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Performance of the Structural Analysis of Ford Car Steering Rod

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Abstract- Steering shaft/rod is an important part of overall steering system. It is a media between Steering wheel and steering box. Whoever there are many issues related to its function-ability occurs. Stresses developed in an object, design requirements at the joints, deformation in body due to vibrations, continuous twisting and loading these are the common one related to steering rod.

In this Paper Various Structural analyses such as Static-Structural, Modal Analysis of a steering rod are done. Static-structural analysis is capable to find out deformation in body in which Von-mises stress are calculated and this state that up to what extent the deformation in the rod occurs. while modal analysis is important in vibration point of view. i.e. Vibrations in body can be calculated up to what frequency the steering rod can sustain the load or Harmonic frequency of the body From above Optimisation of steering rod can be done.

In This Paper I have done structural analysis of ford fiesta classic car steering rod to Optimise the Steering rod with better results than existing one.

Index Terms- Steering rod, Structural analyses, Modal Analysis, Deformation, Harmonic frequency, stress.

I. INTRODUCTION

The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles.

The steering system is a group of parts that transmit the movement of the steering wheel to the front, and sometimes the rear, wheels. The primary purpose of the steering system is to allow the driver to guide the vehicle. When a vehicle is being driven straight ahead, the steering system must keep it from wandering without requiring the driver to make constant corrections.

The steering system must also allow the driver to have some road feel (feedback through the steering wheel about road surface conditions). The steering system must help maintain proper tire-to-road contact. For maximum tire life, the steering system should maintain the proper angle between the tires both during turns and straight-ahead driving. The driver should be able to turn the vehicle with little effort, but not so easily that it is hard to control.

There are Following Types of Steering System

1.Rack-and-pinion Steering
2.Conventional Steering

II. RACK-AND-PINION STEERING SYSTEM

Rack-and-pinion steering transmits circular motion from the steering wheel to a pinion that meshes with teeth on a flat rack. The pinion moves the rack in a linear direction, steering the wheels. Rack-and-pinion steering can be found on cars, mini-vans and small SUVs. It is simpler and less expensive to produce than conventional steering systems.

1.Steering wheel 2.Steering Column 3.Rack and pinion 4.Tie Rod 5.Kingpin

Figure. 1 Rack and pinion steering mechanism

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2.1 Steering Wheel

It is actual physical media between driver and vehicle. It gives vehicle control to the driver. By rotating wheel in required direction vehicle can moved further. The only part of the steering system the average driver is familiar with is the steering wheel. Older wheels are made of hard plastic, are larger in diameter, and are relatively thin when compared to modern steering wheels. The modern steering wheel is generally padded. Most steering wheels have two or three spokes or a large center section that connects the wheel portion to the hub. To prevent slippage, the steering wheel hub has internal splines, which match external splines on the steering shaft.

2.2 Steering Column

Figure 2. Steering column

Steering column is one of the important part of steering system. It provides connectivity between steering Box and steering wheel. It consist of two shafts which are connected through cross joint or any other joint which allows angular rotation for steering a vehicle.
The steering column is the support and cover for the steering shaft and other steering wheel–mounted components and wiring. Some steering columns can be adjusted to change the position of the steering wheel. Adjustable steering columns make driving more comfortable for people who are shorter or taller than average.

