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Design and Development of Multi Spindle Nut Remover

Neil Vinod Deore[1], Prof. B. A. Burkule[2], Piyush Shrikant Khardikar[3]
MVP Karmaveer Adv. Baburao Ganpatrao Thakare College of Engineering, Nashik, Maharashtra[1,3]
Guru Gobind Singh Polytechnic, Nashik, India[2]

Abstract: *Typically, the majority of Indian cars use four or five lug nuts to secure the wheels to the vehicle. The conventional method for replacing a car's wheel involves using a lug wrench to individually loosen the locking lug nuts. Yet, it may prove to be overly tiring and take up too much time. In response, we have created a tool equipped with a planetary gear mechanism. Our project has aimed at reducing the amount of human effort required. The primary goal of this work is to create a single tool capable of opening multiple nuts simultaneously through straightforward mechanisms, making it highly practical for use in assembling and dismantling automobile wheels..*

Keywords: Lug nuts, Lug Wrench, multiple nuts simultaneously

I. INTRODUCTION

Cars are now a necessity rather than a symbol of luxury. However, changing a flat tire has consistently been a challenging task. All automobile manufacturers supply tools like a jack and an L-shaped wrench. Although advancements in technology have enabled the use of high-torque air guns for fitting tires. Removing one nut at a time with the air gun is possible; however, it leads to higher labor effort and increased time consumption. The primary goal of this project is to automate the process of individually tightening or loading lug nuts. The focus of this project is to reduce human effort and time by securing all four or five wheel nuts in a single action. The solution to the aforementioned problem is a multi spindle nut remover, a specialized tool created to simplify the process of opening a wheel. It is built to simultaneously loosen all four or five nuts on a car wheel at once. The ultimate goal is to ensure that the entire process requires minimal effort and time. The tool allows for easy opening and refitting of the wheel. The tool features a straightforward design, is user-friendly, and can be conveniently transported with the vehicle.

II. DEFINITION OF TECHNOLOGY

The tool is designed with a focus on cost- effectiveness. This tool is designed to simultaneously remove five nuts with reduced torque and enhanced efficiency compared to traditional tools. The design aims to create a tool that allows for effortless removal, convenient storage, and easy handling while minimizing time consumption. The goal of the project is to develop a 4/5-in-1 nut remover utilizing CAD, CAM, and CNC technologies. It assists car owners in overcoming the challenges of replacing tires. This tool is compatible with all cars featuring a 100/114.3 mm PCD.

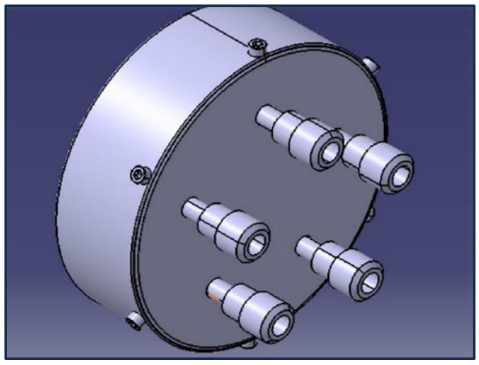

Fig: Final Assembly with Casing

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III. METHODOLOGY

Multi-spindle drilling machines are utilized in mass production, offering significant time savings when drilling multiple holes in numerous workpieces. Multi-spindle head machines are employed in the manufacturing industry to enhance the productivity of machining systems. Multiple spindle drilling machines are designed for production purposes. It is utilized to simultaneously drill multiple holes in a workpiece in a single setup. Holes are drilled into multiple workpieces with consistent accuracy. Thus, we have integrated its core concept into our project.

The gear calculations were carried out using the equations, as the multi-spindle nut remover is intended to be designed for a 114.3 PCD. The design's Factor of Safety (FOS) was evaluated. Subsequently, the product was created using CAD software. Gear transmission plays a crucial role in the overall design, as even minor gear failures can compromise the entire system's functionality. Proper gear design requires an understanding of the stresses on the gear, the meshing of tooth engagement, and the assessment of tooth engagement efficiency.

IV. ADVANTAGES OF TOOL

- It serves as an unconventional but straightforward approach to the wheel replacement process.
- Ideal for reducing time spent on wheel removal across all types of vehicles.
- Minimized labour efforts wasted on wheel replacement.
- This tool is user-friendly and can be operated by individuals of all ages, from the young to the elderly.

V. DESIGN CONSIDERATIONS

This tool is compatible with all cars that have a PCD of 114.3 mm. The product was intended for a 114.3 PCD, requiring a 57.15 mm center distance between the gears. The torque needed to loosen a single nut ranges between 85 and 95 N-m. Hence, the torque needed to loosen 5 nuts is 475 N-m. The entire gears are epicyclic. Spur gear was selected for design.

