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Design and Modelling of 6 In 1 All – Nut Remover for Automobile Wheels

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Abstract: Automotive maintenance is one of the major parameter for keeping its life span. It includes mainly changed the punctured tire, has been always a difficult task. Every automotive manufacture provides tools such as L wrench and jack, but still using these tools requires skilled person. With the increment of the number of passenger cars on the road, the number of car's problem due to tire failure has increased. Often, the car is provided with tire wheel nuts remover and jack for instance spare tire replacement. Many passenger cars, SUV and heavy vehicles accessories manufacturer concentrates on producing wheel nut puller using a single tool to lose the nut one by one. Main problem they have still faced is longer time consumption and tedious work to do skilled worker. Therefore, it is crucial to have a tool that should be designed ergonomically, easy to handle, lightweight, requires small space and can perform a similar task in one time. In 2006, a tire nut removal with 114 pitch circle diameter has been developed to replace T-nut wrench. This tool can open four nuts in one time and the force utilization has been reduced. It will help the car owner to overcome the difficulty of tire replacement. Author already design, manufactured and tested, 5 in 1 nut remover with Pitch circle Diameter (PCD) 114.3mm with assistance of CATIA V5 and simulation by ANSYS 14.5. Testing also proved that all wheel nut removers could efficiently remove all nut simultaneously in 9 sec. All the cars having PCD 114.3 mm with five nuts can use this tool. This paper extending the previous worked done by author and focus on design, development and simulation work on six nuts wheel remover for automotive like Chevrolet Tavera, Land cruser, Fortuner, Pajero etc.

Keywords: Automotive, 6 in 1 All-wheel Nut, Remover, Gear Design, Modelling.

I. INTRODUCTION

An automobile is one of the most basic and fascinating things that one could own. Cars have now become a need and it is not only the symbol of luxury anymore. Car maintenance, for example, is one of the key factors in determining its life span. This includes a basic knowledge of changing the car's tyre. But replacing a punctured tyre has always been a difficult task. Every car manufacturer provides tools such as L wrench and jack but easy and fast removal of nuts using these tools requires a skilled person. Mohd Azman designed a remover as shown in Fig.1 in 2013 with 100 pitch circle diameter to replace L-shaped nut removers and jack which allows driver to remove all nuts at once with less energy consumption and save time. Several static load analyses were performed in order to find safety factor of design. Here, torque applied was reduced by 33% and also reduction in time taken is 53%. The fabrication of all wheel nut removers tool was completed by milling, welding and fitting process. With support, impact wrench was used of 5.5 HP air compressors [1]. In 2014, M. Mukhtar design and fabricated four in one (4 in 1) motorized tire nut puller for a car with 100 pitch circle diameter shown in Fig 2. This tool can dismantle four nuts simultaneously and power up by a car battery. With assistance in CAD, CAM, CNC and Rapid prototyping concurrently reduction of time in part assembly and optimum time in finished product was obtained. Several recommendations have given by author to improve this product in respect of use of polymers material for creating the product casing. The bracket holder diameter size should be made in adjustable type that can be used in various types of cars that have different PCD. Have a stopper to stop the movement of the gear. Have speed controller to control speed of the gear movement for an easier operation. Provide hammering mechanism that can give an impact on loosening the nuts [2].

In 2006, Azizul rahman b abd aziz developed nut removal with 114 pitch circle diameter to replace T-nut wrench that can reduce the force and torque needed to open the nuts and open all four nuts simultaneously. This tool can open four nuts in one time and the force of utilization has been reduced. This tool used mild steel as the main material to fabricate a gearing system and the gear ratio is 21.125 [3]. Amol Bhanage concluded 5 in 1 nut remover with Pitch Circle Diameter (PCD) 114.3 mm has been designed for 080M40 material for Gear and pinion. For validation, finite element simulation is performed for better optimized results. Fabrication of the tool performing various processes, after the overall design the tool was finally seen to meet all the design standards. The results of test proved that the all wheel nut remover could efficiently remove all the nuts simultaneously. Time required for nut removal effectively reduced upto 50% for pneumatic gun, and upto 70% for L wrench. Also, the tool is efficient and with some required modifications could be efficiently used in future [4].

