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Design and Development of All Wheel Nut Remover For Automotive

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Abstract

Tire plays a significant role in the performance of car. Removal of tire is a really a difficult task. In order to facilitate easy removal of tire a simple tool with pitch circle diameter (PCD) of 114.3mm has been designed. 3D modeling of the product in CATIA V5R20 help to design the product. The aim of the project is to design and developed five in one (5 in 1) motorized nut remover, the tool will help to remove all the 5 nuts simultaneously also the time required for removing nuts will be reduced. Finite simulation is carried out using ANSYS Workbench 14.0 for stress analysis. The tool designed is easy to store as well as handy as compared to previous designed available.

Keywords: All Wheel Nut Remover, ANSYS Workbench, Gear design, automotive tool kit

Terminology

D	Diameter of gear (mm)	σ_b	Permissible bending stress
d	Diameter of pinion (mm)	E	Young's Modules
G	Gear Ratio	Y	Lewis form factor
Φ	20˚ Pressure Angle	f_b	Beam strength
Z_g	Number of teeth on gear	K_a	Service Factor
Z_p	Number of teeth on pinion	K_m	Load Distribution Factor
M	Module	K_v	Velocity Factor
b	Face width (mm)	V	Pitch line Velocity (m/s)
S_{ut}	Ultimate tensile strength (N/mm^2)	FOS	Factor of Safety
S_{yt}	Yield strength (N/mm^2)		

Introduction

Automobile is one of the most fascinating devices that a person can own. The history of automobile reflects an evolution that took place worldwide. Any new invention in this industry proves to be the symbol of victory. Cars have now become need and it is no more the symbol of luxury. But replacing a punctured tire has always been a difficult task. Every car manufacturer provides tools such as L wrench and jack. But removal of tire using these tools requires a skilled person. Though, technology advancement has made it possible to fit the tire using air gun with high torque. Yet it is not handy. Using the air gun it is possible to remove one nut at a time. The problems faced are longer time consumption and increased labor work. Therefore it is crucial to have a tool that can remove all nuts in a single attempt. Design of four wheel nut remover is available. But with slight modification a five wheel nut remover will be produced using computer based approach of design and manufacturing. Utmost focus has been given designing the product using CATIA V5R20, as shown in Figure 1.

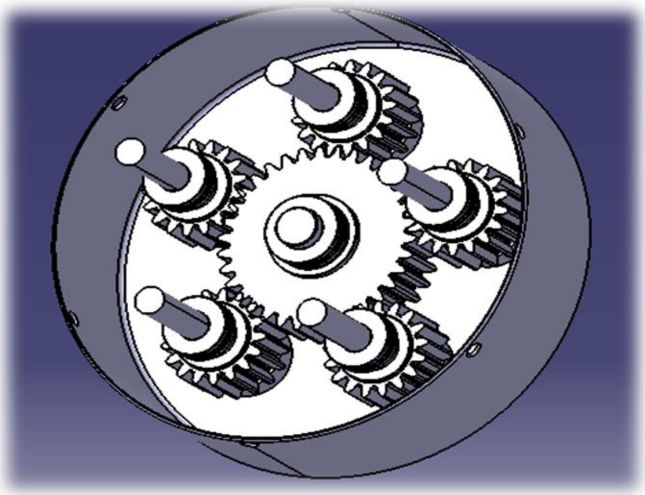

Figure 1: 5 in 1 Nut Remover conceptual Design

While designing it is taken into consideration that the tool is economical. In this study we will carry out improvement in previous design of 4 in 1 nut remover into 5 in 1 nut remover. This tool is expected to remove five nuts at a time with less torque and improved efficiency as compared to the previous design. The purpose of the design is to develop a tool which facilitates easy removal, easy storage, easy handling with minimum time consumption. The objective of the project is to create a 5 in 1 nut remover with Pitch circle Diameter (PCD) 114.3mm with assistance of CAD, CAM and CNC. It will help the car owner to overcome the difficulty of tire replacement. All the cars having PCD 114.3 mm can use this tool. Torque required to remove single nut is around 85-95 N-m. Therefore torque required to remove 5 nuts is 475N-m.

