International Journal of Research in Engineering, Science and Management
Volume-3, Issue-12, December-2020
https://www.ijresm.com | ISSN (Online): 2581-5792

Design Study of an Adjustable Multinut Tighter or Remover for Car Tyre

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***Abstract*: The traditional way to change a car's tire is to loosen the lug nuts one by one with the help of wheel spanner. However, it is exhausting and time consuming in car service centers and workshops. Hence, in this project to we are incorporating sun and planetary gear mechanism to remove all 4 lug nuts of the care wheel simultaneously with the help of primary power source. An adjustable Multi-nut remover or tighter for car tire is designed to change a car's wheel by driving a planetary gear mechanism with a single motor in which all 4 lug nuts can be simultaneously be loosened or tightened, the pitch circle diameter for different model and variants of car is adjusted by Four Jaw Self centering chuck mechanism. The machine can be used for tightening or loosening of lug nuts of 3 different models of car by using a keypad remote. The machine is expected to be 40% more efficient than the traditional method of loosening or tightening of the lug nuts.**

***Keywords*: Car tyre, Multinut tighter.**

1. Introduction

Our day to day life is completely relying on cars and in today's world the major problem which are faced by car owners are tyre issues due to bad road conditions. The tyre has to be replaced for wheel alignment flat type wheel balancing and many other purposes. Tyre changing is a very difficult job and it involves jacking the car and removing and tightening of the lug nuts one by one manually which requires a lot of time and efforts if conventional L shaped wrench is used. Hence in our project we are aiming at the design and study of an adjustable multi-nut tighter and remover for car tyre to overcome the setbacks for traditional method to loosen and tighten the lug nuts of the car wheel. We are trying to reduce the loosening by 40 – 50 % approximately and tightening of 30 – 35%. The machine is designed to tighten or loosen all four lug nuts of a car wheel, with different PCD by using planetary gear arrangement and self-centering mechanism.

The four jaw self-centering chuck mechanism is chosen in order to adjust the pitch circle diameter of the shafts along with a central disk which is rotated and moves linearly inward and outward at the same speed. A DC Motor is used to operate the four jaw self-centering chuck mechanism. ATMega328 microcontroller is used to program the self-centering mechanism to adjust the multiunit remover according to the required pitch circle diameter. The Arduino NANO is used to program the self-centering chuck mechanism and is programmed using Arduino IDE before uploading on the Arduino board for execution the sketch of the Arduino IDE is written in a language similar to C.

The universal joint is fixed between the shafts connecting the gear and socket wrench with shafts being made of mild steel with a diameter of 20mm and length of 40mm connected to gear and universal joint.

In our design an adjustable multinut remover, was designed initially for 114.3 Pitch circle diameter and the socket wrench will not be in line with the shafts when the Pitch circle diameter increases or decreases. Hence universal joint has been chosen with an operating angle of the 0 to 45 degrees. The planetary gear is of a material steel 4140 with a width of 20mm and pressure angle of 20, the planetary gear also consists of sun gear and planet gear with a module of 2.5 which helps in rotation of shafts the self-centering mechanism used to make the system suitable for 3 different PCD'S of a car wheel so that it can be used for different cars. The mechanism is driven by an AC Induction Motor with a voltage of 220V and rotates at a speed of 1400 RPM and in turn used to operate the planetary gear system. The shaft of the motor is connected to the sun gear of the planetary mechanism. Reduction gear box is used in our project to reduce the input speed of the AC motor and to slower the output and generate more torque with a speed of 1000RPM with a reduction ratio of 1:8 along with ball bearing of material 52100 chrome steel with a thickness of 8mm.

The previous projects and papers have focused on designing a multi-nut remover or tighter for fixed PCD of car tire. In our project we aim at designing an automated system that could be adjustable for 3 different pitch circle diameters of car wheels. Objectives of this project is to design a multi-nut tighter and remover, which is capable to reduce the time taken to loosen or tighten the lug nuts, reduce the human effort in loosening and tightening of the lug nuts and be made adjustable for three varying PCD.

2. Methodology

The various steps involved in the process of design of the adjustable multiunit tighter and remover are listed and explained. Our project can be divided into five phases.

- First phase is brainstorming where we collect information about the basic design aspects. In addition, using brainstorming method can specify the features of our design. In this phase, we define the major aspects needed for building the prototype such as, gears, shafts, bearings and spanners.

- Second phase includes gathering information about the conceptual design of our project from, books, journals, and old projects.
- Third phase is analysis and calculation of design. This phase is considered to be an important phase where manufacturing the prototype depends on it. This phase has a lot of calculations that include dimensions such as gears centers, pitch diameter, thickness of gears, size of shafts, number of teeth, and ratio of gears.

