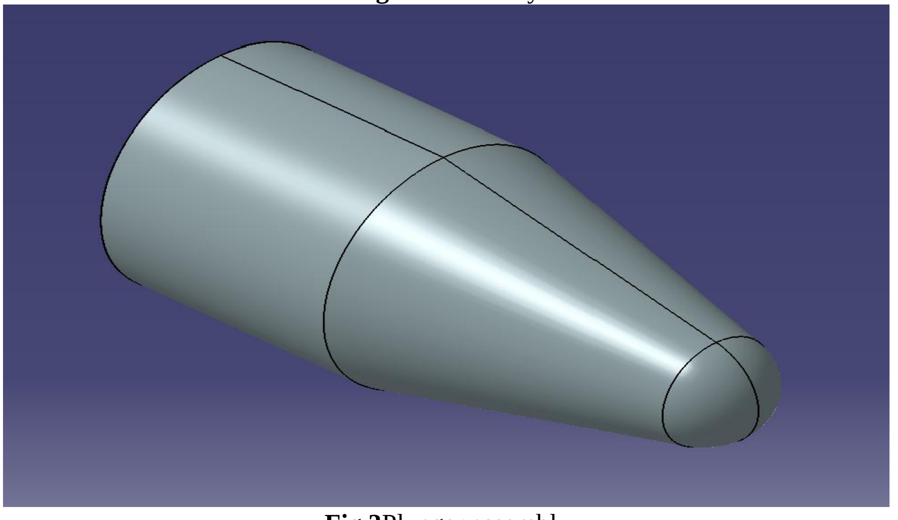


Fig 3 Plunger assembly

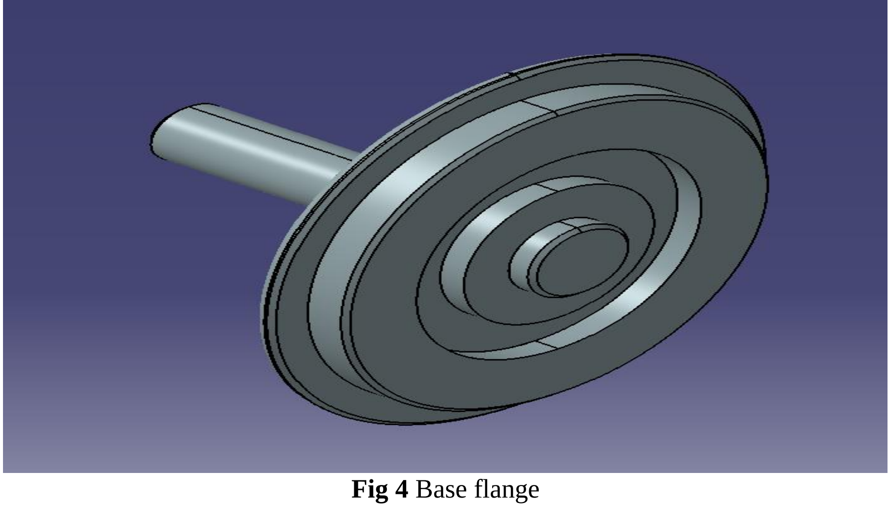


Fig 4 Base flange

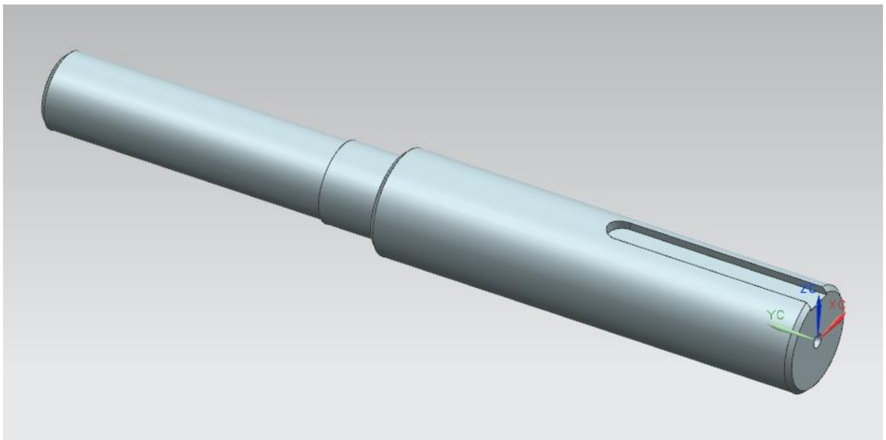


Fig 5 Shaft

5.2 FEA model by using ANSYS

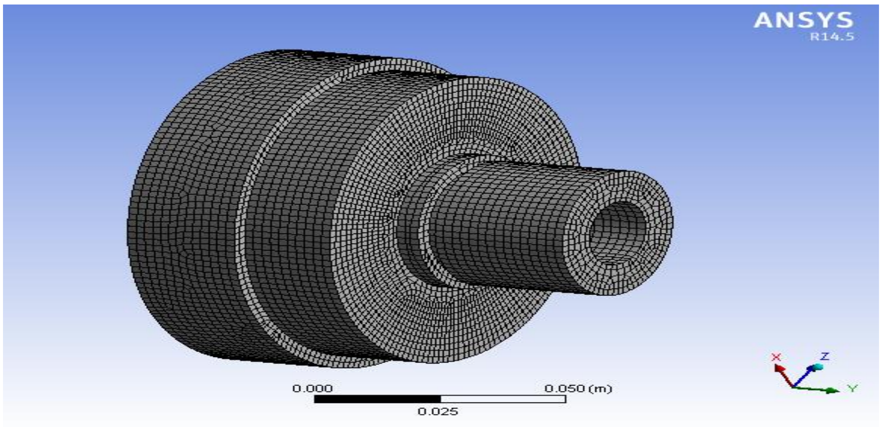


Fig 6. Meshing of Clutch body assembly

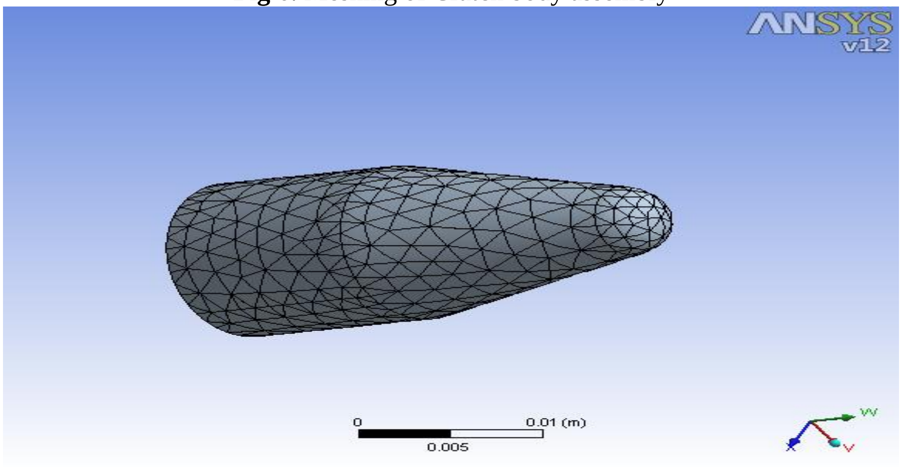


Fig 7. Meshing of plunger assembly

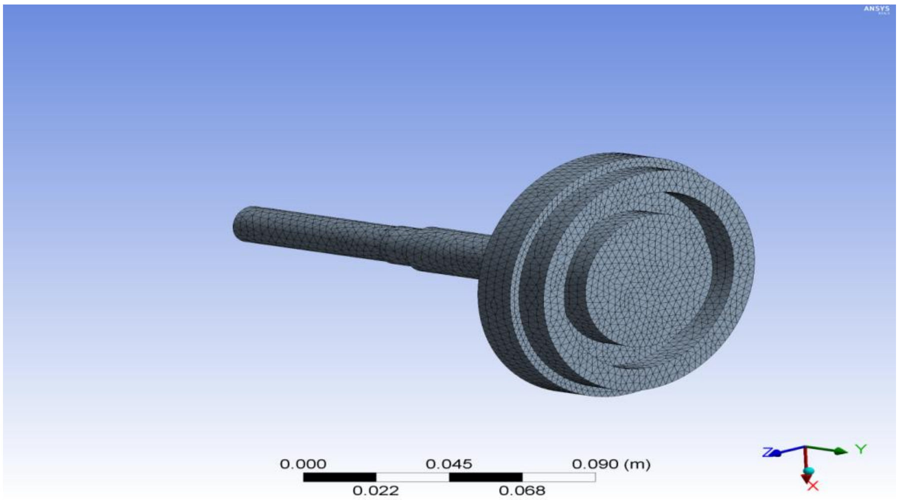


Fig 8 Meshing of flange assembly

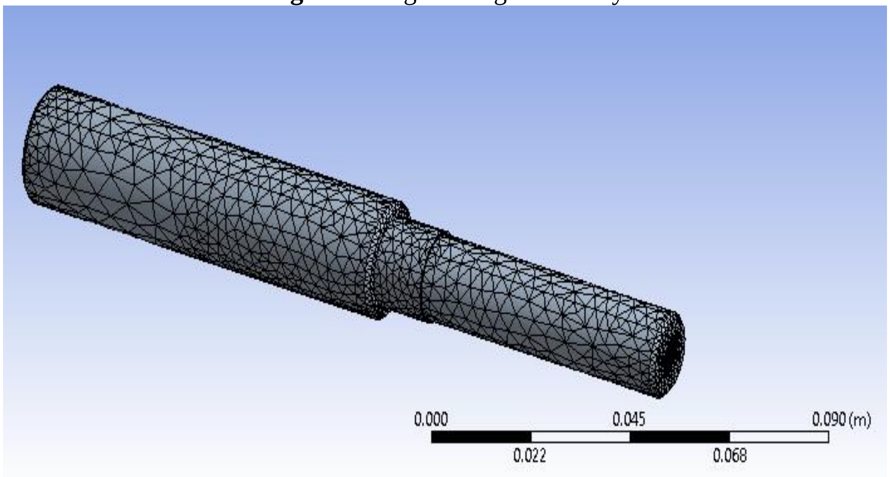


Fig 9 Meshing of shaft assembly

Meshing of all the components is done in the ansys itself. The elements are used for meshing is Solid 148.

5.3 Procedure for Static structural analysis in ANSYS:
Following is the procedure of actual analysis of individual part in torque limiter timer belt pulley.

Part 1: Test rig
The static analysis of base flange is done by means ANSYS Workbench 14.5.7 following are important steps which carried during the analysis
Step 1- First of all it is necessary to select the analysis type from main menu i.e. static structural analysis. After that we have use drag and drop option in order import the base flange to apply the material properties.
Step 2- In this step we have to call the existing model of Test rig ANSYS Workbench.
Step 3- The most important step is to enter into the analysis window by double clicking on geometry icon.
Step 4- The object which calls in step number 3 is followed by the boundary condition, constraints and mesh tool.
Step 5- To mesh the import model we have to define the method of meshing, size of meshing and element size of mesh.

