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Design and Optimization of Steering Rack using CAE Tool

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Abstract: This paper deals with the optimization analysis of Steering Rack. Steering Rack Bending CAE analysis technology is indispensable for developing and mass-producing the Steering Gear assembly. By using Finite Element method, a stress analysis has been carried out. Steering Rack Deflection and Bending stresses are found. Various CAE iterations shows rack weight reduction by keeping Stress constant. Modeling has been done by Creo 1.0 and Analysis has been done by Creo Simulation.

Keywords: CAE, Optimization, Steering Rack, Stress analysis.

Introduction

Recent trends in automobile development activities for reduction of lead time and cost have lead to a current situation where CAE (Computer Aided Engineering) techniques are fully used to skip conventional development steps for making and checking costly prototypes [1]. The Steering System used predominantly in passenger cars today is the Rack and pinion type [2]. Hunor Erdelyi, Doru Talaba and Florin Gibracia presented a virtual prototyping approach by using a one degree haptic system, makes it possible for the customer to test the virtual prototype of the steering unit in a direct and natural way, in early design phase [3].

Y. Kubota presented a comparison of CAE analysis results and Testing results for the Steering Column Assembly [4]. M.Segawa and M. Higashi shows that characteristics of the steering system can be evaluated properly using HIL simulator [5]. T. Kobayashi and H. Shibata made an attempt to design a Rack and Pinion with specifications minimizing swing torque, and then a trial Rack and pinion Product was prepared and evaluated [6]. Naresh Kamble, SK Saha and Rajesh Priyadarshi worked on virtual prototype of Rack and pinion Steering Gear which was made in ADAMS (Automatic Dynamic Analysis of mechanical Systems).This model helped to identify critical parameter which affects the free pinion Torque of Gear Assembly [7].

Bentzion Pliacekos, Antonio Carlos and B. Guimaraes Neto worked on Design Improvement of an Automotive Rack Housing [8]. A number of Analysis has been performed on virtual prototype of Steering Gear Assembly. But Static Rack Bending Analysis of Steering Gear Assembly has not been studied yet. Steering Rack is designed to sustain bending loads during vehicle running. The loads come from tire side and produce the bending loads on Steering Rack. Steering Rack Static Bending Analysis Optimization will be focused in this paper. Specifically, this paper will use a CAD model of Steering Rack Assembly to reduce weight of Rack by Keeping Maximum Stresses as constant. The objective of this work is to carry out Computer Aided design and optimization of Steering Rack. The CAD modeling is done in Creo 1.0 and Finite Element Analysis is done in Creo Simulation.

Rack Bending Stress and Deflection

Rack is subject to not only the Axial Loads but also the vertical Loading. The vertical Load causes the bending stress and if the Load is higher than critical load then it will lead to breakage. Considering the Vehicle Front Axle Weight of 6 kN. The Rack Vertical Load (W) comes on Rack End is Maximum 2 kN. The assembly is considered as cantilever beam. Pinion is fixed and then vertical Load is applied at the Rack End. Refer Fig. 1 for the Rack Assembly and Loading Conditions.

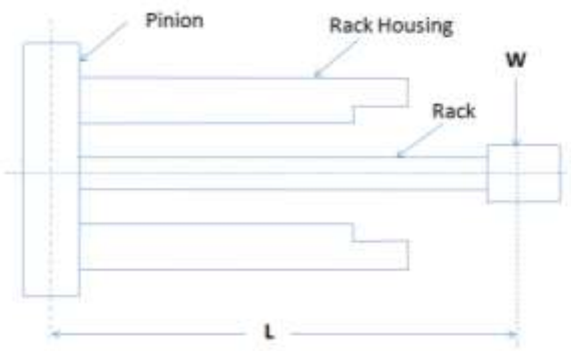

Fig. 1: Rack Assembly and Loading Conditions

Material Assignment

Rack material is considered as High Tensile Steel, as standard material AISI 4140. Mechanical properties of all the materials are in Table 1.

Table 1: Mechanical properties

S.No.	Part Name	Material Selected	Young's Modulus (GPa)	Poiss on's Ratio	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Density (g/cm^3)
1	Rack	Steel	210	0.3	930	770	17	7.8
2	Pinion	Steel	210	0.3	930	770	17	7.8
3	Tube	Steel	210	0.3	400	250	23	7.8
4	Housing	Aluminum Alloy	73	0.33	310	150	3.5	2.79
5	Support Member	Aluminum Alloy	73	0.33	310	150	3.5	2.79

CAD Modeling

Finite Element Software will consider shapes, whatever is made in CAD model. The model of Steering Rack Assembly is prepared by using Creo 1.0 Software. The 3D model of Steering Rack Assembly is shown in Fig. 2