Methodology

As the nut remover was to be designed for 114.3 PCD the calculations for the gears were performed using the equations. Factor of Safety (FOS) of the design was checked. Later the product was designed in CAD.

Product design

The project started with product design, for the design CATIA V5 R20 was used. Parametric modeling of spur gears was done in CATIA V5 R20. The parameters used for design of spur gear were no. of teeth and module.

Design parameters

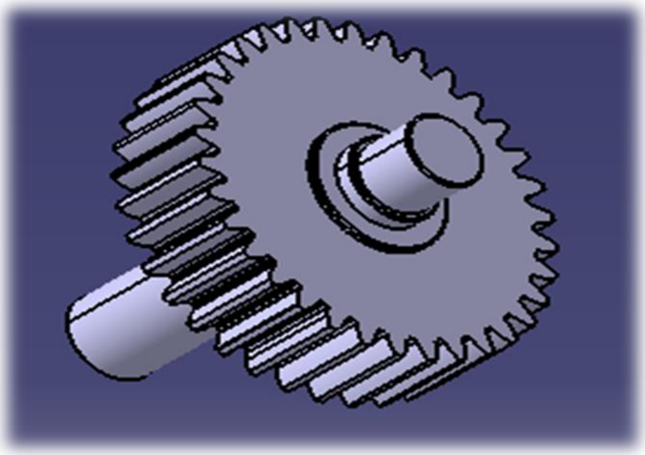

Figure 2: Designed Gear

Table 1: Basic parameters

Parameters	symbol	Value, unit
Central gear no. of teeth	Zg	34
Driven gear no. of teeth	Zp	17

Gear transmission was the important aspect of the entire design even a slight failure of gears will disrupt the entire system. For the proper design of gears one need to know about the stresses acting on gear, tooth engagement meshing etc. therefore it is essential to simulate the gears using DMU kinematics and find tooth engagement efficiency.

Design Calculations

The product was to be designed for 114.3 PCD, so the center distance between gears had to be 57.15 mm. The torque required for removal of one nut is 90 N-m. The entire gears are epicyclic. Spur gear was selected for design because they are easy to design and manufacture. A part from this the velocity ratio in spur gear is constant. Keeping the above factors in mind and selecting 080M40 for Gear and pinion design calculations were performed and the values obtained were as follow Consider,

Pitch Circle Diameter for Gear = D = 76.3 mm
Pitch Circle Diameter for Pinion = d = 38 mm
Pressure Angle (Φ) =20°
Gear Ratio (G) = PCD of Gear/ PCD of pinion = 76.3 / 38 = 2.00
By using Gear Ratio, $Zg = G \times Zp$

Table 2: Number of teeth

Zp	16	17
Zg	32	34

Zp= 17 and Zg = 34 are selected because both the values are present in Lewis form factor table.

Module (m) = D/Zg = 76.3/34 = 2.25 mm.
Face width (b) [4] = 10 m
= 22.5mm

Table 3: Gear And Pinion Parameters Values

Parameters	Gear	Pinion
Teeth	34	17
PCD (mm)	76.3	38
Module (mm)	2.25	2.25
Addendum (mm)	2.25	2.25
Dedendum (mm)	3.125	3.125
Tooth Thickness (mm)	3.93	3.93

Material: EN8/ 080M40

Table 4: Chemical Composition of EN8/080M40

	C	Mn	Si	P	S
Min	0.35	0.60	0.05	0.015	0.015
Max	0.45	1.00	0.35	0.06	0.6

Mechanical Properties [6]

Ultimate tensile strength (Sut)= 550 N/mm^2
Yield strength (Syt) = 280 N/mm^2
Young's Modules (E) = 200000 N/mm^2
Poisson's Ratio = 0.3
BHN=255 HB

Permissible bending stress - (Same material is used for pinion & Gear)

For Gear
σ_{bG} = (1/3) Sut
= 550 /3
= 183.33 N/mm^2

For Pinion
σ_{bP} = (1/3) Sut
= 550 / 3
= 183.33N/mm^2

Lewis form Factor (Y)

Table 5: Lewis form factor standard values [4]

Z	14.5˚ Full depth	20˚ Full depth
17	0.2639	0.3016
34	0.3267	0.3707

$$\sigma_{bp} \times Yp < \sigma_{bg} \times Yg$$

Therefore, pinion is weaker in bending than gear.