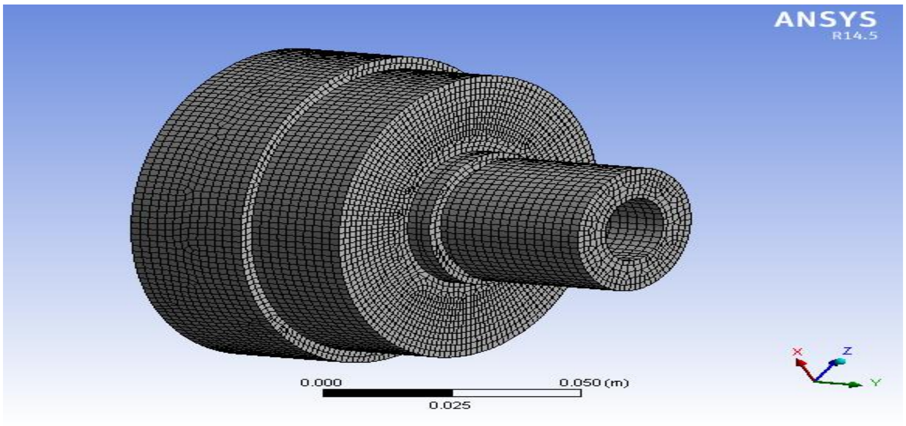


Fig 10. Mesh Test rig

Step 6

Now we have to apply the boundary condition like fixed support, force, moment. In this step we fix the outer end of Test rigand apply the moment on extreme end of Test rig

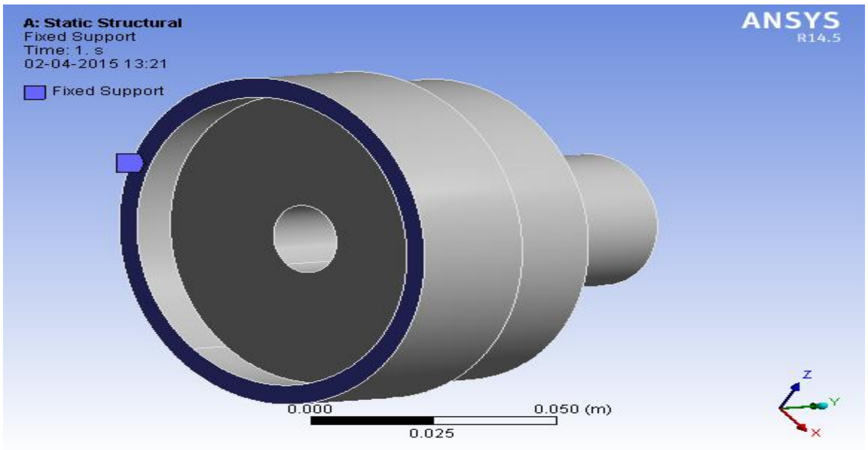


Fig 11 Fix support at outer end of Test rig

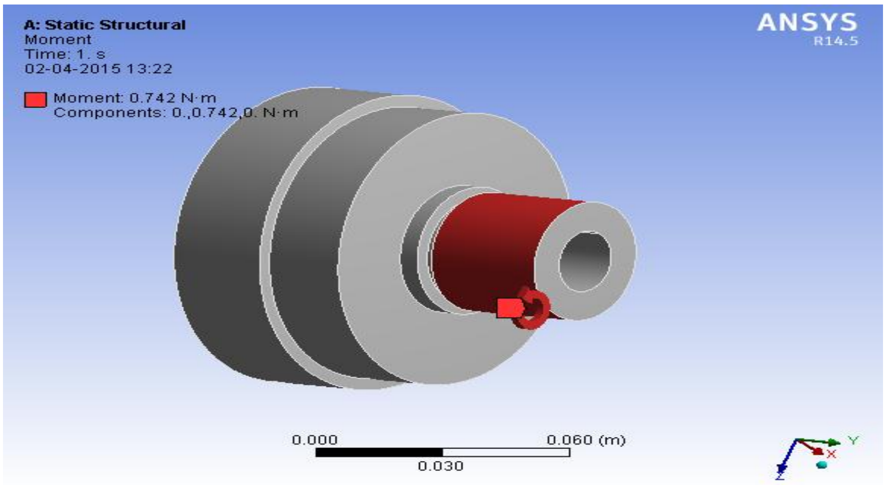


Fig 12. Moment at Extreme end of Test rig

Step 7

We have to insert the actual parameters that we want like Von Misses stress. Now solve this analysis by considering the above stress at each node of the Test rig and it gives the maximum and minimum value of maximum shear stress regarding static analysis of Test rig. This value of von misses stress executes the safe and failure region in the Test rig.

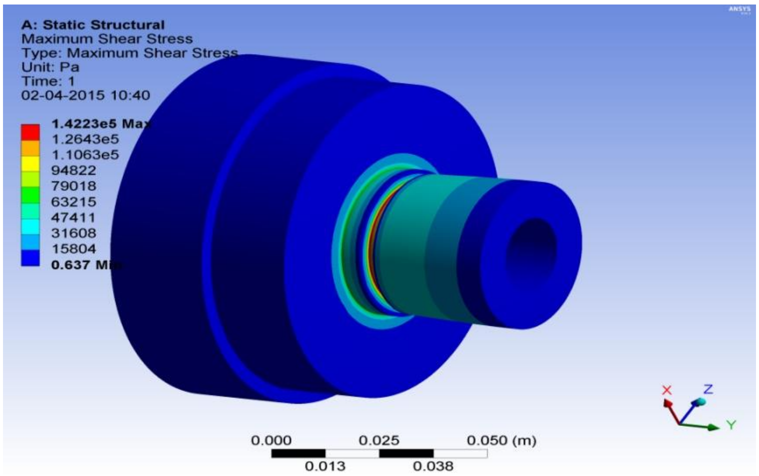


Fig 13 Maximum shear stress

Similarly just like above model we are applying all for seven steps for other models in order to tabulate our results and following table shows Number of Nodes and Elements for Meshing.

