Design & Development of Shock Dynamometer Test Rig.

Prof. Brijesh Patil, Professor, MIT College of Engineering Pune, brijesh.patil@mitcoe.edu.in
Akash Kumar, Student, MIT College of Engineering Pune, akash4442kumar@gmail.com
Shriraj Morankar, Student, MIT College of Engineering Pune, shrirajmorankar05@gmail.com
Krishna Namle, Student, MIT College of Engineering Pune, krishnanamle@gmail.com
Manav Patel, Student, MIT College of Engineering Pune, manavp009@gmail.com

Abstract: **Shock damper or shock absorber is one of the important components of vehicle suspension system. Damper greatly affect the performance of race cars. It has always been a challenge for the engineers to obtain correct characteristics of the damper after its tuning for various riding conditions of the vehicle. This project focuses on the design and development of the Shock Dynamometer which is an important machine to test the damper after tuning. The project explains the method of data collection and result plotting which replaces conventional manual techniques with use of efficient software tools. The project also emphasizes on the testing of damper for varying input speed from the motor and damping as the corresponding output. The results are plotted as the graph of damping force versus piston velocity of the damper. These graphs explain about the behavior dampers at various shock conditions and also give the corresponding value of damping coefficient. Significant conclusions can be made about the behavior of damper from the obtained characteristic curves.**

Keywords — Damping coefficient, damping velocity, damping force, Compression and rebound, Sprung and unsprung mass.

I. Introduction

A shock damper is a component which damps the motion of both the sprung and unsprung masses of the car. The sprung mass is the body and chassis of the car, and everything supported by the springs. The unsprung mass is composed of all the components not supported by the springs. This includes the suspension upright and all components attached to it; the brake caliper, brake disc, wheel, tire and a portion of the suspension arms. The amount of damping for is directly proportional to the velocity of the piston in the damper. The characteristic of any damper is the term used to describe the relationship between piston velocity of the damper and the resulting damping force.

Understanding the characteristics allows engineers to make known design changes and fine adjustments to optimise the performance of the vehicle. The characteristics of the damping action can be controlled by varying the configuration and complexity of the metering orifices provided on the dampers. The best way to better understand and tune dampers is through the use of a shock dynamometer. Dynamometer requires both mechanical and electrical components to work together. Mechanical systems provide movement mechanisms and linkages of different mechanical components to have stable controlled movement structures. Software systems allow users to control mechanical systems by providing an interface to enter desired commands, and displaying current system conditions (data collection). Software systems translate user commands into electrical signals by using a micro-controller to control mechanical movements and collect data samples.

II. Construction & Working

Shock dynamometer consists of vertical column, upper & lower plate, load cell, bearing, slider crank mechanism, connecting rod and driving motor and worm reduction gear box.

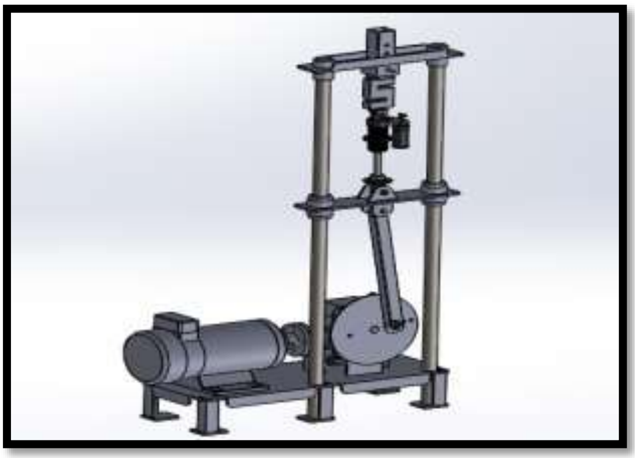

Figure 1: CAD model

Above figure shows a frame holding an electric motor that spins a crank attached to the damper shaft through linear bearing. As the motor spins the crank, the damper piston moves up and down just like the piston in a cylinder of an engine. Bolt holes in the crank allow several different stroke lengths. Different pulley diameters or a variable speed motor give different crank rotation speeds. The load cell measures the damper force. After holding the damper in the dynamometer, the motor is turned ON and is set at specific rpm and stroke. The maximum speed of the damper piston, happens twice each revolution of the crank, once with the piston going up in compression and once again with the piston going down in rebound. Load cell measures the damping force and computer is used to store and read the load cell result.