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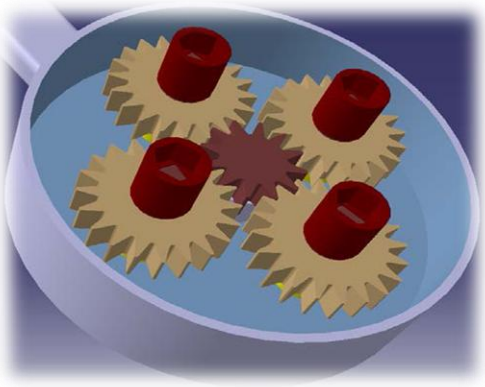

Fig.1. 4 in 1 nut remover

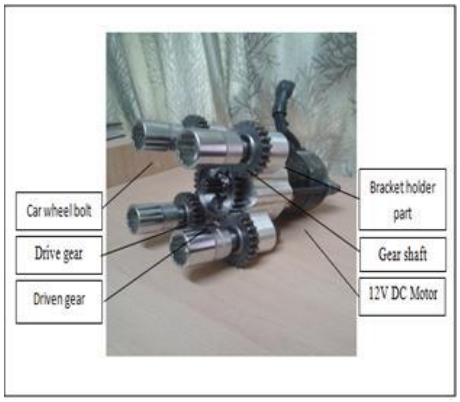

Fig. 2. Product Part Assembly

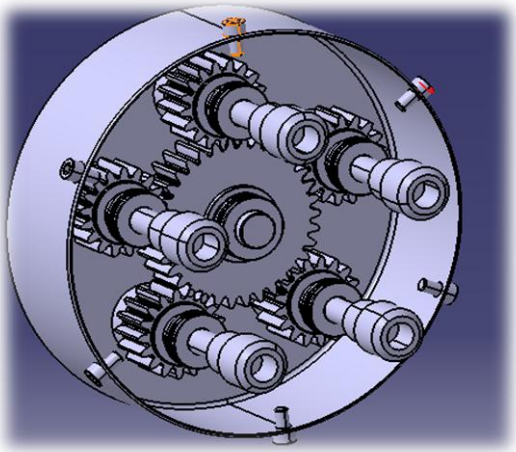

Fig.3. Model of a 5 in 1 nut remover

The tool used to remove the wheel nuts should be designed considering ergonomics, simplicity and compactness. The tool also functions as wheel nuts tightener. Though technological advancement has made it possible to fit the tyre using air gun with high torque, it is not handy enough. Also, using the air gun, only one nut can be removed at a time leading to longer time consumption and increased labour. Therefore, a tool that could remove all nuts in a single attempt is crucial. So, in order to avoid wastage of time and energy in changing the tyre, a special tool is designed and fabricated that allows a driver or mechanic to remove all nuts of a wheel at once with little energy consumption. This tool removes five nuts at a time with less torque and more efficiency compared to the other designs. The tool developed in this work is applicable for any car having a PCD of 114.3 mm. So, with a 2:1 ratio on its input/output rotation, theoretically, it will at least reduce the torque by three times. The epi-cyclic gearing used results in a compact design. The prototype built was used in a trial to show its compatibility for different sizes of wheel rim.

II. DESIGN METHODOLOGY

The calculations for the individual component parameters were performed using the standard design equations. Factor of Safety (FOS) of the design was checked and later the product was modelled using CATIA V5 R20.

A. Design of Gear and Pinion

The product was to be designed for 139.7 PCD, so the centre distance between gears had to be 69.85 mm. The torque required for removal of one nut is 120 N-m. Spur gears were selected due to ease in design and manufacturing. Apart 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 follows.

