WEIGHT OPTIMIZATION OF STEERING RACK AND PINION BY USING DIFFERENT METAL FOR RACK WITH NEW IDEA OF COLD SHRINK FIT

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Abstract - *Rack and pinion type steering system is most common in automobile, each and every automobile industry try to reduce their vehicle weight to increase speed and performance and to reduce inertia losses and by using this idea we reduced weight significantly in a single part, it is observed that the present rack and pinion assembly contains single metal rack i.e. steel, so its weight can be reduced by using different metal in rack which heaviest in rack and pinion assembly, rack and pinion in steering system is used to convert rotary motion of steering wheel to translational motion of tie rod to turn the vehicle, in this patent rack is cold shrink fitted in rack rod for cold shrink fitting we have to cool rack to -196^{0}C in liquid nitrogen, then we have to fit it in rack rod and allow it to come at normal temperature.*

Key words: Rack and pinion, Steering system.

1. INTRODUCTION

The basic aim of steering system is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. 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. The components of a steering rack and pinion are as follows:

[1] Rack teeth
[2] Casing
[3] Rack rod
[4] Clevis
[5] Bushings
[6] Bearing
[7] Circlip
[8] Pinion
[9] Bellows

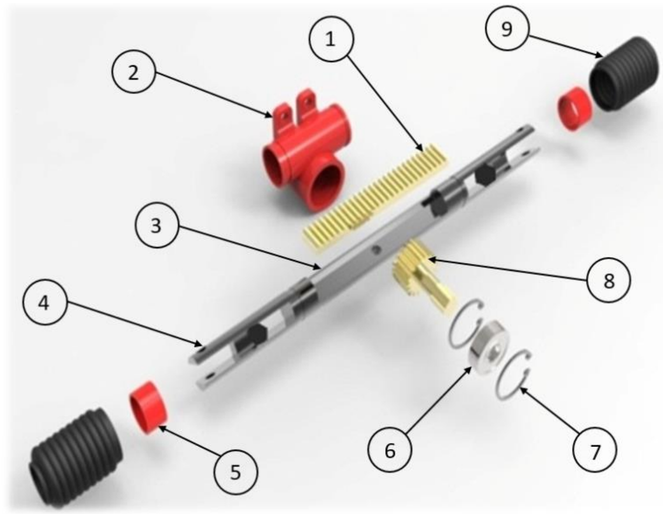

Fig -1: Assembly diagram of steering rack and pinion

The steering rack produces linear motion from an applied torque to the pinion. The pinion is supported by two bushings housed in the Mounting Block. The teeth on the pinion engage those on the rack which translates linearly between two bushings separately housed in the Mounting Block. The rack has extensions and clevises to reach the tie rods on the chassis which in turn rotate the wheel, thus steering the car. The pinion is designed to attach to a steering wheel so that the driver need not grip and turn the pinion directly, as they would be able to produce little torque.

2. DESIGN PARAMETERS

In automobile as the steering system directly governs good control and safety feature. While designing, the main objective is to transfer steering force without inefficiencies in mechanical linkages. As rack is designed with two different materials (composite), Material selection and cold shrink fitting are two major concerns.

The design methodology of composite rack is as follows.

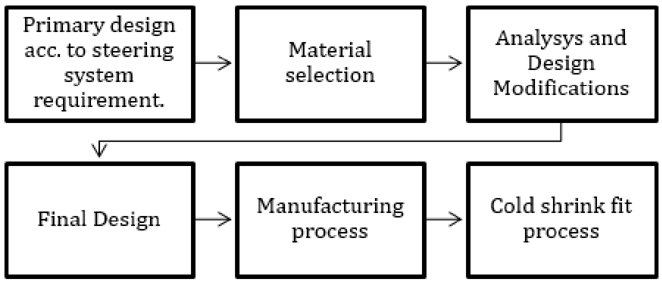

Fig -2: Methodology for design of Composite Rack

3. MODELING OF COMPOSITE RACK

Modeling of rack was done as per requirement of the steering system and assembly constraints.

