Design of Durability Test Setup for S.S Braided Exhaust Pipe Used in Automobiles and Modal Analysis Base Frame of test setup

[1]Sanket Gurav,[2]Shridhar Limaye

[1]M.Tech. (Mechanical-Design Engineering) Student,[2]Adjunct Professor,
[1]Mechanical Engineering Department,
[1]Walchand College of Engineering, Sangli, India.

Abstract: Gentle carbon steel was the material of decision for exhaust frameworks for a long time. Be that as it may, it experienced helpless erosion opposition when presented to street salt and fumes condensate. Therefore, exhaust frameworks produced using this material had an exceptionally short life whenever presented to the earth experienced by numerous individuals on-street vehicles. Since about the mid-1990s, plain carbon and low composite prepares have been supplanted by treated steel as the essential material for exhaust frameworks downstream of the ventilation system or turbocharger. Generally treated steel adaptable lines are utilized in vehicle to convey the hot gases from ventilation system to different gadgets like supercharger, turbocharger, particular reactant decrease and so on where these gadgets uses the vitality present in the fumes gases. This change has occurred due to advertise requests for service agreements and on account of requests ordered by emanation norms. Advances to satisfy progressively tough discharge guidelines can raise exhaust temperatures which makes the assignment of meeting quality and solidness prerequisites particularly testing. Along these lines, we are going to structure and build up the solidness test arrangement for the hardened steel pipe utilized in vehicle applications. In this test arrangement two slider crank mechanism are intended to give direct development along two pivot with fundamental warmth shield and control board.

Keywords–S.S.(Stainless steel) braided pipe, Treated steel , Supercharger, Turbocharger, Slider crank mechanism.

1. INTRODUCTION

Design of durability test setup is the as per the requirements and specifications of exhaust pipe used in automobile application provided by firm.

The durability test setup is designed to measure the fatigue life of the S.S braided pipe.As per requirement, the linear movement of pipe in both directions is required so it is decided to use two slider crank mechanism along with hard chrome bar and linear bearing in the system to give the linear movement in both the directions.
As there are two types of slider crank mechanism

i. Inline slider crank mechanism:

In this type slider positioned so the line of travel of hinged joint of the slider passes through the base joint of the crank. It moves with same velocity back and forth as the crank rotates.

ii.Offset slider crank mechanism:
Slider situated so the line of movement of pivoted joint of the slider doesn't goes through the base joint of the crank. It moves with different velocity back and forth as the crank rotates and those velocities depends on the offset provided in the system.
As we require the same velocities in both forward and reverse stroke, inline slider crank mechanism is chosen for the system.

2. DESIGN OF TEST SETUP

Linear movement of component is 25 mm in both direction. So, Stroke Length is equal to Linear movement of component.

Design of components:

i. Crank Design

Stroke Length is equal to Linear movement of component

$$\text{Crank Length} = \frac{\text{Stroke length}}{2} = \frac{25}{2} = 12.5 \text{ mm}$$

ii. Connecting rod design

Length of connecting rod can take any value as it does not affect the stroke, however a shorter connecting rod yields greater velocities and acceleration for the slider, therefore its length should be as large as possible. However, a rule of thumb where the connecting rod length is no less than three times the crank length is preferred.
So according to the above rule length of connecting rod taken as ten times the crank length.
Therefore, Length of connecting rod= 125 mm

It is subjected to axial compressive force of significant magnitude compared to other forces. Therefore, the connecting rod is designed as a column or a strut.

Connecting rod is four times stronger for buckling about plane YY axis (perpendicular to plane of motion) than XX axis (plane of motion) in case of rectangular cross-section. For circular section both planes are equally strong. It is observed that the proportions of I-sections of the connecting rod are satisfactory.