Sr.No	Name of components	Number of Nodes	Number of Element
1	Test Rig	239095	65233
2	Plunger	34365	23891
3	Base Flange	42453	28216
4	Output Shaft	25125	16509

Table1. Number of Nodes and Elements for Meshing.

Part 2: plunger

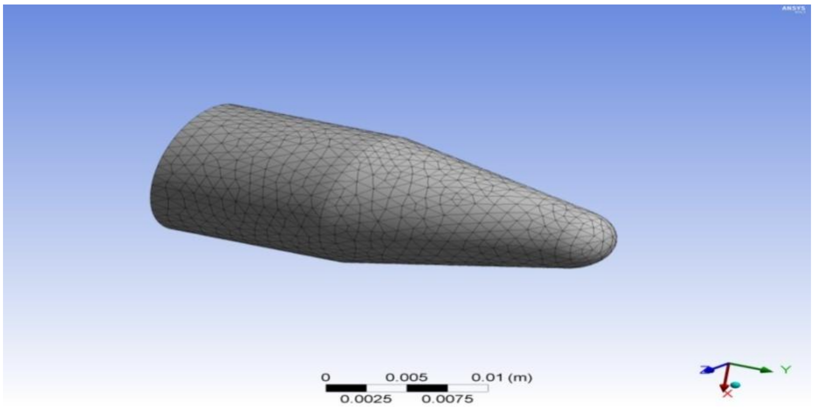


Fig 14 Meshing of plunger

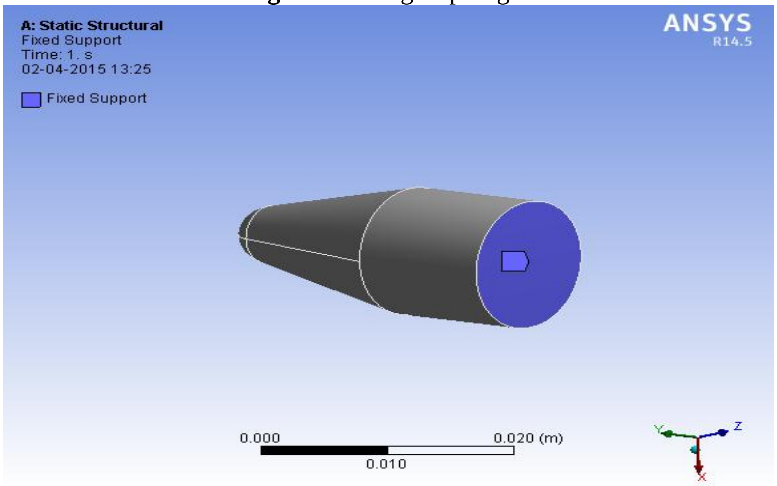


Fig 15 Fixed supports to plunger end

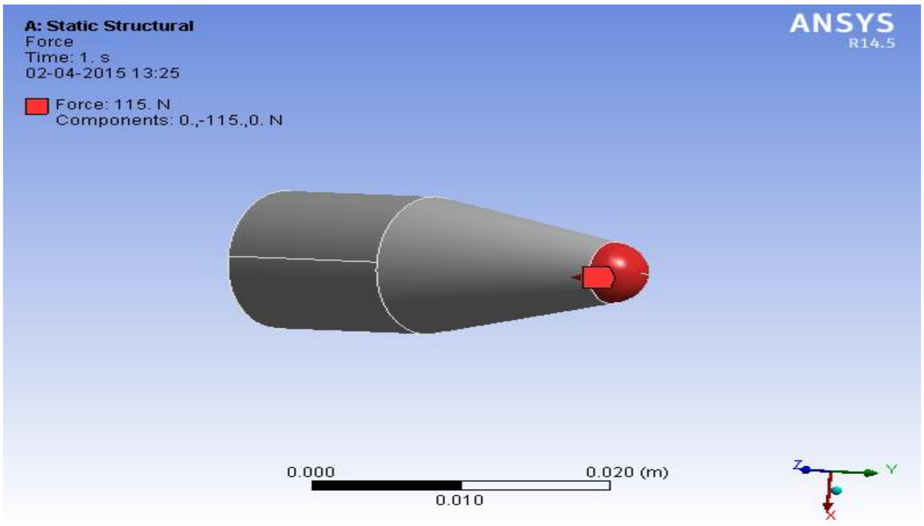


Fig 16 Application of force to plunger

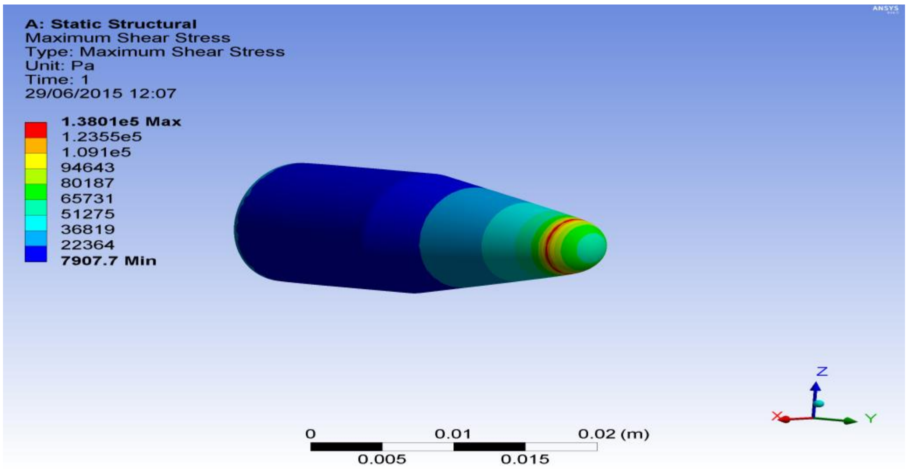