Moreover, the calculations include the torque required to unscrew one nut, power transmitted from the motor and factor of safety (FOS). Additionally, the design of our prototype is made using SolidWorks. SolidWorks includes all dimensions of the parts, 2D drawing, and assembly of the parts.

- The first step is design calculations for the components using suitable formulas that are referred from mechanical design data handbook. The calculations are done for components such as gears, shafts, self-centering mechanism. Torque equation for AC motor, and power equation of DC motor are also obtained.
- The second step is modelling of mechanism which is modelled in solid works with the obtained dimensions.
- The third step involves, static structural analysis, torsional analysis, Maximum principal stress analysis is done for the universal joint and Von Mises stress contour analysis is done for the spur gear.
- At the fourth step the self-centering mechanism is programmed with the use of Arduino IDE so to adjust the mechanism for different pitch circle diameters. Results are validated experimentally to check whether all the calculations are satisfied.

3. Results

This section is dedicated to the results obtained from design considerations and the analysis of the universal shaft. The summary of design factors and the corresponding design values are illustrated in the table 1.

The area of the gear housing and the center distance between the gears were designed to be 640350 mm2 and 57.15 mm respectively. Due to the convenience and ease in design and manufacturing spur gear were selected for the design.

A. Analysis of Universal Joints

Static structural analysis, Torsional analysis and Maximum principal stress analysis was done for the universal joint and gears. The meshing is done in Ansys 2020 R1 by Ansys Inc. The completed CAD model is imported in Ansys work bench, and then the materials are assigned and meshing done as the first step of finite element analysis.

Table 1
Design factors and considerations

S. No.	Design factors and considerations	Parameter
1	Area of the gear housing	640350 m^2
2	Centre distance between the gears	51.15 mm
3	Minimum Torque required for the removal of one nut	94.187 Nm
4	Maximum Torque required for the removal of one nut	201.83 Nm
5	Gear ratio	1.88:1
6	Larger Gear Diameter	71.24mm
7	Smaller Gear Diameter	31.24mm
8	Pressure Angle	20˚
9	Module	2.5
10	Ultimate Tensile Strength	550MPa
11	Yield Strength	280Mpa
12	Young's Modulus	200000Mpa
13	Minimum Force required	4348.42N
14	Maximum Force required	9251.96N
15	Bending moment of the shaft	22072.5Nm
16	Diameter of the shaft	20mm
17	Length of the shaft connected to gear	40mm
18	Length of the shaft connected to universal joint	40mm
19	Torque of the motor	137.5 Nm
20	Power of the motor driving the four jaw chuck mechanism	0.02414hp
21	Operating angle of the universal joint	2.25˚
22	Coefficient of Friction of the universal joint	0.10
23	Bending moment of the universal joint	57396 Nm
24	Torque required from the universal joint	357600Nm
25	Pitch Diameter of the universal joint	0.479522 m
26	Inner Diameter of the Ball Bearing	25mm
27	Outer Diameter of the Ball Bearing	47mm
28	Basic Dynamic Load Rating	8.06KN
29	Basic Static Load Rating	4.75KN
30	Fatigue Load Limit	0.212KN

Table 2
Analysis of universal joints

S. No.	Parameters	Value
1	Preprocessor	Ansys Mesh
2	No. of Nodes	5989
3	No. of elements	2889
4	Solver	Ansys Mechanical

The material of the universal joint is Steel 4140.The properties of which are given in the table 3.

Table 3
Properties of material used Steel 4140

S. No.	Property	Value
1	Tensile Strength	655 MPa
2	Yield Strength	415 MPa
3	Bulk Modulus	140 GPa
4	Elastic Modulus	190 Gpa

B. Static Structural Analysis

The universal joint is subjected to an axial load of 300N. The deformation obtained due the application of load is 0.007017.

Table 4
Results obtained from ANSYS

S. No.	Type of analysis	Type of load	Load value	Result
1	Static Structural Analysis	Axial load	300 N	Deformation: 0.007017m
2	Torsional Analysis	Moment at the end	3 N-m	
3	Maximum Principal Stresses	Force in positive y direction	3N	Maximum Principal Stress: 4.3328 MPa

Table 5
Results obtained from Solidworks simulation

S. No.	Type of analysis	Type of load	Load value	Result
1	Von-Misses Stress Contour analysis	Torque	140 N-m	Von-Misses stress value is 26 MPa