III. DESIGN & CALCULATIONS

Shock dynamometer consists of vertical column, upper & lower plate, load cell, bearing, slider crank mechanism, connecting rod and driving motor and worm reduction gear box. The static and dynamic design of aforementioned components is as follows. Static design of mechanical structures is aimed at finding the effect of constant loads on components neglecting the effect of inertia and shock. Following are the calculations for different parts of the assembly.

A. *Slider crank Mechanism*

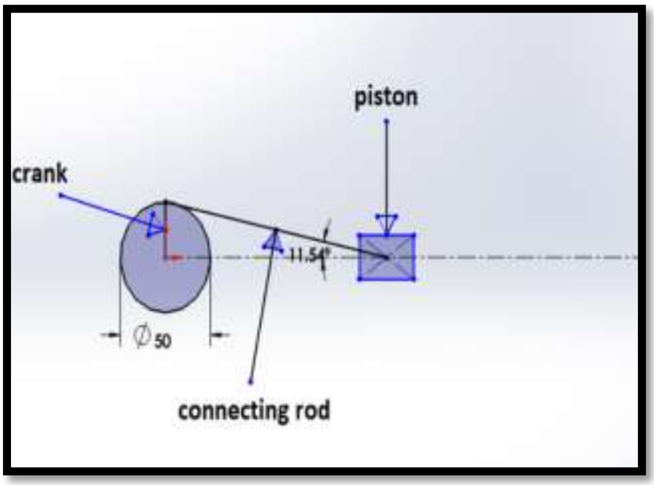

Figure 2: Slider crank mechanism

Speed of motor (N) = 15 r.p.m.
Power of motor (P) = 0.5 H.P
Stroke length of crank = 50mm
Radius of crank(R) = 25mm
Obliquity ratio = 5
Angular velocity of crank (ω) = (2x∏xN)/60 = 1.57 rad/sec
Linear velocity of lower plate=R x ω = 39.25 mm/s
Torque at top point of crank (τ) = P/W = 237.58 N-m
Force along the connecting rod (F) = τ/R= 9503.2 N
Angle made by connecting rod with axis of crank **(θ)** $=\tan^{-1}(R/L)$ =11.31°
Force along the piston (F_a) = $F_x$sin(11.31)= 9318.65 N
Thrust force (F_t) =$F_x$cos(11.31) = 1863.7 N

B. *Vertical Column*

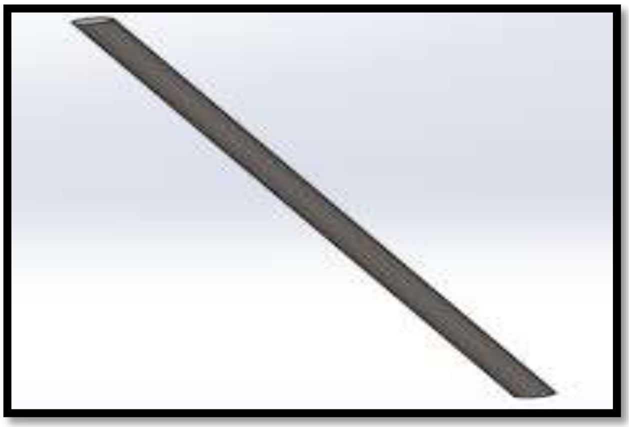

Figure 3: Vertical column

Material-4130 chromyl steel
Yield strength (σ_{yts}) = 460 Mpa
Young modulus (E) = 205000 Mpa
Poison ratio (μ) = 0.285
Maximum thrust force acting on shaft (F_a) = 1863.7 N
Maximum force acting at distance (l) = 420mm
Considering rod as cantilever beam