Beam Strength

$$f_b = m \times b \times \sigma_b \times y = 2861.37 \text{ N}$$

When pinion and gear are made up of same material then at that time pinion is weaker than gear in bending, so we have to find out F_{eff} for calculating factor of safety.

Effective load for Precise Estimation

F_{eff} = (Ka × Km × Ft) / Kv
As, Ka=1.25 for moderate shock & precise gearing
Km=1.2 face width upto 50 mm
V= 22m/s for fine hobbing process
As torque required for removal of 5 nuts is 475N-m

N= 200 rpm (Pneumatic motor with rpm 200)
Therefore,
$P = (2\times\pi\times N\times T)/60 = (2\times3.14\times200\times475)/60 = 10\times10^3$ W
$Ft = P/V = 10\times10^3/22 = 454.54$ tangential force
$Kv = 5.6/(5.6+\sqrt{V}) = 0.5441$
$F_{eff} = (Ka \times Km \times Ft) / Kv = (1.25\times1.2\times454.54) / 0.5441 = 1253.096$ N

Calculation for available Factor of Safety

1 < FOS < 1.25	Uniform load without Shock
1.25 < FOS < 1.5	Medium Start, Frequent Starts
1.5 < FOS < 1.75	Moderately heavy shock
1.75 < FOS < 2	Heavy shock

$$F_b = FOS \times F_{eff}$$
$$FOS = 2.28$$
$$\text{As, } FOS = 2.28 > 1.5$$

As the Available FOS of Gear pair is higher than that of required factor of safety, the design of gear pair is safe.

Product Assembly
All the gears were assembled together within the assembly design workbench of CATIA V5 R20. Driver gears were mounted in between on the shaft and rest of the five gears were mounted encircling it so as to form a sun and planetary gear system. Exploded as well as assembled were captured. Simulation was done within DMU kinematics workbench so as to check the tooth engagement efficiency.

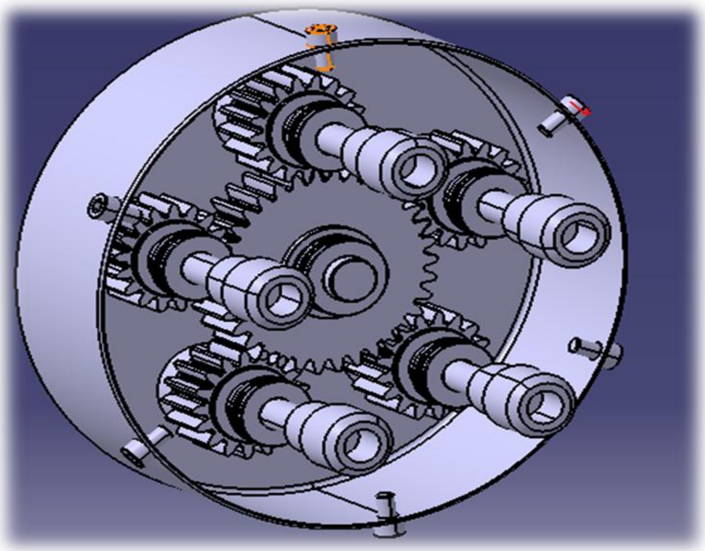

Figure 3: Product Assembly

Product casing

The product casing is used to cover the entire assembly. All the gears are mounted within the casing. The 3D model of the casing has been designed using CATIA V5R20.