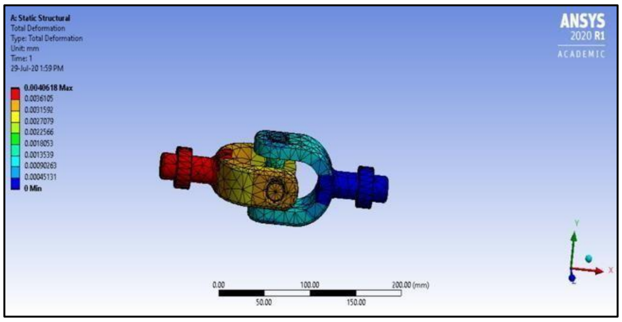

Fig. 1. Structure analysis of the universal joint

C. *Torsional Analysis*

The universal joint is subjected to 3Nm of moment in order to find the breaking point of Universal joint due to torsion, because the lugnut is fixed to the universal joint on one end and other end is fixed to the gears and hence the initial torque is required.

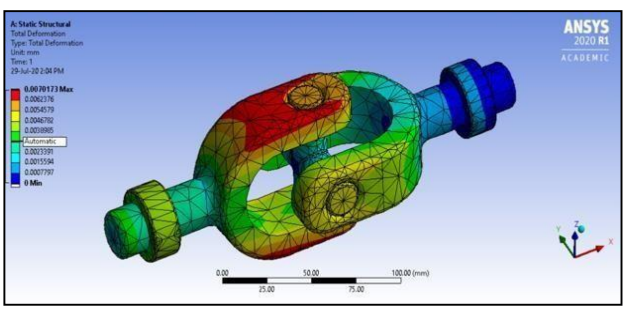

Fig. 2. Torsional analysis of the universal joint

D. *Maximum Principle Stress*

A force of 3 N-m is applied in positive Y-Direction on one side of the universal joint and the maximum principal stress obtained is 4.3328Mpa.

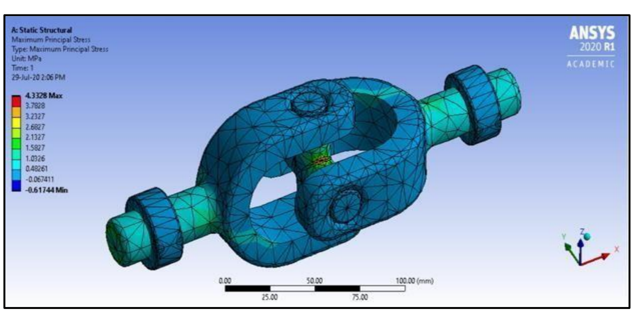

Fig. 3. Maximum principle stress

E. *Analysis Results of Universal Joint*

To find out various stresses and strains we perform static structural analysis, torsional analysis and maximum principal stress analysis or universal joint in Ansys work bench. The results obtained from the ANSYS are summarized in table 4.

F. *Analysis of Spur Gear*

The sun gear of the planetary gear system is static load analysis in SolidWorks Work bench

G. *Analysis Results of Spur Gears*

A torque of 140 N-m is applied on the sun gear, where the results have been presented by contour and numerical values, the maximum Von-Misses stress value for this model is 26.3 Mpa.

To find out the various stresses and strains we perform static structural analysis on the universal joint in ANSYS. The material of the joint is structural steel (SAE 4140), the properties of which are given in table 1. One end of the coupling is fixed while other end is subjected to a moment of 3 N-m.

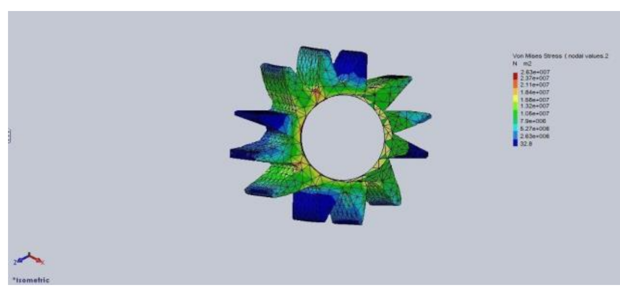
Fig. 4. Von Mises stress contour analysis

The results obtained from Solidworks simulation is summarized in table 5.

4. Discussion and Conclusion

The device reduces the time consumed in loosening by 41% and time for tightening was reduced by 35% compared to conventional method. The torque applied by the device is comparatively higher leading to be more efficient by 35-40 % than usually required to remove a single lugnut by the conventional method. Hence the replacement of wheels can be done fast and consumes less time than usual. The device is cost effective compared to the hydraulic and pneumatic devices. It reduces human efforts can be operated by the people of different age groups. The device weighs less and hence it is easy to store and carry. Since the device is adjustable it can be used to changes wheels of different pitch circle diameters.

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