Fig 17 Maximum shear stress on plunger

Part 3: output shaft

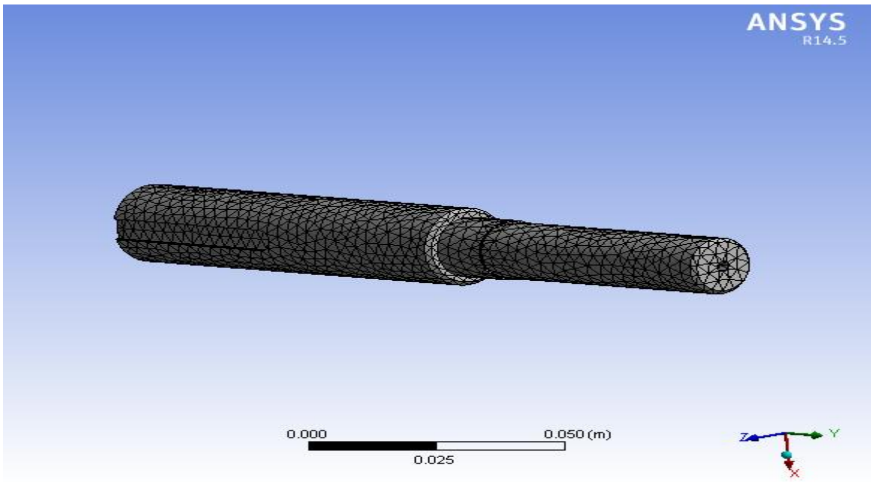


Fig 18 Meshing of output shaft

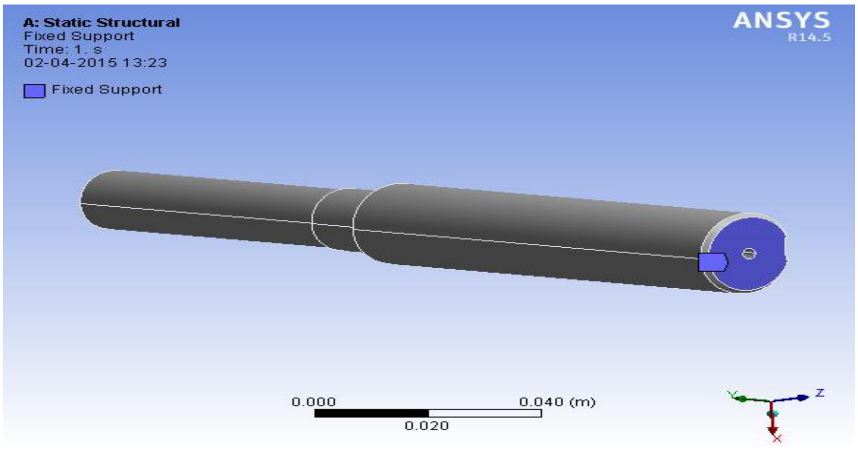


Fig 19 Fixed supports to output shaft

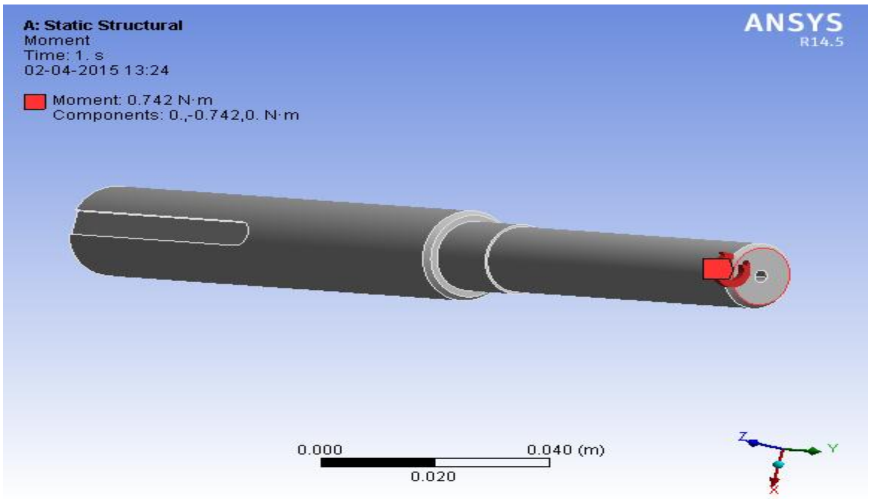


Fig 20 Application of Moment to output shaft

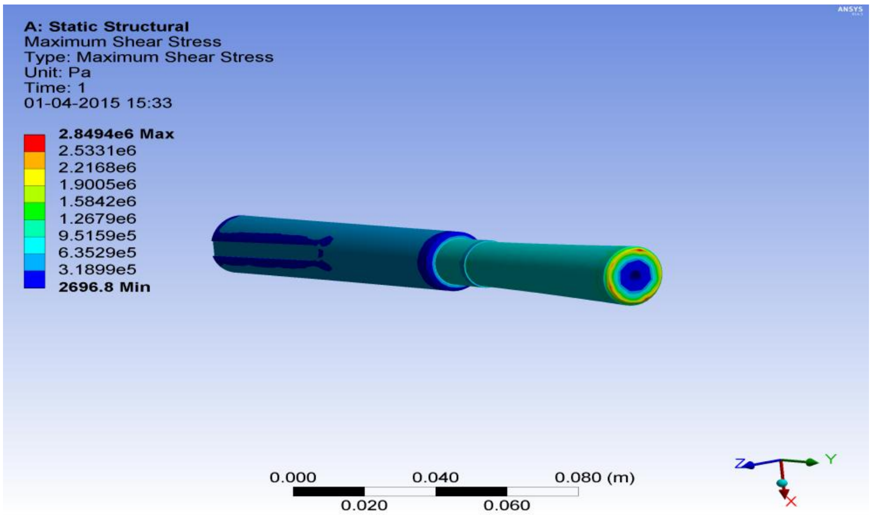


Fig 21 Maximum shear stress on output shaft

Part 4: Base Flange

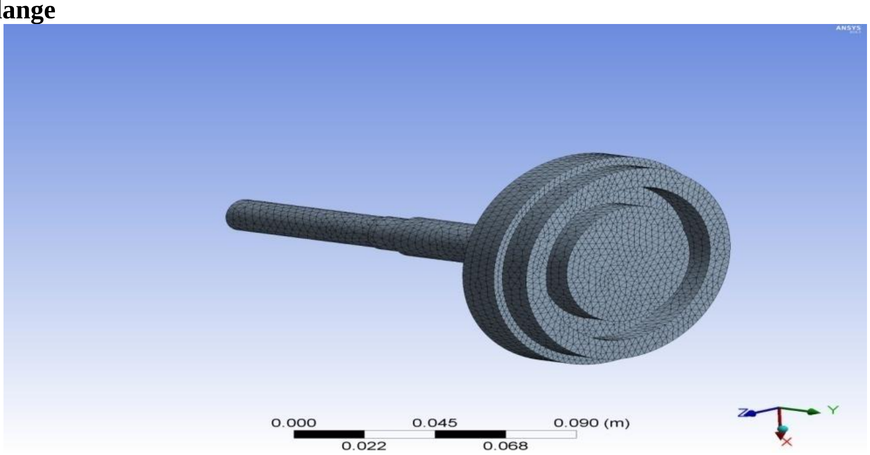


Fig 22 Meshing of Base Flange