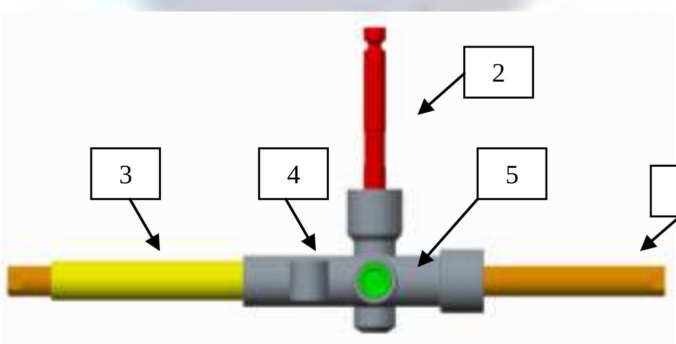

Fig. 2: 3D model of Steering Rack Assembly

Variable Parameter for Optimization

The Rack Gun Drill Hole Dimension changed from initial value of 10 mm to 290 mm .Fig. 3 shows the Rack view for gun drill length of 10mm and Fig. 4 shows the Rack view for gun drill length of 290mm.

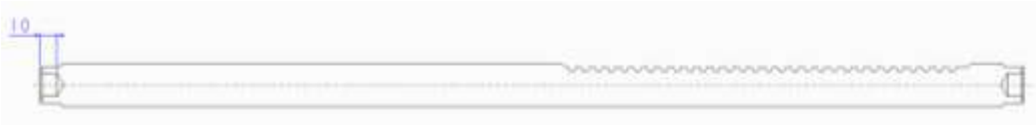

Fig. 3: Rack with Gun Drill Hole length of 10mm

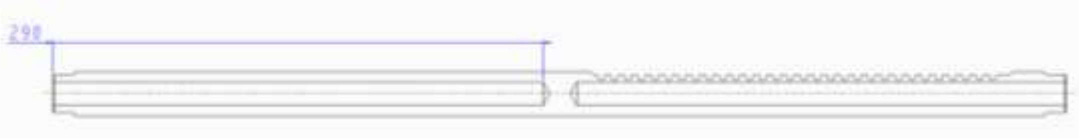

Fig. 4: Rack with Gun Drill Hole Length of 290mm

Finite Element Analysis

The Finite Element method (FEM) has developed into a key, indispensable technology in the modeling and simulation of advanced engineering systems in various fields like housing, transportation, manufacturing and communications and so on. The Steering Rack taken into consideration is having a Load carrying Capacity of 2kN.Steering Rack Static Bending Analysis is to be performed with Creo Simulation Software.Fig.5 shows the Meshing model, Fig.6 shows the Boundary Conditions and Application of Load, Fig. 7 shows the Deflection plot for Steering Rack, Fig. 8 shows the Stress plot for Steering Rack with Gun Drill Hole Length 10mm, Fig. 9 shows Stress Plot for Steering Rack with Gun Drill Hole length of 90mm and Fig. 10 shows Stress Plot for Steering Rack with Gun Drill Hole length of 290mm.