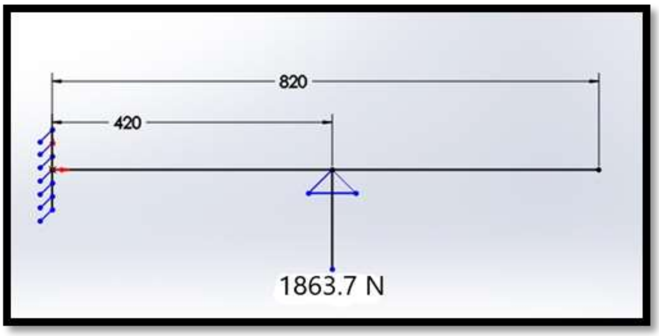

Figure 4: Vertical column as cantilever

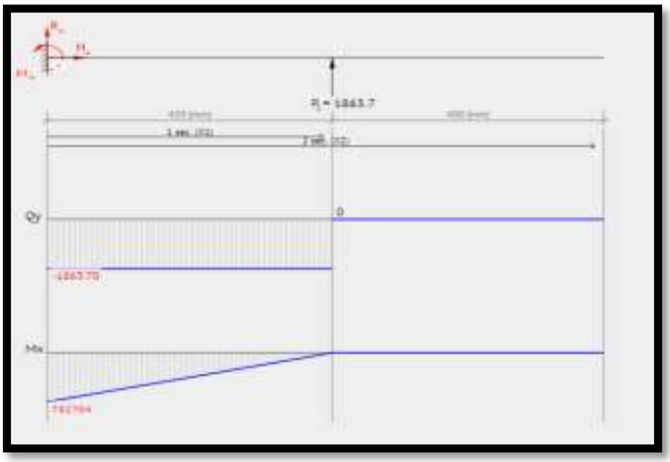

Figure 5: SFD & BMD of Vertical column

Maximum bending moment (M) =F_a x l = 782754 N-mm
By using flexures formula: -

$$\frac{\sigma}{Y}=\frac{M}{I}=\frac{E}{R}$$

Moment of inertia (I) = (∏xd^4)/64

Diameter of shaft (d) =1/3√ ((32xM)/ (∏x [illegible]) = 25.8 mm ≈ 26 mm

C. Upper Plate

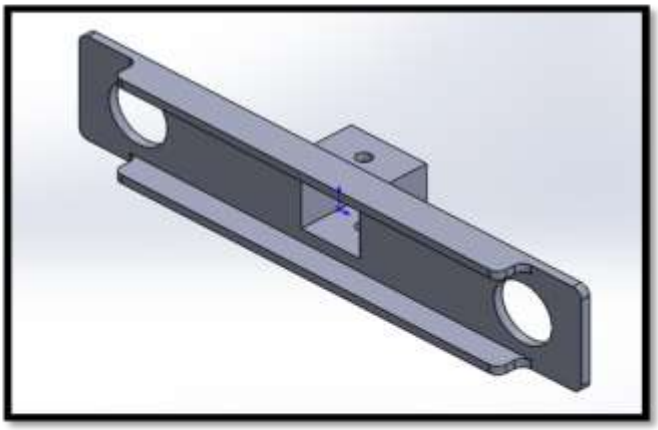

Figure 6: Upper Plate

Material = mild steel 1020
Yield strength = 350Mpa
Width=60mm
Force acting at Centre of plate (F) = 9503.2 N
Consider as simply supported beam

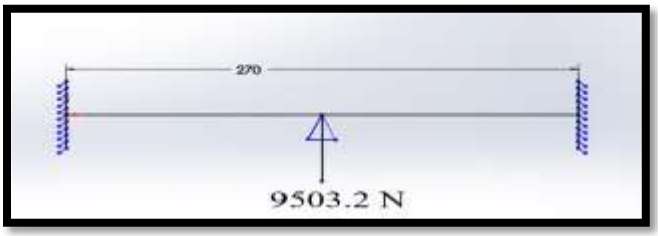

Figure 7: Upper Plate as simply supported beam

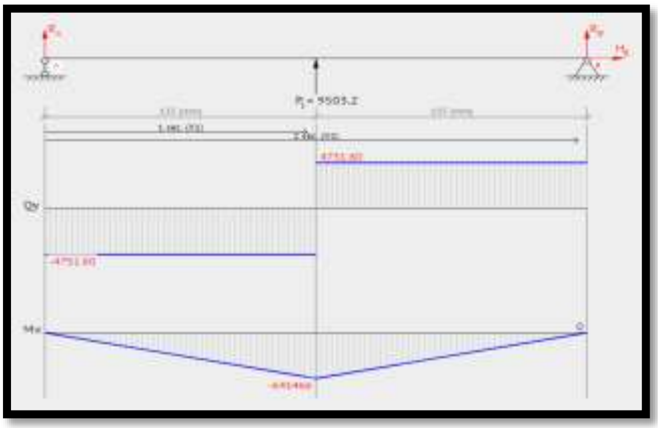

Figure 8: SFD & BMD of Upper plate

Reaction force at end point (F_r) =9503.2/2= 4751.6 N
Maximum bending moment (M) = (F_r×L)/4 =320733 N-mm
By using flexure formula

