Design and Analysis of Rack and Pinion Mechanism

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Abstract

The main of the project is to design and analyze the rack and pinion mechanism and to reduce the weight of the components to increase the efficiency of the rack and pinion mechanism. The project describes the design and material selection methodology of the rack and pinion mechanism. The design of rack and pinion mechanism in such a manner that it satisfies the maximum loading conditions. The rack and pinion mechanism designed in the solid works CAD software and analyzed in the ANSYS workbench. The main objective of this project is to design and analyze to reduce the weight of components.

Introduction

The advantages of high transmission efficiency, strong carrying capacity and the stability of the transmission ratio, the gear and rack transmission system is commonly used in force and motion transmission in the mechanical system. The reliability and stability of the gear and directly influences the regular operation of the mechanical equipment.

However, when the load changes with time, the dynamics and statics characteristics which the system represented are different. The three-dimensional model of the gear and rack transmission system was built by the 3D design software solidworks and the structural analysis was done in ANSYS workbench in order to identify the factor of safety of respective materials.

In this paper we have designed a rack and pinion mechanism and analyzed the rack and pinion mechanism to reduce the weight of the components.

Problem formation

In this Project, we have designed rack and pinion mechanism which consists following parts

(1) Rack

(2) Pinion

(3) Rack and pinion cup

(4) Casing

So currently automobile industry is using the metal gears in the automobiles. So here, we are going to design and change the material to Nylon of the rack and pinion components.

Advantages for changing the material from metal to nylon are

- Corrosion free
- Weight reduction as compared to metal casing
- No usage of external lubrications
- Noise reduction

Design dimensions of rack and pinion

Rack travel = 5”

Rack shaft length = 16.66”

Module = 1.75

Teeth on pinion = 31

Teeth on rack = 32

Diameter of pinion = 54.5mm

Steering wheel lock to lock turns or angle = 0.9 turns or 324 degree

Steering ratio 4:1 (Approx)

Ackermann arm length = 3.8”

Total king pin torque = 21.97 N m

Force on tie rods = 227.62 N

Torque on steering wheel = 5.975 N m

From the above dimensions we have designed the rack and pinion components that includes rack, pinion, casing of rack and pinion and casing cup.

Figure 1. CAD model of Rack Gear

It is flat gear which is parallel to the front axle that moves left or right when the steering wheel is turned.

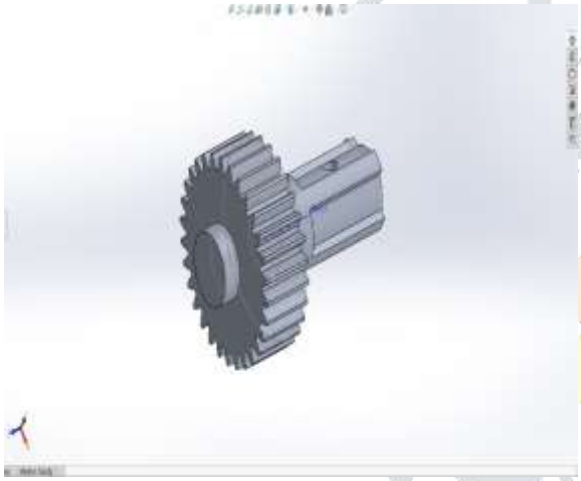

Figure 2. CAD model of Pinion gear.

It is a small gear pinion that which connected at the end of vehicle's steering column that which engages with the rack gear.

Figure 3. CAD model of casing cup.

It is casing cup that which attached to casing.