The dimensions of cross section of connecting rod are calculated by applying Rankine's formula for bucking of connecting rod in plane of rotation (XX axis). According to Rankine's formula [3]

$$P_{cr} = \frac{\sigma_c A}{1 + a\left(\frac{L}{K_{xx}}\right)^2}$$

Material: Mild Steel

Where, P_{cr} = Critical buckling load(N)= P_c x FOS = 4441.32 x 5 = 22206.6 N

σ_c = Compressive yield stress (MPa) = 250 MPa

A= cross section area of connecting rod (mm^2) = $11t^2$ mm^2

a = constant depending upon material and end fixity coefficient = 1/7500

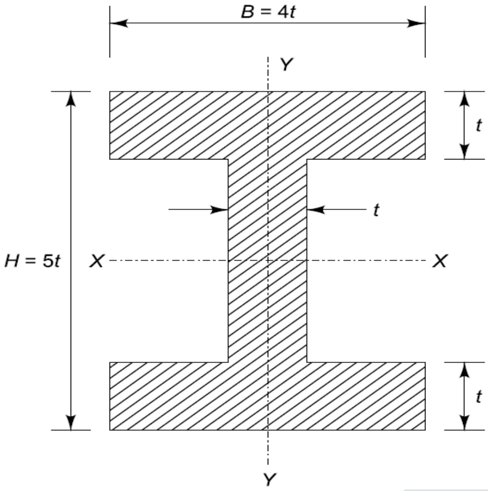


Fig2.1 Cross-section of the connecting rod

After Substitution we get,

$t = 2.95 \approx 3$ mm

So, B = 4t = 12 mm

H = 5t = 15 mm

The height H varies from the big end to the small end in the following way:

At the middle section, H = 5 t = 15 mm

At the small end, H_1 = 0.75 H to 0.9 H = 0.825 H = 12.4 mm

At the big end, H_2 = 1.1 H to 1.25 H = 1.175 H = 17.6 mm

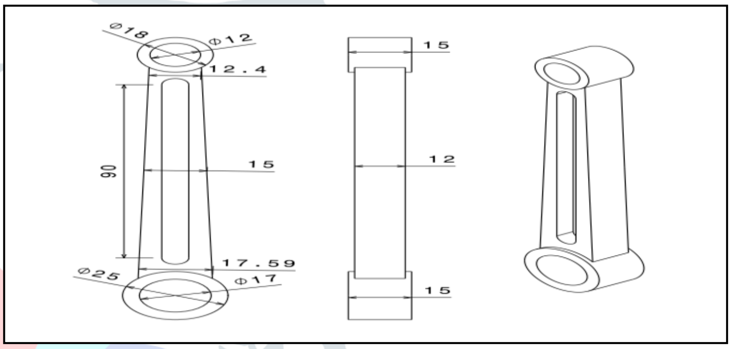


Fig 2.2 Connecting rod

iii. Design of crank pin

Crank pin is subjected to single shear force through the connecting rod. Shear force = 4441.32 N

The shear stress is given by[3], $\tau = \frac{F_{CR} \times fos}{\frac{\pi}{4} d^2 \times 1}$

For Mild Steel, τ = 250 N/mm^2

***d* = 11 mm**

iv. Design of connecting rod pin

Connecting rod pin subjected to double shear. Shear force =4441.32N

The shear stress is given by[3], $\tau = \frac{F_{CR} \times fos}{\frac{\pi}{4} d^2 \times 2}$

For Mild Steel, τ = 250 N/mm^2

***d* = 8 mm**

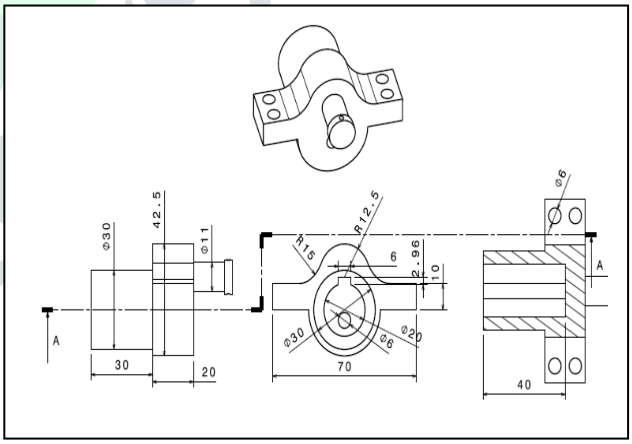


Fig 2.3 Crank

The big end bearing is usually have a phosphor bronze bush of 3 mm thickness and small end bearing is of same material with 2 mm thickness.

v. Design of bolts

The cross section of bolt at core diameter is the weakest section so, bolt is designed for its core diameter.