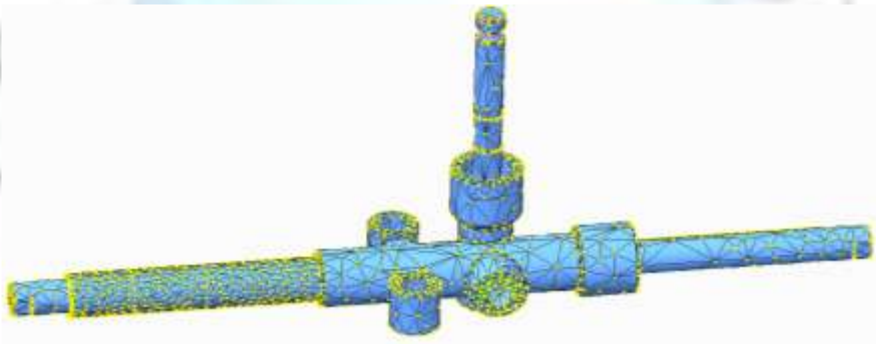

Fig. 5: Meshing Model

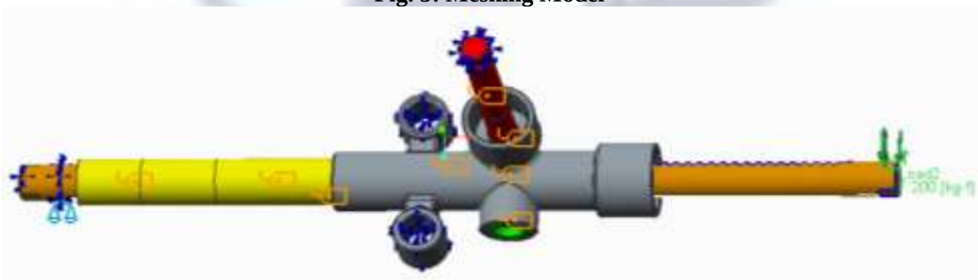

Fig. 6: Boundary Conditions and Application of Load

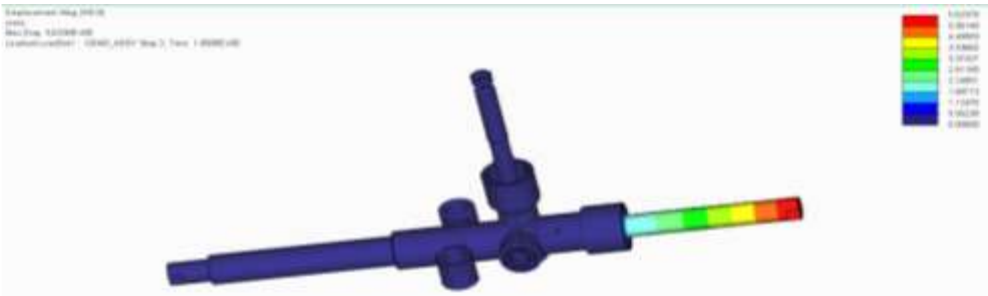

Fig. 7: Deflection plot for Steering Rack with Gun Drill Hole Length 10mm

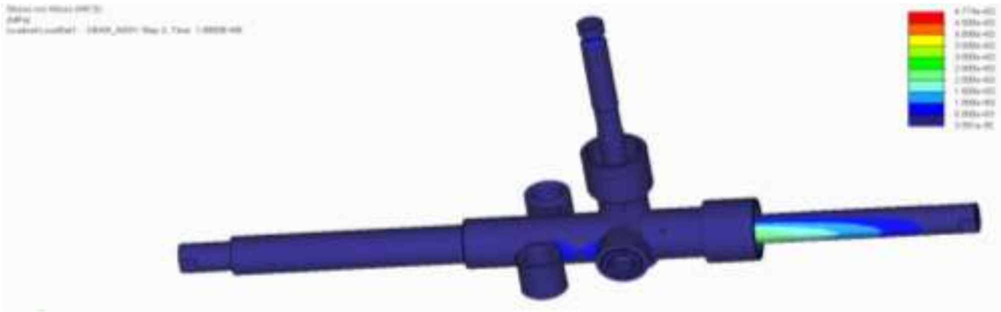

Fig. 8: Stress plot for Steering Rack with Gun Drill Hole Length 10mm

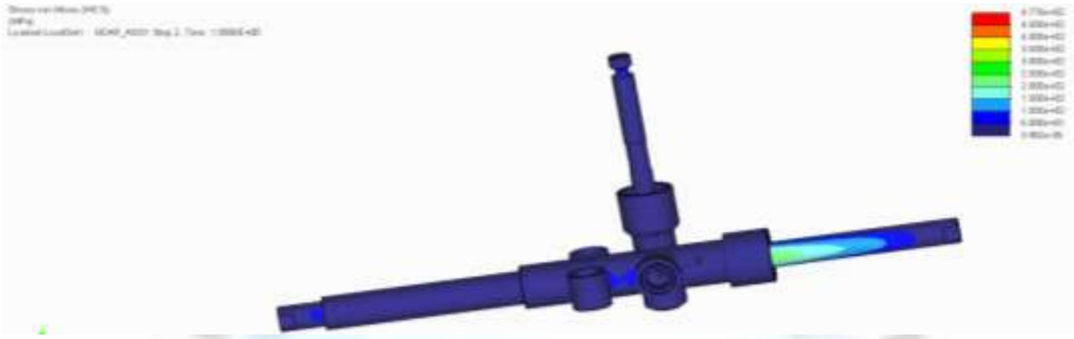

Fig. 9: Stress Plot for Steering Rack with Gun Drill Hole length of 90mm

Fig. 10: Stress Plot for Steering Rack with Gun Drill Hole length of 290mm

Results and Discussions

Steering Rack Static Bending Analysis completed. CAE results of Von-Mises Stresses with the Gun Drill Hole Length are compared in below Table 2.

Table 2: Comparative Analysis of Stress with Gun Drill Hole Length of Steering Rack at Load of Apply Load 2kN.

S.No.	Gun Drill Hole Length (mm)	Stress(MPa)	Rack Weight (Kg)
1	10	477.4	2.378
2	20	477.4	-
3	90	477.4	2.185
4	100	507.0	-
5	150	511.0	-
6	200	665.3	-
7	290	689.6	-

As after 90mm the Stress Value is increasing. So, by adopting the Hole Length in rack by 90mm instead of 10mm we get the same Stress.
Weight Reduction = 2.185-2.378=0.193kg.

Conclusions

The following conclusions can be drawn from analysis:

1. CAE technology is very helpful during the product development. It allows the application on the steering gear of the actual loads that came from the vehicle during operation. The results of this study showed the strength of steering rack in static condition.

2. The Maximum Von-Mises stresses in Rack are less than as compared to its Yield Strength as well as maximum Tensile Strength. The models presented here are safe and under permissible limit of stresses.

3. Checking of the need to make any design change (material, dimensional, etc) also can be performed before the prototyping. It reduces the costs and the time to market. Moreover, the Bending Strength of Rack is very critical point, can be measured even before the physical model manufacturing.

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