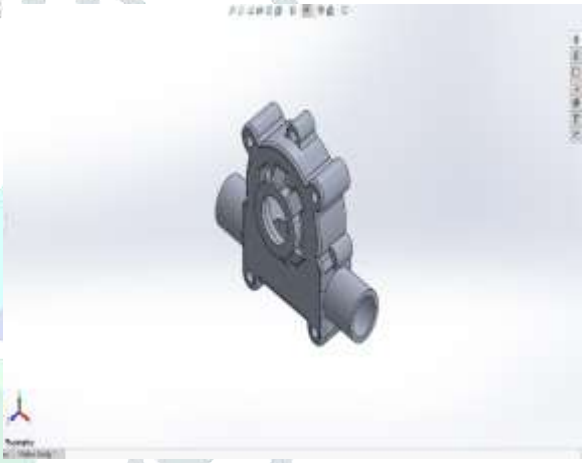

Figure 4. CAD model of casing.

It is the casing of rack and pinion mechanism that which encloses the rack and pinion engagement.

Figure 5. CAD model assembly of rack and pinion gear

It is the assembly of rack and pinion mechanism in which rack engages with pinion to convert rotational motion to linear motion.

Methodology and Material Selection

In this project our main is to change the material of casing from metal to other material which is applicable to 3d printing process to reduce the weight of casing.

The materials which are using in the fused filament fabrication 3d printing process are:

- PLA – Polylactic acid
- ABS- Acrylonitrile Butadiene Styrene
- PET- Polyethylene terephthalate
- NYLON
- TPU- Thermoplastic polyurethane
- PC- Polycarbonate

Choosing the right type of material to print a given object is becoming increasingly difficult, as the 3D printing market sees the regular emergence of radically new materials. In this project we are going to focus on pure polymers that exist in the market today: PLA, ABS, PET, Nylon, TPU and PC.

By comparing all the properties of the material, we have chosen the best material for our project, while comparing the materials we have taken the following properties into consideration, that are post processing, layer adhesion, impact resistance, elongation at break and max stress.

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Material	Post-processing	Layer adhesion	Impact resistance	Elongation at break	Max Stress
ABS	yes	2	3	1	3
PET	yes	3	3	1	3
NYLON	yes	1	4	3	2
TPU	no	3	5	5	2
PLA	yes	4	1	1	4
PC	yes	3	3	3	5

Table:1 Comparison of materials through grading

Each material has been ranked along the following criteria on a 1 (low) to 5 (high) scale. These are relative grades for the FDM process - they would look quite different if other manufacturing technologies were taken into account.

After comparing of the above materials we have chosen the NYLON which have good impact resistance and elongation at break and which is applicable to post processing.

FEM ANALYSIS

Finite Element Analysis was performed on many of the critical components in the modified steering system. This analysis was performed in ANSYS workbench. This software package is a very basic solver that automatically applies a 3D tetrahedral mesh to the part. Apart from the mesh only few parameters are required by the software as input for the analysis. The deflection characteristics were analyzed for casing component under maximum expected loading conditions. The analysis for rack and pinion mechanism is shown below.