$$\frac{\sigma}{Y} = \frac{M}{I} = \frac{E}{R}$$

Thickness of upper plate (t) =√ (M/ (10x [illegible])) = 9.57≈ 10

IV. STRUCTURAL ANALYSIS

A. Upper Plate

Force acting at Centre of plate (F) = 9503.2 N

By Von Mises theory,

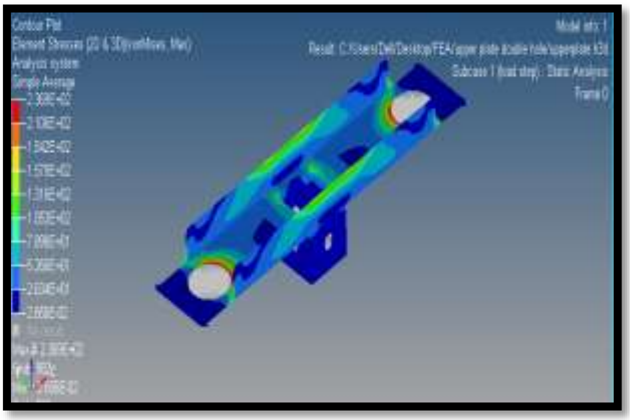

Figure 9: Stress analysis of Upper plate

Maximum stress = 2.36E+02 Mpa
Minimum stress = 2.66E-02 Mpa
Factor of Safety= 1.48

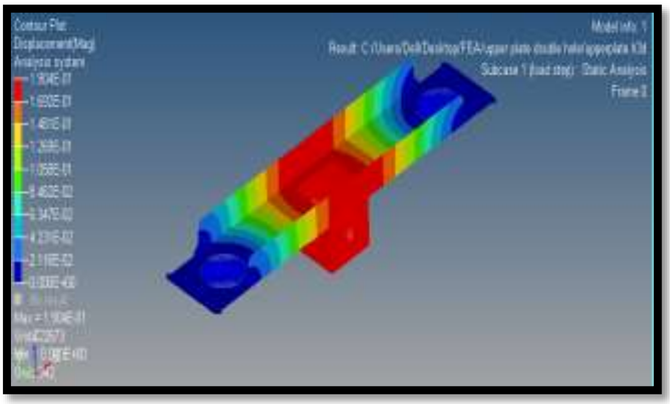

Figure 10: Deflection analysis of Upper plate

Maximum deflection = 0.19 mm

B. Vertical Column

Maximum thrust force acting on shaft (F_a) = 1863.7 N.
By Von Mises theory,

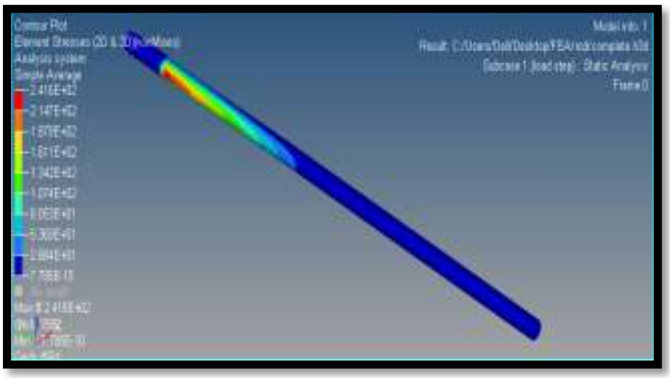

Figure 11: Stress analysis of Vertical column

Maximum stress = 2.41E+02 Mpa
Minimum stress = 7.78E-10 Mpa
Factor of Safety= 0.19