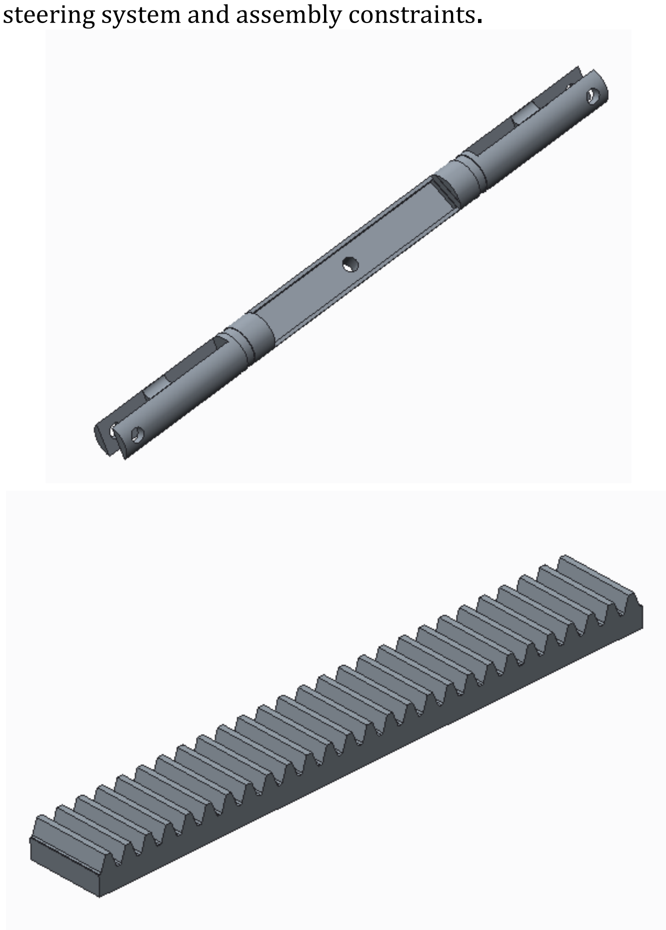

Fig -3: CAD model of Rack rod and Rack teeth

4. MATERIAL SELECTION OF RACK

To design steering system light weight without compromising systems strength and integrity steering rack is customized with two different materials. Materials selection is carried out by Ashby Method.

In the graph of tensile strength vs. Density the aluminum materials are only allowed because it is lightweight and higher grade of it gives us higher strength to sustain under loading. From different materials high grade aluminum 7075 T6 is finalized for the Rack rod. For the rack teeth EN24 (400BHN) is finalized as pinion is also made up of same material there will be less wear between these two mating parts.

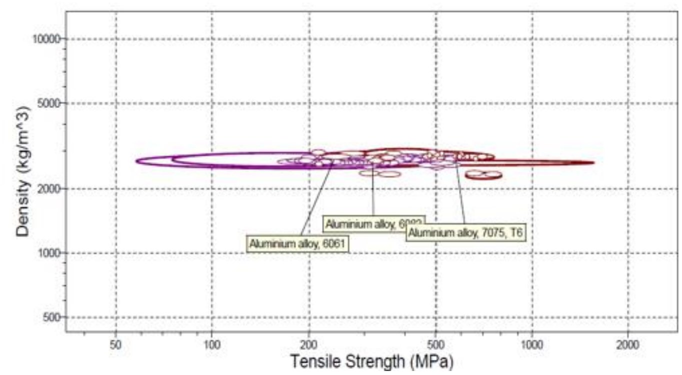

Figure-4: Ashby chart for material selection

5. DESIRED WEIGHT REDUCTION

[1] Weight of current rack assembly with complete EN 24 material: 585 gm
[2] Desired weight of rack rod (AL 7075 T6): 164 gm
[3] Desired weight of rack teeth (EN 24): 112 gm
[4] Desired weight of rack composite assembly: 276 gm

6. SHRINK FIT

Shrink-fitting is a technique in which an interference fit is achieved by a relative size change after assembly. This is usually achieved by cooling one component before assembly and allowing it to return to the ambient temperature after assembly, employing the phenomenon compression to make a joint. As the adjoined pieces reach the same temperature, the joint becomes strained and stronger. Shrink-fitting include compression shrink fitting, which uses a cryogen such as liquid nitrogen to cool the insert, and shape memory coupling, which is achieved by means of a phase transition.