VI. TERMINOLOGY

D - Diameter of gear (mm)
σb - Permissible bending stress
d - Diameter of pinion (mm)
E - Young's Modules
G - Gear Ratio
Y - Lewis form factor Φ - 20˚ Pressure Angle **fb** - Beam strength
Zg - Number of teeth on gear
Ka - Service Factor
Zp - Number of teeth on pinion **Km** - Load Distribution Factor **M** - Module
Kv - Velocity Factor
b - Face width (mm)
V - Pitch line Velocity (m/s)
Sut - Ultimate tensile strength (N/mm2)
FOS - Factor of Safety
Syt - Yield strength (N/mm2)

VII. DESIGN CALCULATIONS (I)

(Dimensions)
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 × Zp Zp= 17 & Zg = 34
Module (m) = D/Zg = 76.3/34 = 2.25 mm. Face width (b) [4] = 10 m = 22.5mm Addendum (mm) = 2.25
Dedendum (mm) = 3.125 Tooth Thickness (mm) = 3.93

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DESIGN CALCULATIONS (II)

(Material Properties & Strength) Material Selected: EN8/ 080M40

Ultimate tensile strength (Sut)= 550 N/mm2 Yield strength (Syt) = 280 N/mm2

Young's Modules (E) = 200000 N/mm2 Poisson's Ratio = 0.3

BHN=255 HB

Permissible bending stress -

(Same material is used for pinion & Gear)

For Gear For Pinion

$\sigma bG = (1/3)$ Sut $\sigma bP = (1/3)$ Sut

= 550 /3 = 550 / 3

= 183.33 N/mm2 = 183.33N/mm2

By Lewis Form Factor (Y)

For 20˚ Full Depth Profile

For Gear For Pinion

Yg = 0.3707 Yp = 0.3016

So, $\sigma bp \times Yp < \sigma bg \times Yg$

Therefore, the pinion is weaker in bending than gear.

Beam strength –

$fb = m \times b \times \sigma b \times y = 2861.37$ N

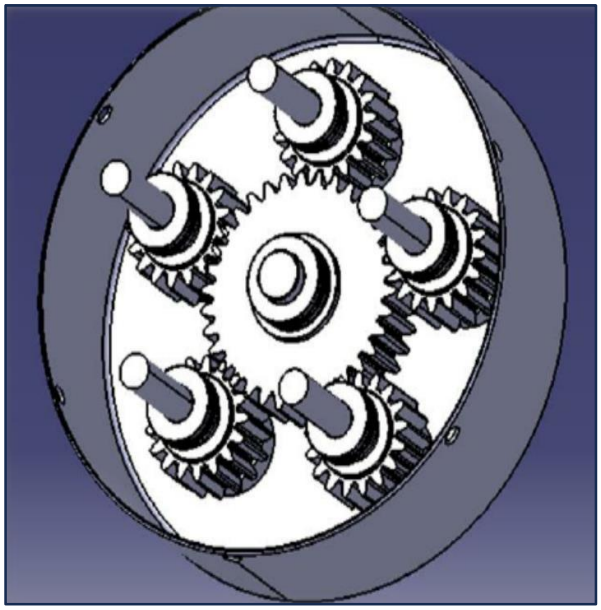

Fig: Epicyclic Gear Train Assmebly

DESIGN CALCULATIONS (III)

(Design Safety)

Effective Load for Precise Estimation Feff = (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,

$P = (2\times\pi\times N\times T)/60 = (2\times3.14\times200\times475)/60$

=10×103 W

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Ft= P/V=10×103/22= 454.54 tangential force Kv = 5.6/(5.6+√V) = 0.5441
Feff = (Ka × Km × Ft) / Kv = (1.25×1.2×454.54) / 0.5441 = 1253.096 N
For Factor of Safety
Fb = FOS × Feff FOS = 2.28
As, FOS = 2.28 > 1.75
As we know, FOS>1.75 for heavy shock
As the Available FOS of Gear pair is higher than that of required factor of safety, the design of gear pair is safe.

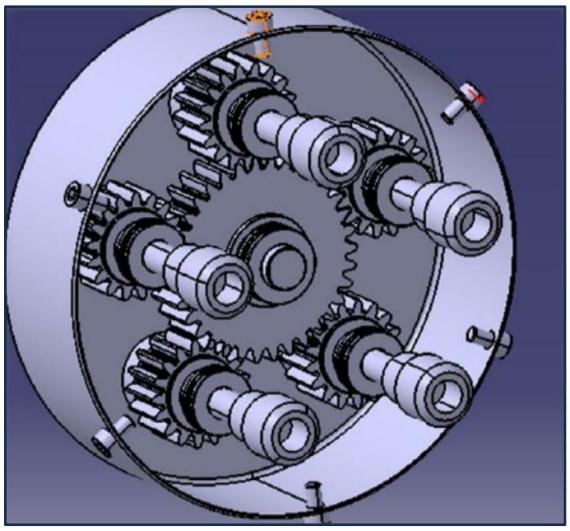

Fig: Final Assembly Without Casing

VIII. CONCLUSION

CATIA V5R20 was used in the design of the Multi Spindle Nut Remover with Pitch Circle Diameter (PCD) 114.3mm. Design calculations were conducted in order to select 080M40 material for the gear and pinion. The gear pair's design is safe because, according to calculations, its FOS is greater than its design factor of safety. Product assembly will be manufactured and tested in the future.

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