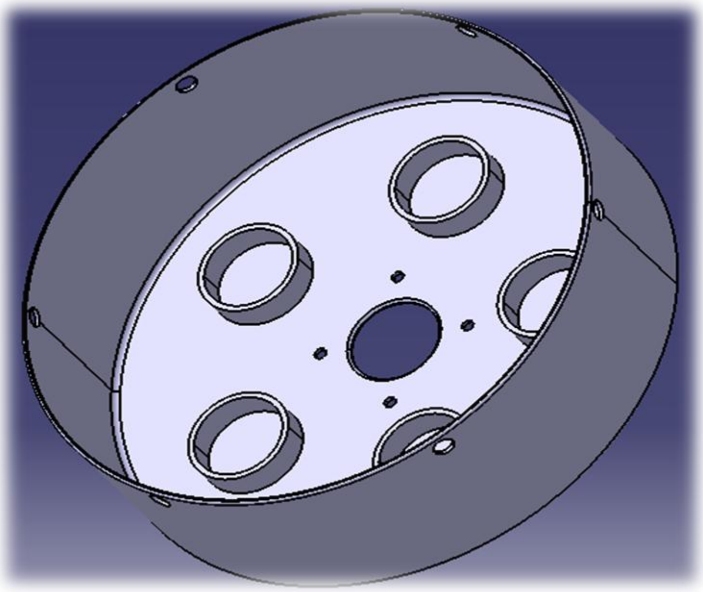

Figure 4: Product Casing

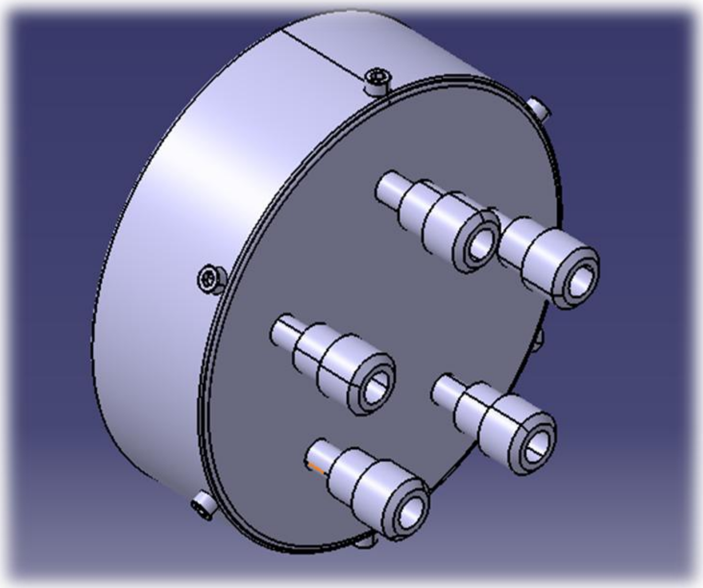

Figure 5: Assembly with Casing

Finite Element Simulation

All Wheel nut remover product assembly configurations are imported into ANSYS Workbench 14.0 for finite element analysis. Assembly casing are not considered for analysis. Finite element modeling of All Wheel Nut Remover is as shown in Figure 6.