The maximum compressive stress in the bolt at this cross section is given by [3]

$$\frac{\sigma_c}{fos} = \frac{P}{\frac{\pi}{4} d_c^{\,2} \times n}$$

Where, $\sigma_c = 250$ N/mm^2 and P = 4441.32 N

n = No. of bolts = 2

After solving above equation,

$d_c = 8.53$ mm

For d_c = 8.160 to 8.576 mm

M10 bolt is selected

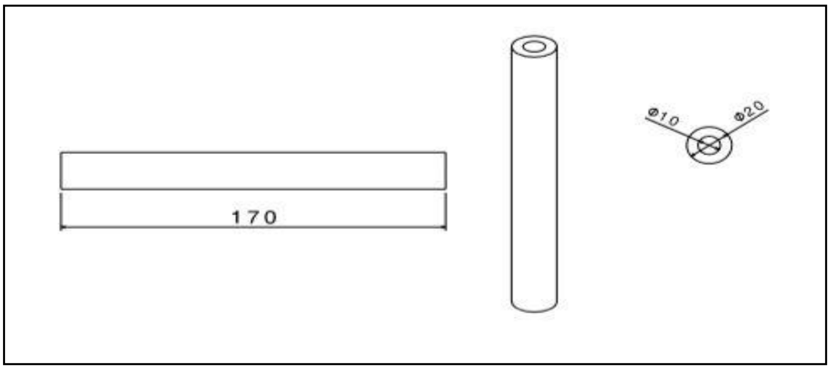


Fig 2.4 Hard chrome bar

vi. Design of Hardchrome bar

Hard chrome, also known as industrial chrome or engineered chrome, is used to reduce friction. Engineering chromium is usually applied directly to the basis metal and is finished by grinding to the specified dimensions.

Diameter of hardchrome bar = Bolt diameter + (2 x Thickness on either sides)

= 10+(2 x 5)

= 20 mm

Selection of motor, crank key and linear bearing is done by using the standard procedure for respective components.
Helical geared motor of 1 hp with 900 rpm output speed is selected for the test setup.