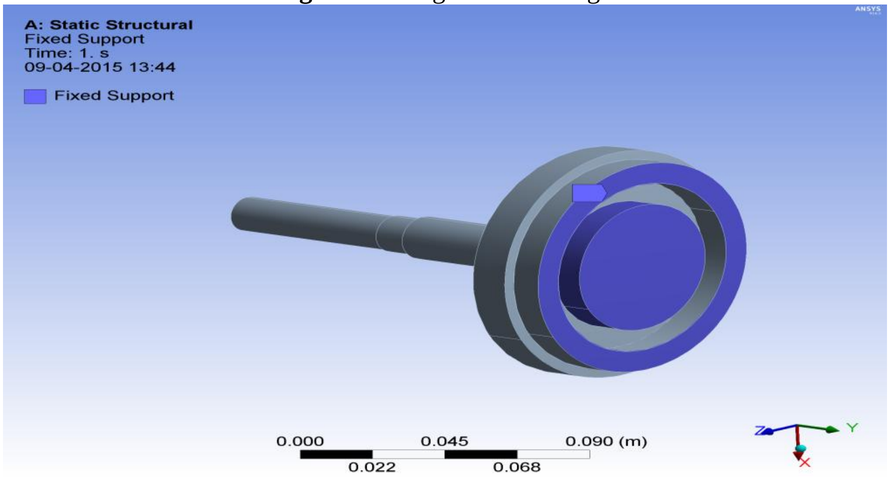


Fig 23 Fixed supports to Base flange

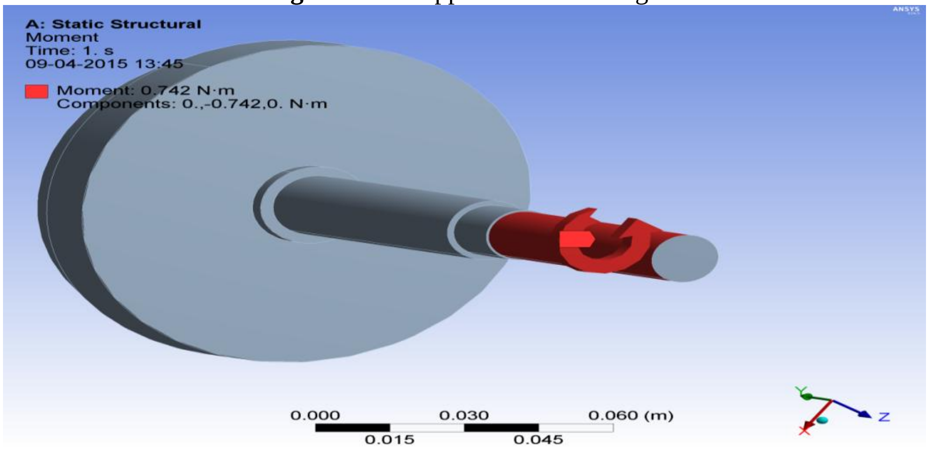


Fig 24 Application of Moment to Base flange

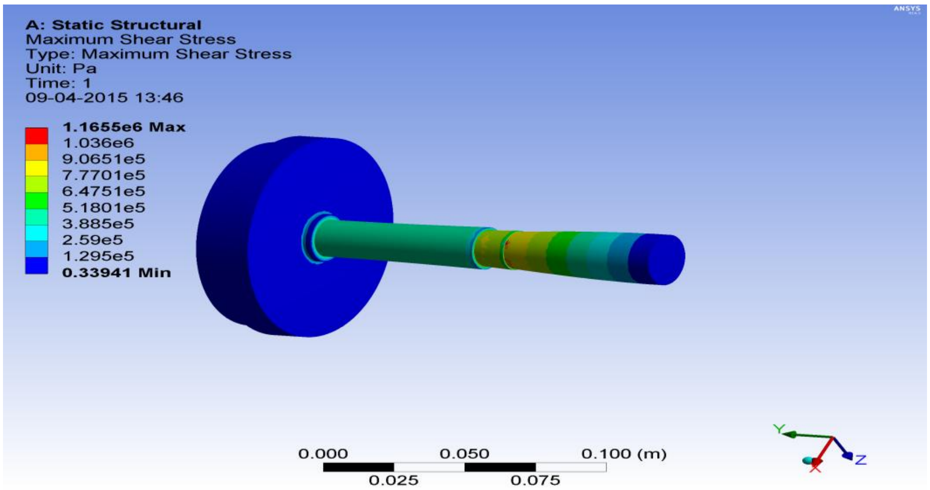


Fig 25 Maximum shear stress on Base flange

VI. RESULTS AND DISCUSSION

By tabulating theoretical data and FEM analysis we conclude that the obtained results of each component that is maximum shear stress can be tabulate by considering following table for each component.