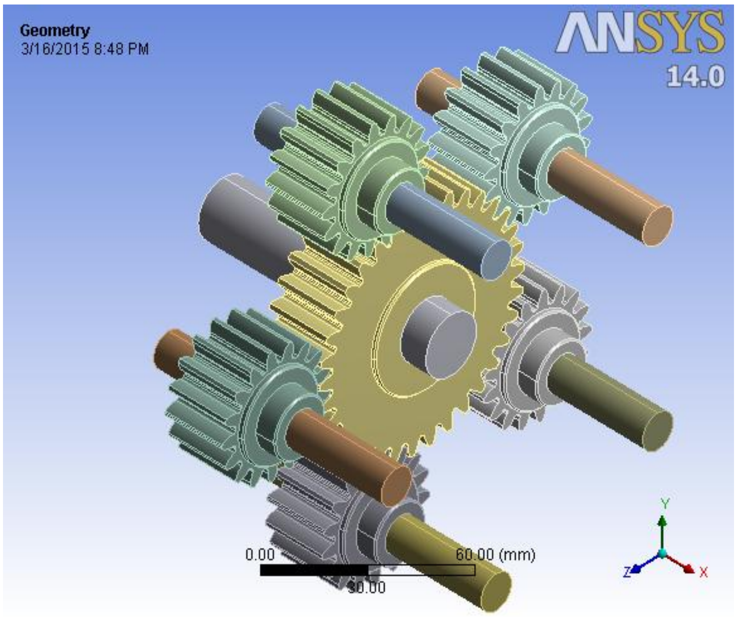

Figure 6: FE Modeling of All Wheel Nut Remover

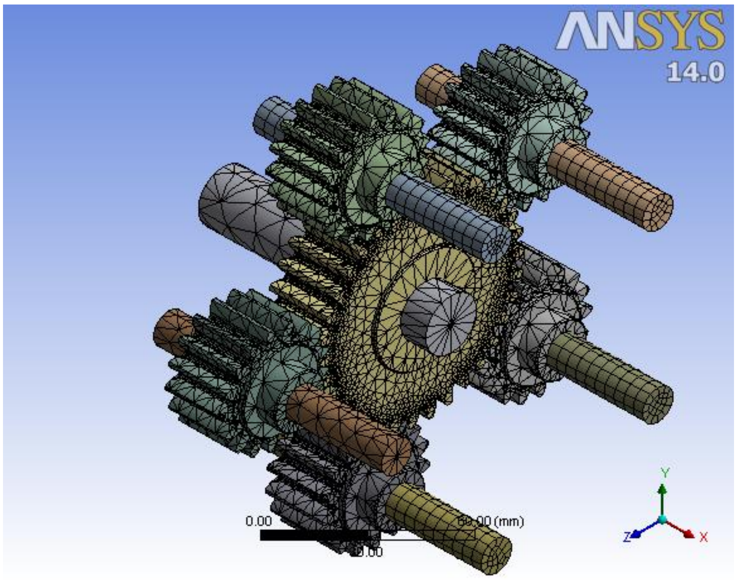

Figure 7: FE Meshing of All wheel nut remover

Static structural analysis is done using solid elements. All Nut remover assembly consists of 59686 solid elements. Meshing of assembly is shown in Figure 7. In boundary condition for assembly for successful FE analysis, revolute joints – ground are given to pinion and gear shafts. Bonded Contacts maintained between teeth of five pinions and main gear. In this, contact body is gear and target bodies are pinions. Frictionless supports are given to all pinions and gear shaft for simplicity of analysis. Moment of 475 N-m is applied to gear shaft for FE analysis purpose.

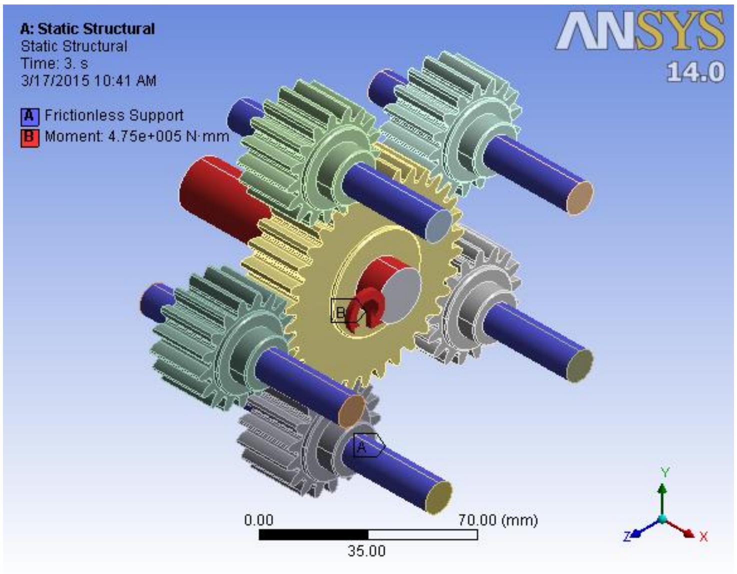

Figure 8: Boundary condition of all wheel nut remover

Stress and strains are main interest of our FE analysis. Finite element elastic stresses are calculated according to assumptions and design calculations. After FE structural analysis, Von-mises stress of 430. 77 MPa and Maximum Principal Stress of 352.55 MPa are observed with maximum displacements of 0.02014 mm.