[1]Cryogen liquid used: Liquid Nitrogen(-196^{0}C)
[2]Component cooled: Rack teeth (EN 24)
[3]Component at room temperature:
Rack rod (AL7075T6)
[4]Rack teeth part is to be kept excess 70micron material

7. FINITE ELEMENT ANALYSIS

After the numerical calculations all the parameters such as Rack rod diameter, No of teeth, mounting, etc. are decided and then the CAD modeling of the rack rod and rack teeth part was done using UG-Nx 8.5. This model was analyzed by applying the forces. Static structural analysis of the CAD model was carried out in ANSYS 15.0. Following material parameters were considered.

Table-1: Properties of Al 7075

No.	Parameter	Value
1	Density	2700 kg/m^3
2	Young's Modulus	72 GPa
3	Yield Tensile Strength	503 MPa
4	Ultimate Tensile Strength	590 MPa

Table-2: Properties of EN 24

No.	Parameter	Value
1	Density	7850 kg/m^3
2	Young's Modulus	205 GPa
3	Yield Tensile Strength	710 MPa
4	Ultimate Tensile Strength	1110 MPa

7.1 Meshing

The different mesh parameters like aspect ratio, skewness were considered to improve the mesh quality. Out of the different element types like hex dominant, sweep etc. tetra elements were considered as they capture the curvatures more accurately than in any other method. Proximity and curvature was used in order to ensure finer mesh along the curved regions and varying cross sections.

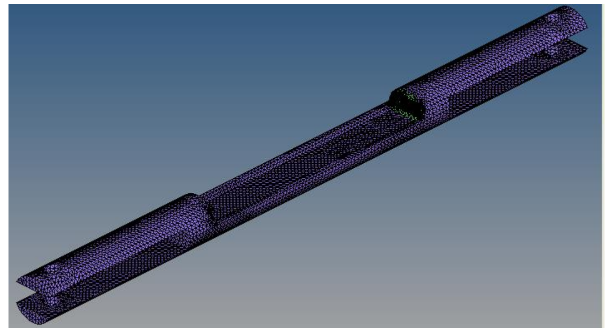

Figure-5: Meshed model of rack rod

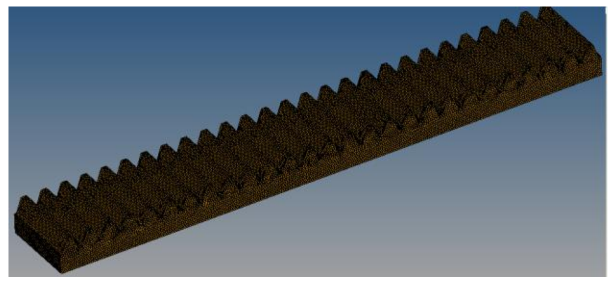

Figure-6: Meshed model of rack teeth

7.2 Load conditions

Rack rod is mainly subjected to tensile or compressive load
Rack teeth is mainly subjected to tangential load through pinion

7.3 Load Calculation

Rack teeth

Calculation for maximum tangential load on rack teeth

Maximum force can be applied by both hands on steering wheel(**E**): 280N

Considering

Couple on steering wheel = Moment on pinion

$$[\ E \times D_s = F_t \times R_p\ ]$$

D_s = Diameter of steering wheel
F_t = Tangential force on pinion
R_p = radius of pinion

Max. tangential load on rack teeth = F_t

Rack rod

Maximum tensile or compressive load on rack rod is equal to the maximum tangential load which will be transferred through rack teeth