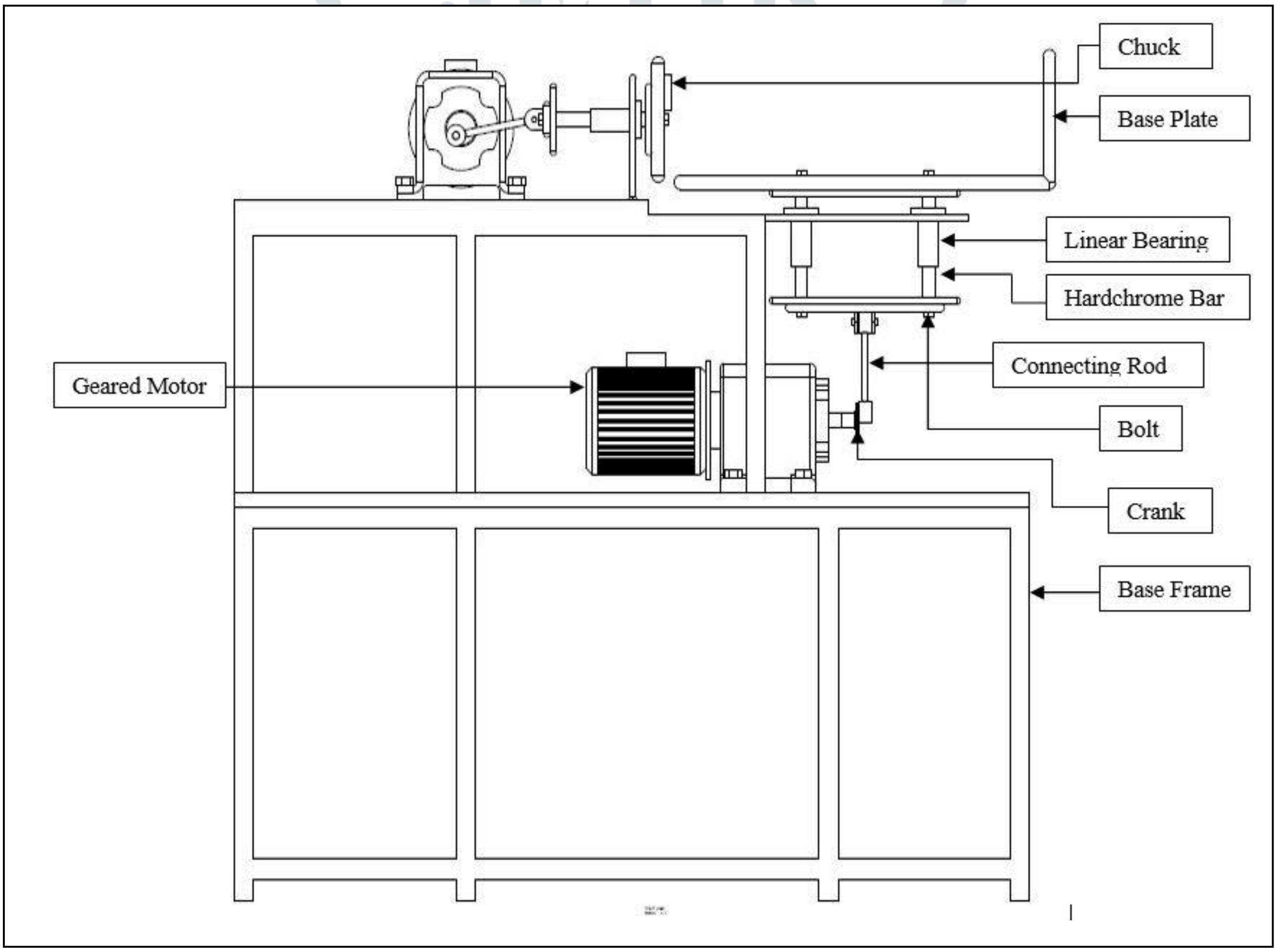


Fig 2.5 Schematic diagram of Test Setup

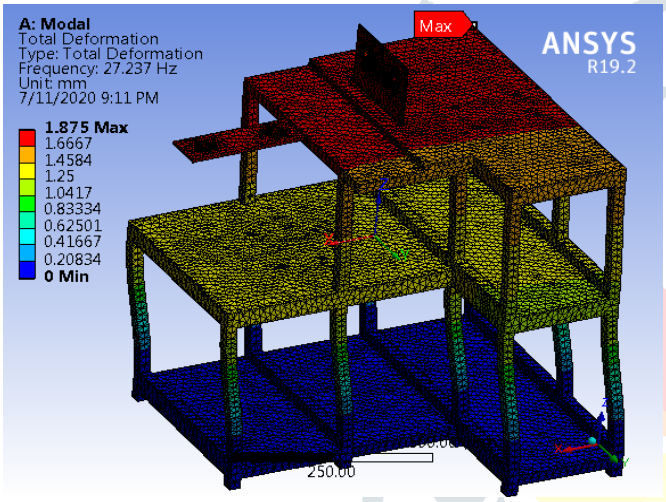
3. MODAL ANALYSIS OF BASE FRAME OF TEST SETUP

The entire assembly of test setup is going to mount on the base frame. Thus, modal analysis of base frame is necessary. The modal analysis of the base frame is done using ANSYS 18.2. The tetrahedral linear element is used. The convergence analysis of natural frequencies is done for various mesh sizes. It was found that the solution gets converged for mesh size of 10mm. The convergence analysis is shown in table 3.1

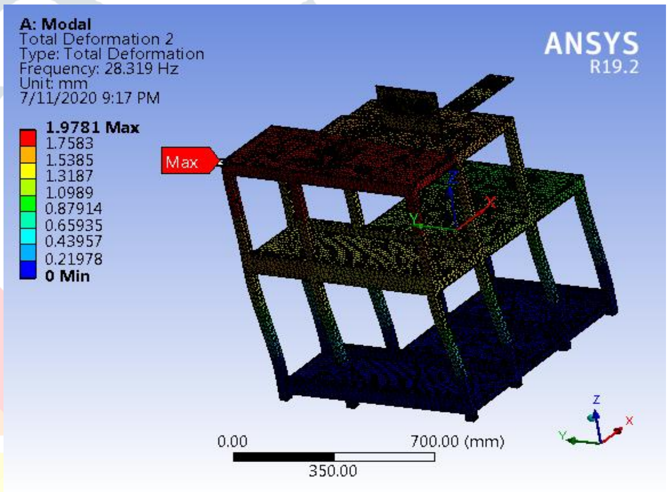
Table 3.1 Mesh Convergence analysis for base frame.