6.1 For Test Rig

Maximum shear stress	Allowable shear stress(consider Factor of safety 10)	Actual shear stress(By calculation)	Shear stress in ANSYS
700 x 10^6N/m^2	90×10^6 N/m^2	75.95×10^3 N/m^2	1.42x10^5 N/m^2

6.2 For output shaft

Maximum shear stress	Allowable shear stress(consider Factor of safety 10)	Actual shear stress(By calculation)	Shear stress in ANSYS
900 x 10^6N/m^2	90×10^6 N/m^2	922.6×10^3 N/m^2	2.489x10^6N/m^2

6.3 For plunger

Maximum shear stress	Allowable shear stress(consider Factor of safety 10)	Actual shear stress(By calculation)	Shear stress in ANSYS
700 x 10^6N/m^2	70×10^6N/m^2	866.4 x10^3N/m^2	1.3801 x 10^5N/m^2

6.4 For Base flange

Maximum shear stress	Allowable shear stress(consider Factor of safety 10)	Actual shear stress(By calculation)	Shear stress in ANSYS
700 x 10^6N/m^2	70×10^6N/m^2	866.4 x10^3N/m^2	1.165x10^6 N/m^2

VII. EXPERIMENTATION OF TORQUE LIMITER.

7.1 Introduction of experimentation of Torque Limiter.

A part of static analysis gets completed in previous chapter and it gives result related with maximum shear stress of each component. In order to analyse efficiency of Torque limiter and value of maximum shear stress at maximum load i.e. 1 KG on the available model at company workshop. With the help of this model different characteristics like Load vs. speed Characteristics and efficiency vs. load Characteristics are obtain on test set up.

Fig 27 Experimental setup of Torque limiter assembly

7.2 Procedure followed during the testing on the setup

- Make all necessary connection in order to start the set up.
- Start motor by turning electronic speed variation knob.
- Let mechanism run & stabilize at certain speed (say 1300 rpm)
- Place the pulley cord on pulley and add 100 gm weight into the pan and note down the output speed for this load by means of tachometer.
- Similarly add another 100 gm weight in pan and observed the reading & take reading accordingly.
- Same step are followed by adding a different weight in the pan and note down all readings.
- Tabulate the readings in the observation table.
- Plot load vs. speed characteristic and Efficiency vs. load characteristic.
- Once the observation table is form then calculate the value of efficiency along with maximum shear stress by taking the respective dimension of components and maximum load acting on the shaft i.e. 1 kg means 9.81 N which is acting on the output shaft. So our calculation can be categorised in two parts.

7.3 Calculation of Efficiency of Torque Limiter assembly during various loading condition- Following table indicates speed variation according to load application and it considers a condition of loading and unloading respectively.

Sr.No	Loading		Unloading		Mean Speed (rpm)
	Weight (gm)	Speed (rpm)	Weight (gm)	Speed (rpm)	
1	100	2100	100	2100	2100
2	150	1820	150	1820	1820
3	200	1680	200	1680	1680
4	250	1540	250	1540	1540
5	300	1400	300	1400	1400
6	350	1260	350	1260	1260
7	500	840	500	840	840
8	600	700	600	700	700
9	700	560	700	560	560
10	800	420	800	420	420
11	1000	280	1000	280	280

Table 1 Observation Table

7.4 Sample Calculations: - (AT 0.6 kg Load)

Calculation of Average Speed:-

- $N = (N_1 + N_2)/2$
- $N = (650 + 650)/2$
- $N = 650$ rpm

Calculation of Output Torque:-

- $T_{d\,p}$ = Weight in pan x Radius of Pulley
- $T_{d\,p} = (0.6 \times 9.81) \times 37.5$
- $T_{d\,p} = 202.725$ N.mm
- $T_{d\,p} = 202.75$ N.mm

Input Power:- ($P_{i/p}$)

- $P_{i/p} = (2\,\Pi\,N\,T_{i/p})/60$
- $P_{i/p} = (2 \times \Pi \times 850 \times 0.225)/60$

- $P_{i/p}$ =20.27 watt

Output Power:-($P_{o/p}$)

- $P_{o/p}$ =(2 Π N $T_{o/p}$)/60
- $P_{o/p}$ = (2 x Πx 850 x 0.203)/60
- $P_{o/p}$ =18.06 watt

Calculation of Efficiency:-

- Efficiency = (Output power) / (Input power)
- Efficiency = (18.06 x 100) / 20.27
- Efficiency = 89 %
- **Efficiency of transmission of Torque Tender = 89%**