Initially consider,
Pitch Circle Diameter of Gear D = 90 mm
Pitch Circle Diameter of Pinion d = 54 mm
Pressure Angle Φ =20˚

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Gear Ratio G = 1.67

By using G, $Zg = G \times Zp$

Z_p = 18 and Z_g = 30 are selected from the Lewis form factor table.
Module m = 3 mm
Face width b = 30 mm

B. Properties of the Material - EN8 Carbon Steel
EN8 is an unalloyed medium carbon steel grade with reasonable tensile strength. It is widely used for applications which require better properties than mild steel but does not justify the costs of an alloy steel.

Ultimate tensile strength S_U = 550 N/mm^2
Yield strength S_Y = 280 N/mm^2
Young's Modules E = 200000 N/mm^2
Poisson's Ratio ν = 0.3
Brinell hardness = 255 HB

Permissible bending stress is same for both gear and pinion as the material used is same.
Now, for both gear and pinion,

$$\sigma_b = \frac{1}{3} S_U = 183.33\ N/mm^2$$

C. Beam Strength

The beam strength of both gear and pinion is given by,

$$f_b = m\ b\ \sigma_b\ y = 5075.30\ N$$

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.

D. Effective load
The effective load must be calculated for precise estimation.

$$F_{eff} = \frac{K_a K_m F_t}{K_v}$$, where,

For moderate shock and precise gearing, $K_a = 1.25$

For face width up to 50 mm, $K_m = 1.2$

For fine hobbing process, $V = 22\ m/s$.

Torque required for removal of 6 nuts is 720 N-m,

$N = 200\ rpm$ (Since, Pneumatic motor with rpm 200 is used)

Therefore,

$$P = \frac{2\pi NT}{60}$$

$$P = \frac{2 \times 3.141 \times 200 \times 475}{60}$$

$$P = 15.039 \times 10^3 W$$

Now, tangential force is given by,

$$F_t = \frac{P}{V} = \frac{10 \times 10^3}{22} = 685.43\ N$$

$$K_v = \frac{5.6}{\left(5.6 + \sqrt{V}\right)} = 0.5441$$

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Thus, the effective load is,

$$F_{eff} = \frac{(K_a K_m F_t)}{K_v}$$

$$= \frac{1.25 \times 1.2 \times 454.54}{0.5441}$$

$$F_{eff} = 1891.19\ N$$

E. Calculation for Available Factor of Safety (FOS)

$$F_b = FOS \times F_{eff}$$

$$FOS = \frac{5075.3}{1891.19}$$

$$FOS = 2.68$$

So, $FOS = 2.68 > 1.5$

As the Available FOS of Gear pair is higher than that of required factor of safety, the design of gear pair is safe. The final gear and pinion parameters are tabulated below.

TABLE I: FINAL DESIGN PARAMETERS

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

Parametric modelling of spur gears was done in CATIA V5 R20 and is shown below in Fig.4.

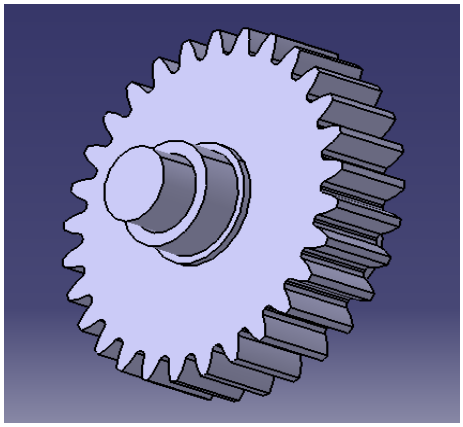

Fig.4. Gear modelled according to tabulated parameters

F. Design of Shaft

In actual practices, the shafts are subjected to shock and fatigue loading. Hence, in the design of shaft, the shock and fatigue is accounted by using the factors known as combined shock and fatigue factor. After performing the standard design calculations for design of shaft as prescribed in [8], the material selected is EN8 Carbon Steel and the final dimensions are,

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Diameter of input Gear shaft D = 10.076 mm. A diameter of 20 mm was selected for the provision of lug at the input end of the Gear Shaft. Diameter of output Pinion shaft d = 6.43 mm. A diameter of 12 mm was selected so that the square head for the mounting the lug can be made.