2.3 Rack and Pinion

This unit mounted in the cockpit of an ariel atoms sports car chassis. For most high volume production, this is usually mounted on the other side of this panel Many modern cars use rack and pinion steering mechanisms, where the steering wheel turns the pinion gear; the pinion moves the rack, which is a linear gear that meshes with the pinion, converting circular motion into linear motion along the transverse axis of the car (side to side motion). This motion applies steering torque to the swivel pin ball joints that replaced previously used kingpins of the stub axle of the steered wheels tie rods and a short lever arm called the steering arm.
The rack and pinion design has the advantages of a large degree of feedback and direct steering "feel". A disadvantage is that it is not adjustable, so that when it does wear and develop lash, the only cure is replacement.
Older designs often use the recirculating ball mechanism, which is still found on trucks and utility vehicles. This is a variation on the older worm and sector design; the steering column turns a large screw (the "worm gear") which meshes with a sector of a gear, causing it to rotate about its axis as the worm gear is turned; an arm attached to the axis of the sector moves the Pitman arm , which is connected to the steering linkage and thus steers the wheels.
The re-circulating ball version of this apparatus reduces the considerable friction by placing large ball bearings between the teeth of the worm and those of the screw; at either end of the apparatus the balls exit from between the two pieces into a channel internal to the box which connects them with the other end of the apparatus, thus they are "re-circulated".
The re-circulating ball mechanism has the advantage of a much greater mechanical advantage , so that it was found on larger, heavier vehicles while the rack and pinion was originally limited to smaller and lighter ones; due to the almost universal adoption of Power Steering, however, this is no longer an important advantage, leading to the increasing use of rack and pinion on newer cars. The re-circulating ball design also has a perceptible lash, or "dead spot" on center, where a minute turn of the steering wheel in either direction does not move the steering apparatus; this is easily adjustable via a screw on the end of the Steering box to account for wear, but it cannot be entirely eliminated because it will create excessive internal forces at other positions and the mechanism will wear very rapidly. This design is still in use in trucks and other large vehicles, where rapidity of steering and direct feel are less important than robustness, maintainability, and mechanical advantage.

2.4 Tie rod

It is used to give direction to tires according to steering wheel movement. A tie rod assembly is attached to each end of the relay rod. The tie rod assembly consists of inner and outer tie rods that are usually connected through an adjusting sleeve.

2.5 Kingpin

Tyre and axle is connected through kingpin and it also act as an media for giving direction to the tyres.

III. CONVENTIONAL STEERING

Conventional steering transmits the circular motion from the steering wheel through a gear that moves an arm through a back-and forth arc, acting on a set of linkages to steer the wheels. It is also referred to as "re-circulating ball" or "worm gear" steering, for the type of gear it uses, or "parallelogram," "trapezium," or simply "linkage" steering, for the shape formed by the linkage set. This type of system can be found on most rear wheel drive cars, light trucks and full size vans.

3.1 Recirculating Ball Steering

Re-circulating-ball steering is used on many trucks and SUVs today. The linkage that turns the wheels is slightly different than on a rack-and-pinion system

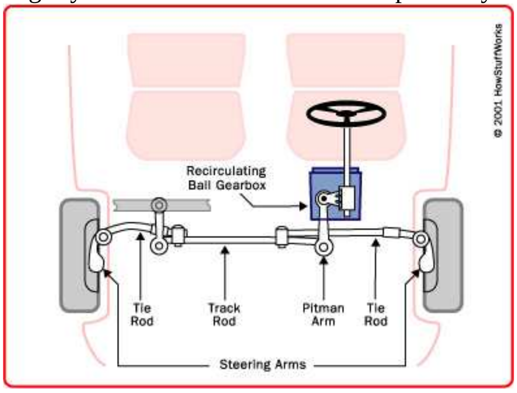

Figure 3. Recirculating-ball steering

The recirculating-ball steering gear contains a worm gear. You can image the gear in two parts. The first part is a block of metal with a threaded hole in it. This block has gear teeth cut into the outside of it, which engage a gear that moves the pitman arm (see diagram above). The steering wheel connects to a threaded rod, similar to a bolt that sticks into the hole in the block. When the steering wheel turns, it turns the bolt. Instead of twisting further into the block the way a regular bolt would, this bolt is held fixed so that when it spins, it moves the block, which moves the gear that turns the wheels.

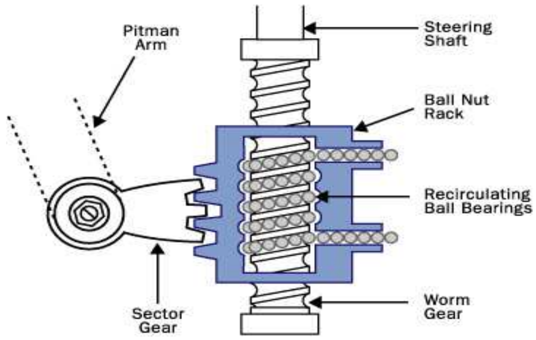

Figure 5. Worm gear steering system

Instead of the bolt directly engaging the threads in the block, all of the threads are filled with ball bearings that re-circulate through the gear as it turns. The balls actually serve two purposes: First, they reduce friction and wear in the gear; second, they reduce slop in the gear. Slop would be felt when you change the direction of the steering wheel -- without the balls in the steering gear, the teeth would come out of contact with each other for a moment, making the steering wheel feel loose.