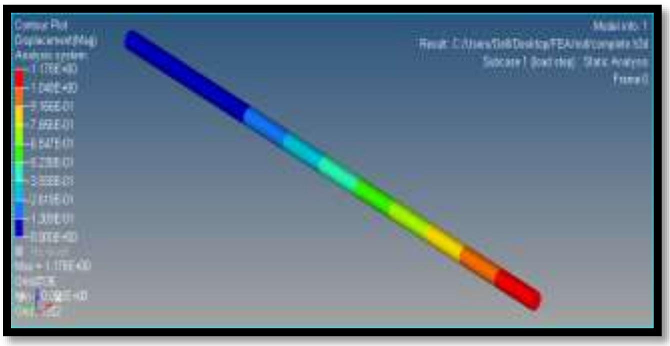

Figure 12: Deflection analysis of Vertical column

Maximum deflection = 1.17 mm

C. Connecting Rod

Force along the connecting rod (F) = τ/R= 9503.2 N

By Von Mises theory,

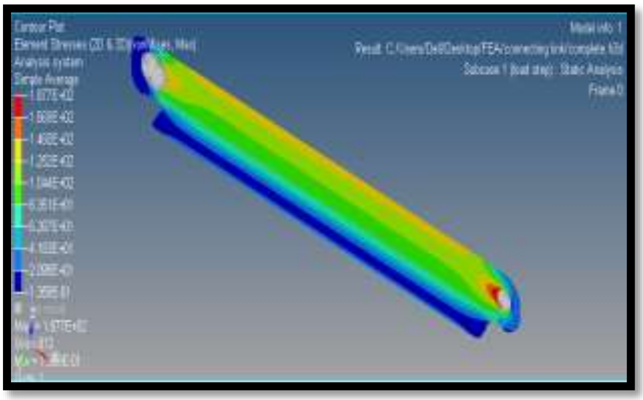

Figure 13: Stress analysis of Connecting rod

Maximum stress = 1.87E+02 Mpa
Minimum stress = 1.36E-01 Mpa
Factor of Safety= 1.87

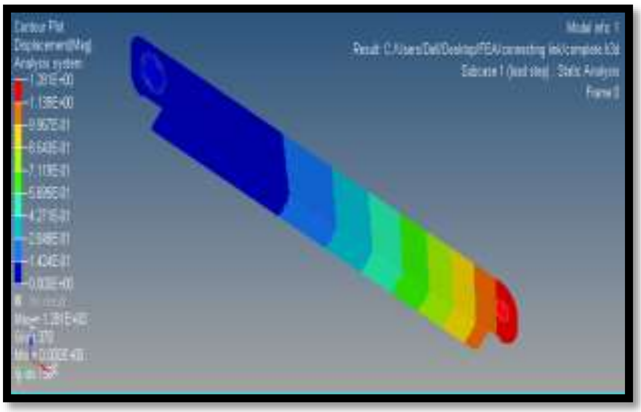

Figure 14: Deflection analysis of Connecting rod

Maximum deflection = 1.28 mm

D. Crank (Rotor)

Torque at top point of crank (τ) = P/W = 237.58 N-m

By Von Mises theory,

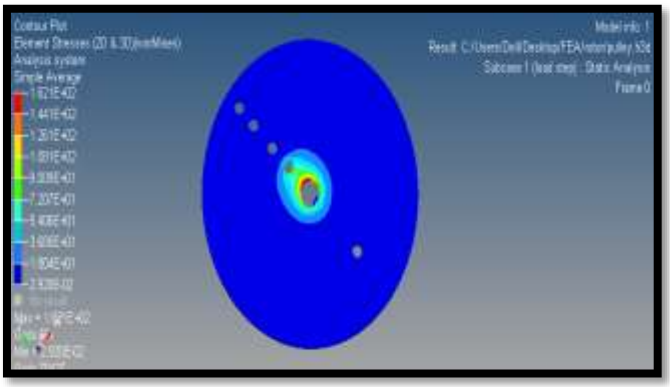

Figure 15: Stress analysis of Crank

Maximum stress = 1.62E+02 Mpa
Minimum stress = 2.92E-02 Mpa
Factor of Safety= 2.16

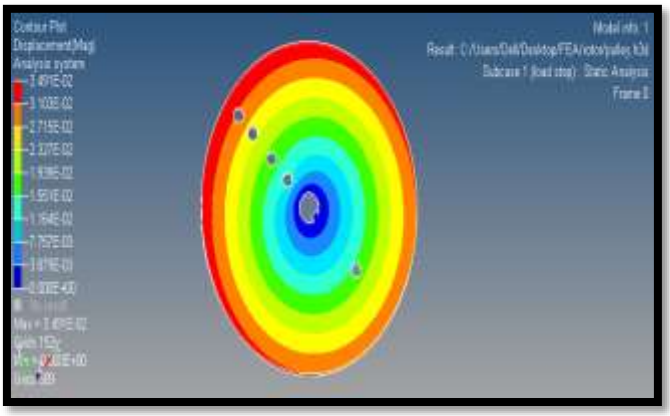

Figure 16: Deflection analysis of Crank

Maximum deflection = 0.39 mm

V. Conclusion

This project is intended to help racing professionals understand the characteristics of their shock dampers. Understanding the characteristics of the shocks enable those to fine tune the behaviour of the shock. The FEA analysis of components conclude that considering all the assumptions the structural design of dynamometer is safe.

VI. References

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