Mesh Size (mm)	First Natural Frequency (Hz)
14	32.165
13	29.650
12	28.465
11	27.240
10	27.237
9	27.234
8	27.230

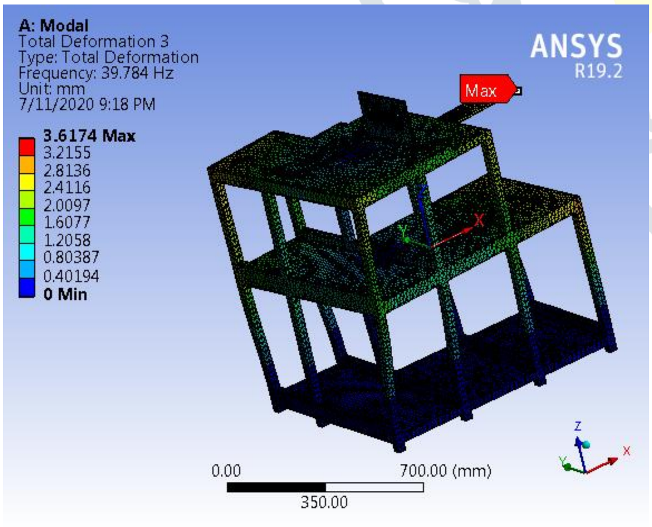
The results obtained from the above analysis are shown in figures below,



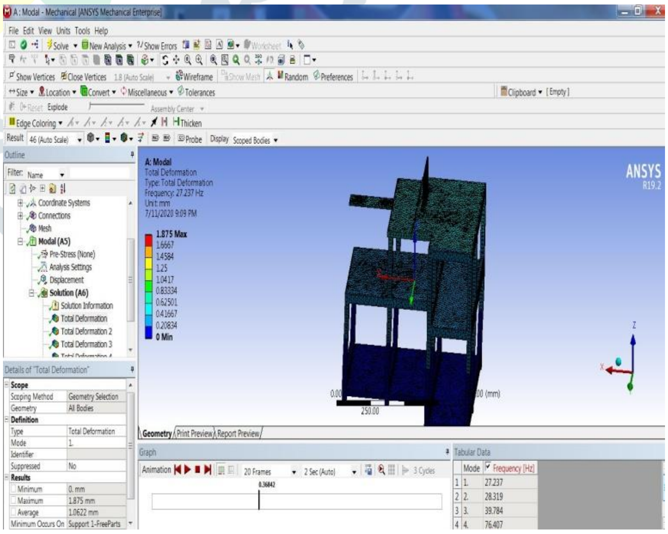
a) Mode 1



b) Mode 2



c) Mode 3



d) Solution

The above figure shows the first three mode shape and solution of the base frame. The first natural frequency obtained in this simulation 27.237 Hz i.e. 1634.22 rpm which is well above the operating frequency of the system which is 900 rpm. Thus, the frame design is safe for use.

4. CONCLUSION

As per the requirement of firm that is as per design inputs given by firm, the basic slider crank mechanism is finalized to give linear movement to the component in both directions and slider mechanism with its main components like crank pin, connecting rod, connecting rod pin, bush for small and big end of connecting rod etc. are designed, with addition to these the hard chrome bar, bolt size and linear bearing is selected. These designed components are modelled in cad software and assembled. After that modal analysis of base frame of test system is done and results shows that the first natural frequency (Mode1) obtained in this simulation is well above the operating frequency of the frame. Thus, these frame design safe for use.

REFERENCES

[1] Jonas Truong, Camille Brousseau and Alexis Lussier Desbiensa, "A Method for Measuring the Bending and Torsional Stiffness Distributions of Alpine Skis", Procedia Engineering 147 394-400 (2016)

[2] Murilo Augusto Vaz, Luis D'Angelo and Segen Farid Estefen, "Experimental determination of axial, torsional and bending stiffness of umbilical cables", Conference Paper January 1998

[3] V. B. Bhandari, *Design of Machine Element*s, Fourth Edition, McGraw New Delhi, 2017

[4] S. S. Ratan, *Theory of machines*, Third Edition, McGraw New Delhi.

[5] Norton, Robert L. *Design of machinery: an introduction to the synthesis and analysis of mechanisms and machines*. WCB McGraw-Hill, 1999.