3.2 Power Steering

There are a couple of key components in power steering in addition to the rack-and-pinion or recirculating-ball mechanism.

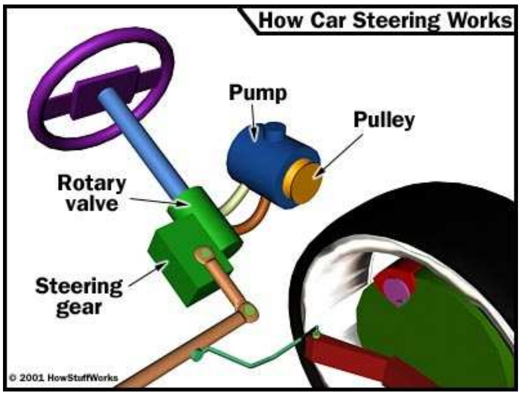

Figure 4. Power steering system

The hydraulic power for the steering is provided by a rotary-vane pump (see diagram below). This pump is driven by the car's engine via a belt and pulley. It contains a set of retractable vanes that spin inside an oval chamber.

As the vanes spin, they pull hydraulic fluid from the return line at low pressure and force it into the outlet at high pressure. The amount of flow provided by the pump depends on the car's engine speed. The pump must be designed to provide adequate flow when the engine is idling. As a result, the pump moves much more fluid than necessary when the engine is running at faster speeds.

IV. PERFORMANCE OF STRUCTURAL ANALYSIS

In structural analysis we can calculate the deformation in the body. In this All the stress can be determined such as X-direction shear component Y-direction shear component Z-direction shear component and Principle stresses such as Von-mises stress. In this von-mises stress are taken into consideration to find the deformation of steering rod.

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4.1 Von-mises stress

Von Mises stress is widely used by designers, to check whether their design will withstand given load condition. Von mises stress is considered to be a safe haven for design engineers. Using this information an engineer can say his design will fail, if maximum value of Von Mises stress induced in the material is more than strength of the material. It works well for most of the cases, especially when material is ductile in nature.

Material used is High Chrome Steel
Young's modulus of chrome steel $=2.2\times10^6$Mpa
Poission's Ratio =0.28
Density=7600Kg/m^3
On the steering there is load of 30N.

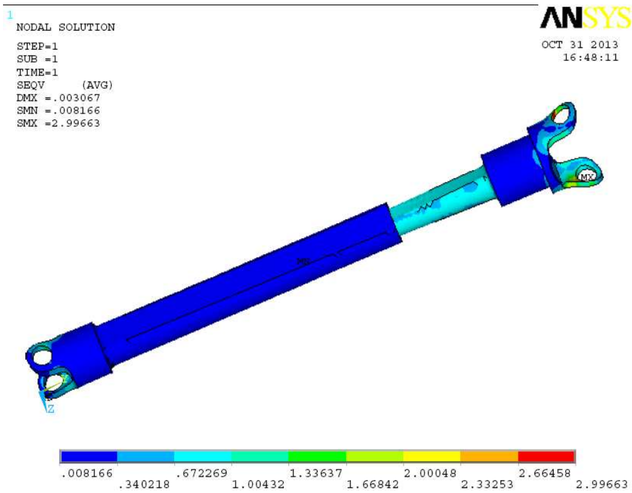

Figure 6. Von mises stress.

Table1. Von mises Stress and Deformation Table

Sir. No.	Nature	Values
1.	Maximum Deformation	0.03067 mm
2.	Minimum stress	0.008166 MPa
3.	Maximum Stress	2.99663 MPa

4.2 Performance of Modal Analysis

Modal analysis is important in vibration point of view. i.e. Vibrations in body are calculated up to what frequency the steering rod can sustain the load or Harmonic frequency of the body.

Use modal analysis to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed.

It also can be a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

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*****  INDEX OF DATA SETS ON RESULTS FILE  *****

 SET   TIME/FREQ    LOAD STEP   SUBSTEP  CUMULATIVE
   1  4.8258           1          1          1
   2  5.7182           1          2          2
   3  6.4204           1          3          3
   4  7.7571           1          4          4
   5  39.660           1          5          5
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- In First Mode of Vibration

Maximum deformation of 1.61793 mm is obtained in this mode in the male shaft as shown in Fig. at the frequency value of 4.8251 Hz. The deformation is negligible in this mode.