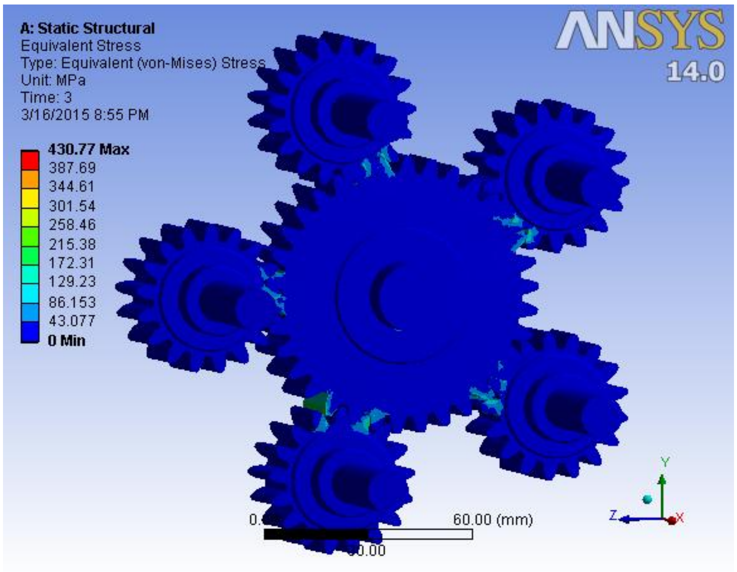

Figure 9: Von-Mises Stress of All wheel nut remover

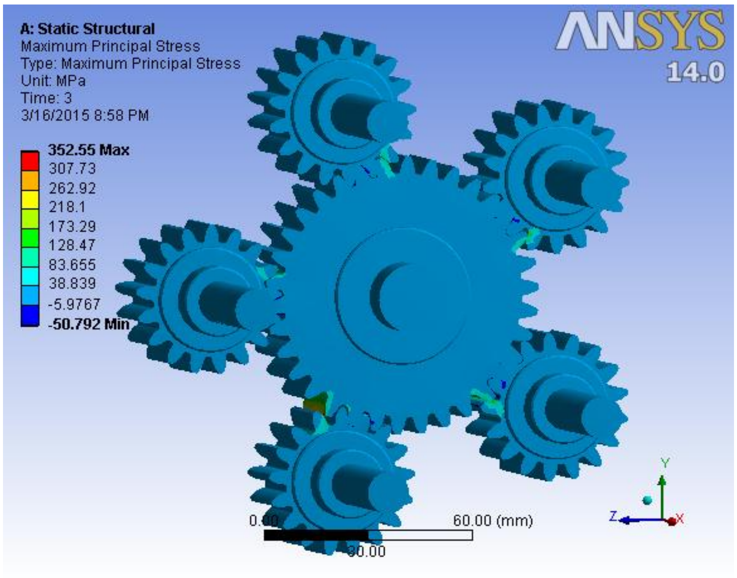

Figure 10: Maximum Principal Stress of all wheel nut remover

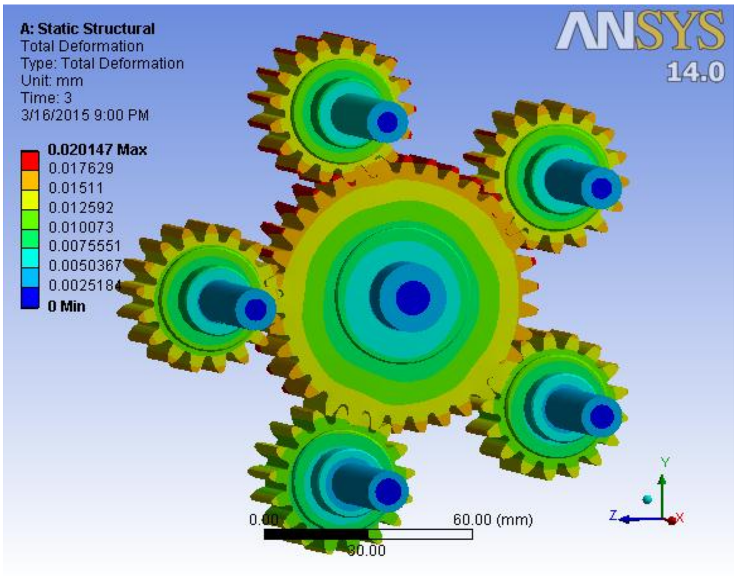

Figure 11: Maximum displacement of all wheel nut remover

Conclusion

5 in 1 nut remover with Pitch Circle Diameter (PCD) 114.3mm has been designed using CATIA V5R20. Selecting 080M40 material for Gear and pinion, design calculations were performed. With calculations, FOS of Gear pair is higher than that of design factor of safety; the design of gear pair is safe. For validation, finite element simulation is performed for better optimized results. In future, Product assembly will be manufacture and tested.

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