G. Design of Casing

The product casing is used to cover the entire assembly. All the gears are mounted within the casing. The casing was designed according to the standard design procedure mentioned in [9] and the final casing parameters are listed below.
Actual periphery of the assembly = 153 mm
Diameter of cover plate = 193 mm
Cover thickness (S_c) = 4 mm
Base thickness = 10 mm
Bolt Diameter (d_b) ≈ 6 mm
Therefore M6 bolt was selected.
Bolt spacing is 72° around the periphery.
Finally, the 3D model of the casing has been designed using CATIA V5 R20 according to the above dimensions.

III. 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 six 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.

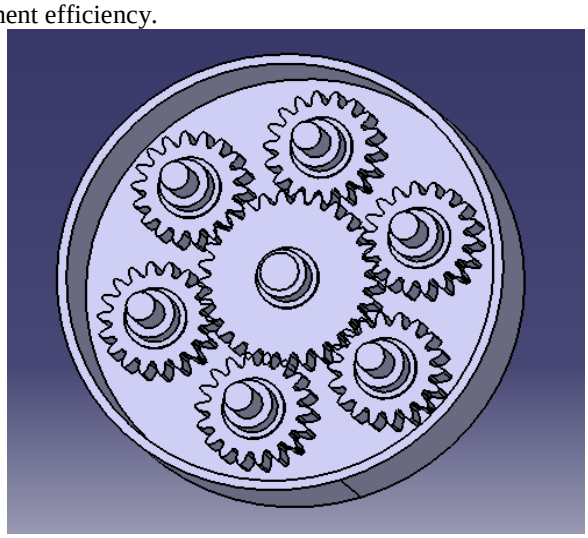

Fig.5. 6-1 Nut Remover Product Assembly

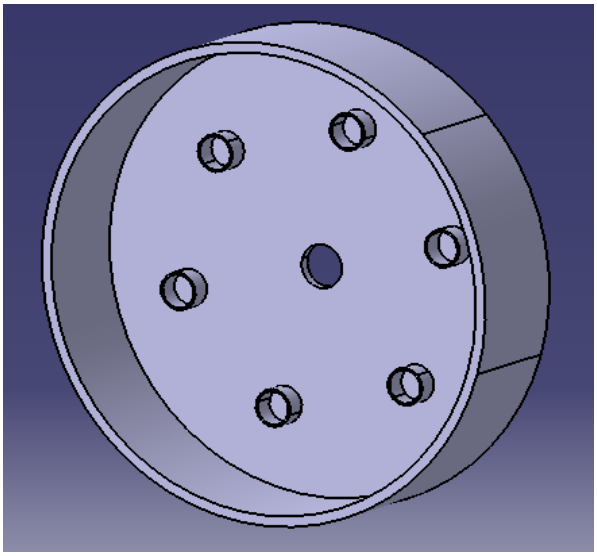

Fig.6. 6-1 Nut Remover Product Casing

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IV. TESTING

In order to analyse the efficiency of manufactured all-wheel nut remover, testing was performed using the various available nut remover tools such as Lug wrench, Pneumatic gun and all – wheel nut remover tool.

Procedure to be followed during testing

1. Firstly, the torque required for each nut using lug wrench will be tabulate using the torque measuring equipment. Now, the time taken for removal of all nuts using each of equipment will not down.
2. Then, the nuts are again re-tightening using all the tools mentioned tools and time required for the same was noted.
3. Finally, all the results were analysed and conclusion was drawn. The results of test proved that the all-wheel nut remover could efficiently remove all the nuts simultaneously. Also, the tool is efficient and with some required modifications could be efficiently used in future.

V. CONCLUSION

6 in 1 nut remover with Pitch Circle Diameter (PCD) 139.7mm has been successfully 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 will be performed for better optimized results. In future, Product assembly will be manufacture and tested.

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