For Nylon

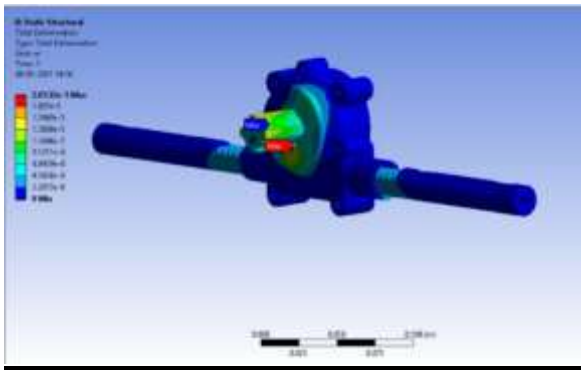

Figure 6: Total deformation using nylon

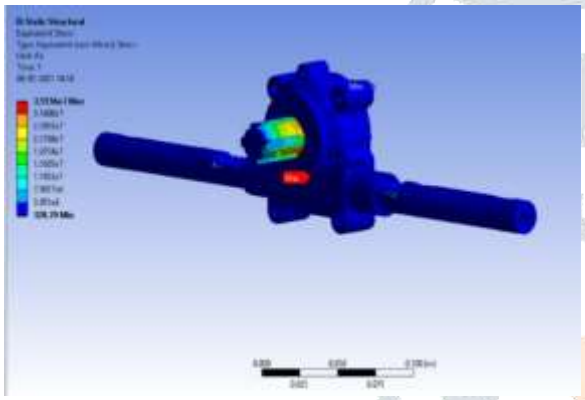

Figure 7: Equivalent stress using nylon

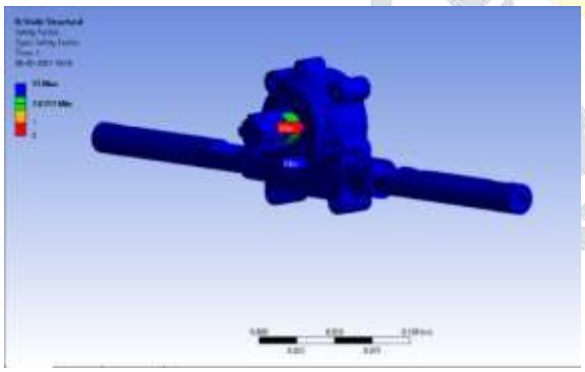

Figure 8: factor of safety using nylon

For steel

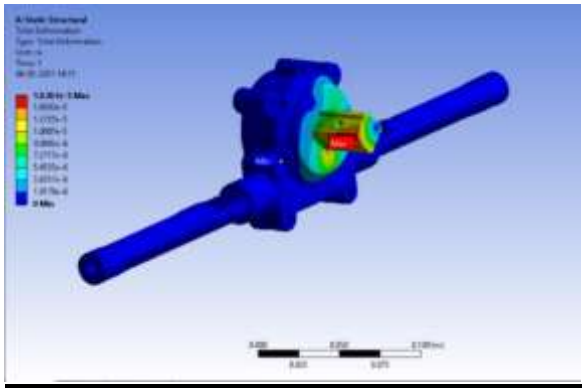

Figure 9: Total deformation using steel.

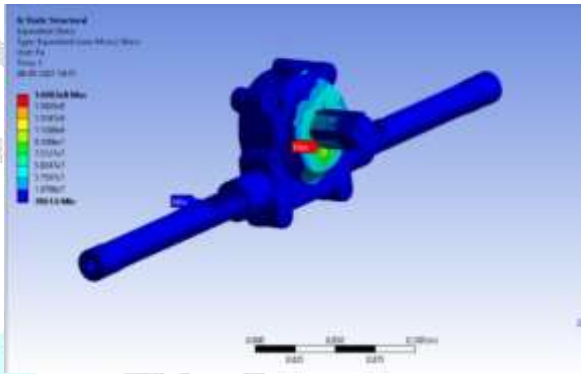

Figure 10: Equivalent stress using steel

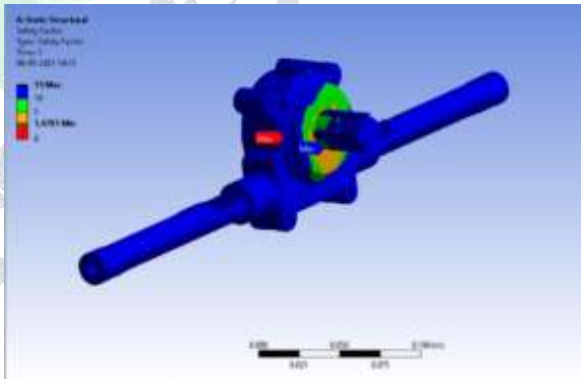

Figure 11: Factor of safety using steel

CONCLUSION

By considering various parameters we have designed and analyzed the rack and pinion mechanism. After the analysing the rack and pinion mechanism using different materials nylon and steel and we got the factor of safety 7.03 and 1.4 respectively. So from this we can say that the two materials are sustained. Among those materials we have chosen nylon as a primary material to reduce the weight

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