8. RESULTS AND DISCUSSIONS

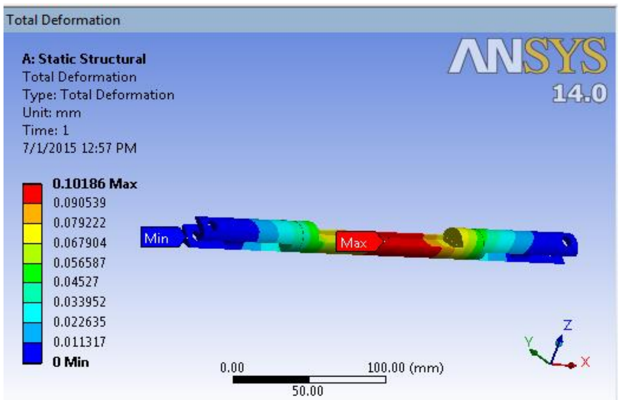

Figure-7: Total deformation of rack rod

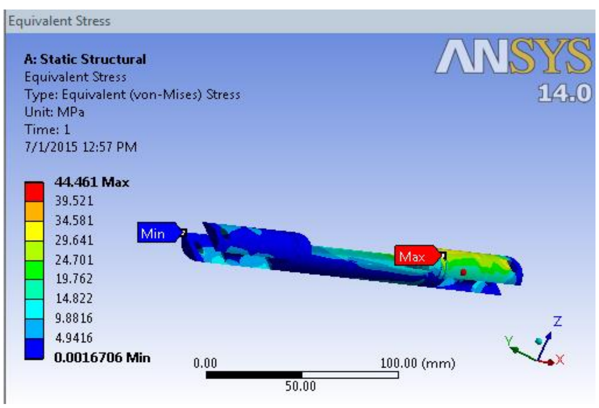

Figure-8: Equivalent stress (von-misses) of rack rod

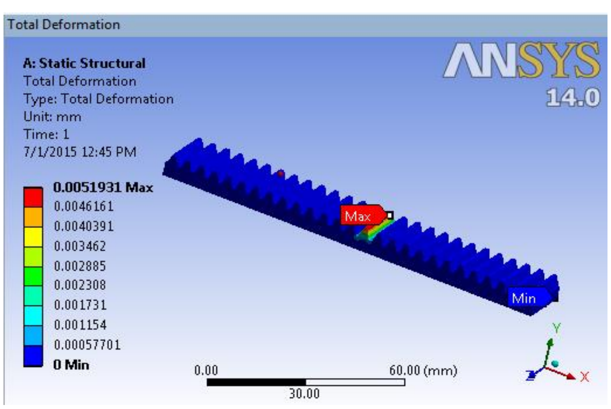

Figure-9: Total deformation of rack teeth

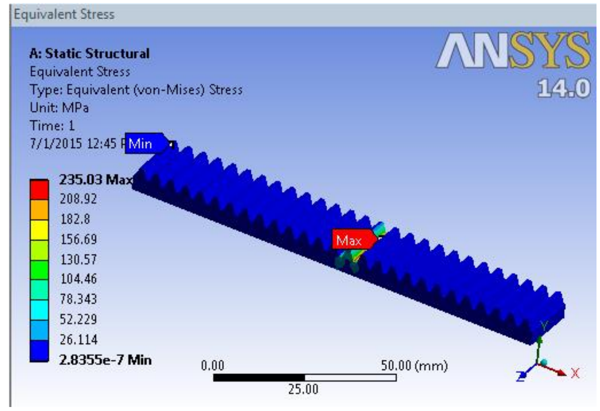

Figure-10: Equivalent stress (von-misses) of rack rod

Parameter	Rack rod	Rack teeth
δ_{max} mm	0.10	0.005
σ_{max} (MPa)	44.46	235.03
FOS	11	3

Table-3: Deformation & Stress variations

The stress results show that factor of safety for the designed model is within limits. The parameters decided could help in further lowering the manufacturing cost and weight.

9. CONCLUSION

The following comments could be concluded:-

[1]The main objective is to reduce weight steering rack and pinion.

[2] This idea for weight reduction using two different metal without hampering strength and it also maintains pitting strength of rack and pinion because both meshing parts are made up of steel.

[3] Cold shrink fit insures that both part will become single component without affecting function of rack and pinion assembly.

[4] Because of lightest assembly it reduces inertia losses and response of steering system become faster.

[5] The results obtained after analysis proves that composite rack for the steering rack and pinion assembly is safe to use.

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