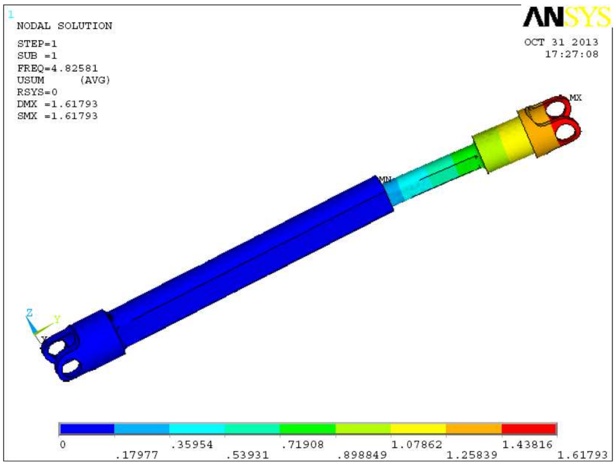

Figure 7. Behaviour of rod in First Frequency set

- In Third mode of vibration

The frequency value is increasing with slight increment in deflection. This will affect the performance of steering rod and its twisting. The values obtained in this mode are 6.42035 Hz frequency with 1.25014 mm deflection.

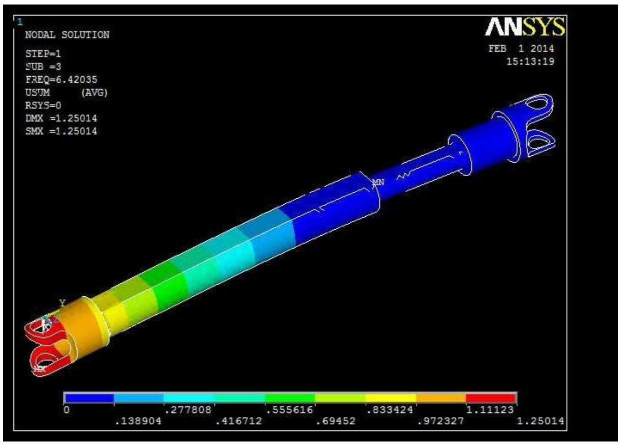

Figure 8. Behaviour of rod in Third Frequency set

- In Fifth Mode of Vibration

Here the maximum frequency with maximum deformation is shown in Fig 2.2. Above this frequency value shaft may damage due to maximum deformation. The maximum deformation of 2.20442 mm is obtained on frequency value of 39.66 Hz.

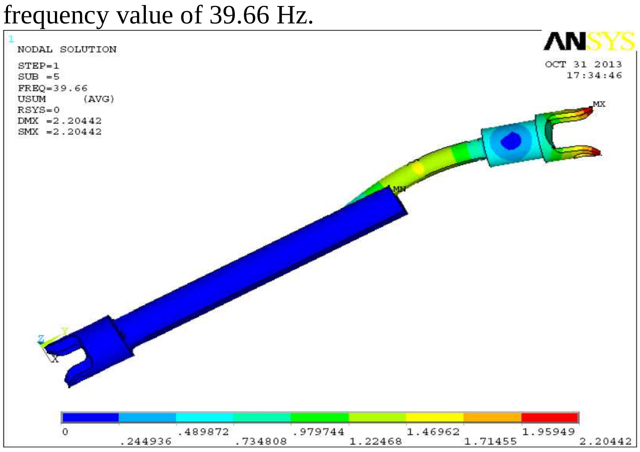

Figure 9. Behaviour of rod in Fifth Frequency set

V. CONCLUSIONS:

In this structural analysis is done to find the maximum deformation of the steering rod and stresses in the steering rod and it is noted that the deformation is negligible and the stresses by von-mises stress are below the yield point stress so the steering rod is safe.

Maximum deformation occurs at the corner points of the circular hole at both the ends of the rod and the stresses are also maximum at the corner points.

Modal analysis is done to calculate the Harmonic Frequency of the rod. The frequencies of the rod are calculated in five sets. In all five stages behaviour of the rod is different i.e. it varies from 1Hz to 39.66Hz. From this it is clear that Harmonic frequency is 39.66Hz. Further this frequency can be used to do the Harmonic analysis of the steering rod and for Optimisation.

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