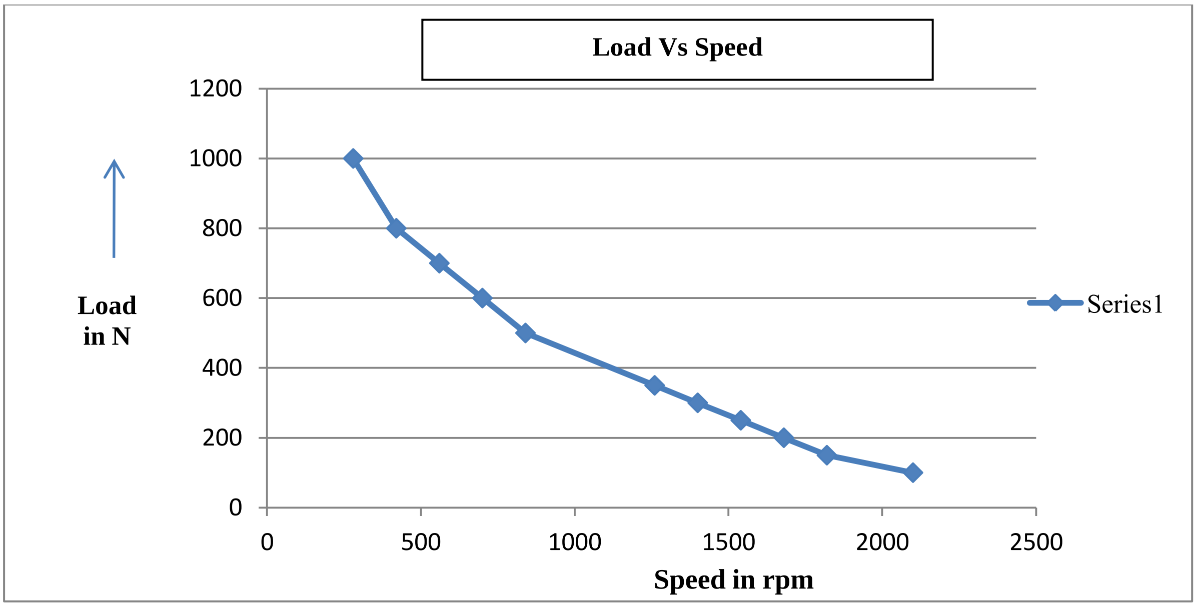
7.5 Result Table

Sr. No	Load (gms)	Speed(rpm)	Torque(N.M)	Power (watt)	Efficiency
1.	100	2100	0.036788	11.1760425	55.32694
2.	150	1820	0.055181	11.1760425	55.32694
3.	200	1680	0.073575	13.3048125	65.86541
4.	250	1540	0.091969	15.2055	75.27475
5.	300	1400	0.110363	14.25515625	89.09473
6.	350	1260	0.128756	13.97005313	87.31283
7.	500	840	0.183938	15.39556875	96.2223
8.	600	700	0.220725	14.8253625	92.65852
9.	700	560	0.257513	14.23614938	88.97593
10.	800	420	0.2943	15.81372	98.83575
11.	100	280	0.367875	14.445225	90.28266

Table No 2 Result table

7.6 Different characteristics of Load vs. speed and Efficiency vs. load.

7.6.1 Load Vs. Speed characteristics –



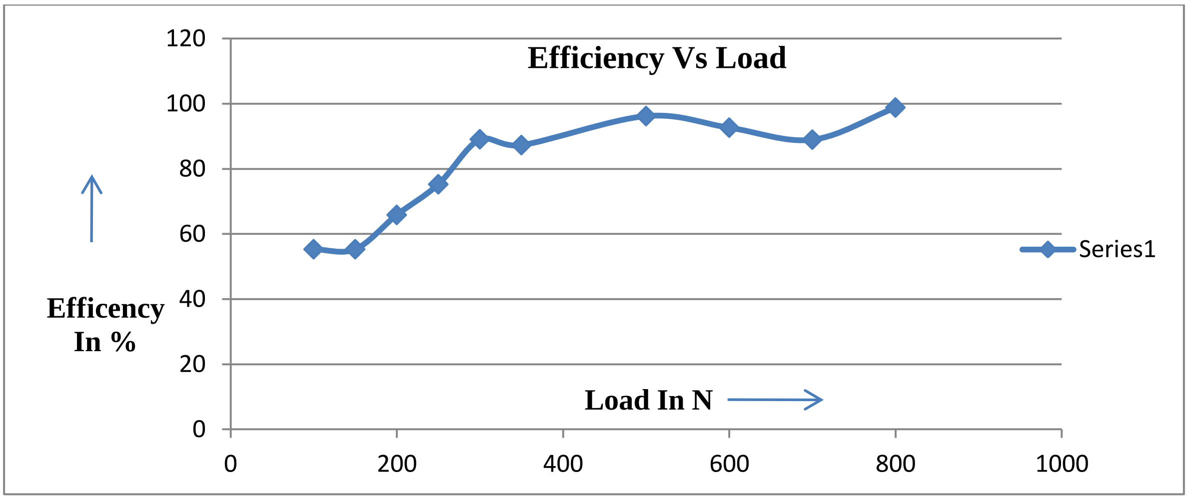
Graph No 1 Load vs. Speed characteristics

Above characteristic is obtained by plotting a graph by taking load on Y axis and speed on X axis respectively. The following graph indicates as load increasing on the output shaft then speed torque limiter gets decreases. In this case load taking on Y axis is in Newton and speed is in revolution per minute. Following figure indicates Load Vs. Speed characteristics.

7.6.2 Efficiency vs. Load characteristics –

Following characteristic is obtained by plotting a graph by taking load on X axis and efficiency on Y axis respectively. The following graph indicates when torque limiter are subjected to higher load then torque limiter are work very efficiently which clearly indicates in figure.

Efficiency Vs. Load characteristics –



Graph No 2 Efficiency Vs. Load characteristics

VIII. CONCLUSIONS

- Excess load acting on output shaft can be reduced by Design and Analysis of Torque Limiter Timer Belt Spindle Drive for Overload Protection.
- The torque carrying capacity can be obtained by varying three number of Ball & spring sets.
- With the help of Integration of the timer pulley set and torque limiter to form final drive system can be achieved.
- In this way stalling of motor can be avoided by design and development of torque limiter.

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