CHAPTER 1
INTRODUCTION

An automobile is known to be one of the most basic and fascinating things that a person could own. The Cars have now become essential 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. But an automated multi-spindle nut driver allows the driver to remove all nuts at once with less energy consumption and save time.

In case of emergency puncture in the tires of the ambulance, it will be a time consuming process for removal of nuts. In those cases, it will be more useful in automated multi-spindle nut driver.

The automated multi spindle nut driver removes all the nuts by torque, the gear system. The wheel will be replaced by low consumption of time. This design helps to avoid time wasting and a lot of energy used to change the tyre. It allows the driver or mechanic to remove four wheel nuts at once with little energy consumption.

1.1. OBJECTIVE

The main objective of work is to develop a single tool, which can be made use during assembling and disassembling of wheels in automobiles. It can be successfully used as a standard tool irrespective of the model of the vehicle. Also ,it can be used in garages, workshops and service stations.

1.2. OUTCOME

The automated multi spindle nut driver is designed to be ergonomic to be used, easy maintenance, easy storage, easy to handle and able to remove all nuts at once. It is used as a standard tool irrespective of the any model of the vehicle.

CHAPTER 2

WORKING OF AUTOMATED MULTI-SPINDLE NUT DRIVER

The working of the automated multi-spindle nut driver is simple and can be performed by anyone. It does not require any skills or anything, just basic knowledge about the setup is required for operation. This works under the principle of removing all the wheel nuts at the same time by automatic process with the help of an electric motor. It consists of an electric motor, five spur gears, a shaft which has been connected to the central spur gear, and box sockets at each end of the four spur gears and the electric motor is run by batteries.

• First the machine setup is placed with correct fitting of the box socket to the nuts of the vehicle.

• Then the motor is turned on. The motor drives the gear which drives the meshed spur gears through the shaft.

• Each spur gear is connected with the box socket.

• As the spur gear rotates the socket also turns and the nuts in the wheels are thus removed or tightened by the rotation of the socket.

• The tightening and removing process can be changed by changing the rotation of the motor.

Thus all the wheel nuts can be tightened and removed by this process. It is found to be a simple process and very much convenient for every one for the tyre removal and tightening process . Thus with this simple process we succeeded in making a convenient process in the tyre replacement technique. By this setup the tyre could be easily removed and tightened more efficiently with less wastage of time and energy used.

The battery is connected to the two way switch. The two way switch is used to change the direction of rotation of D.C. Motor. The switch is in one position, the motor rotates in one direction. The switch position is changed to the other side, the direction of rotation of the motor changes reversely. The multi spindle head arrangement is driven by the central gear which is connected to the motor. The sockets connected to the other gears through the shafts are used to loosen or tighten the nuts of the wheel.

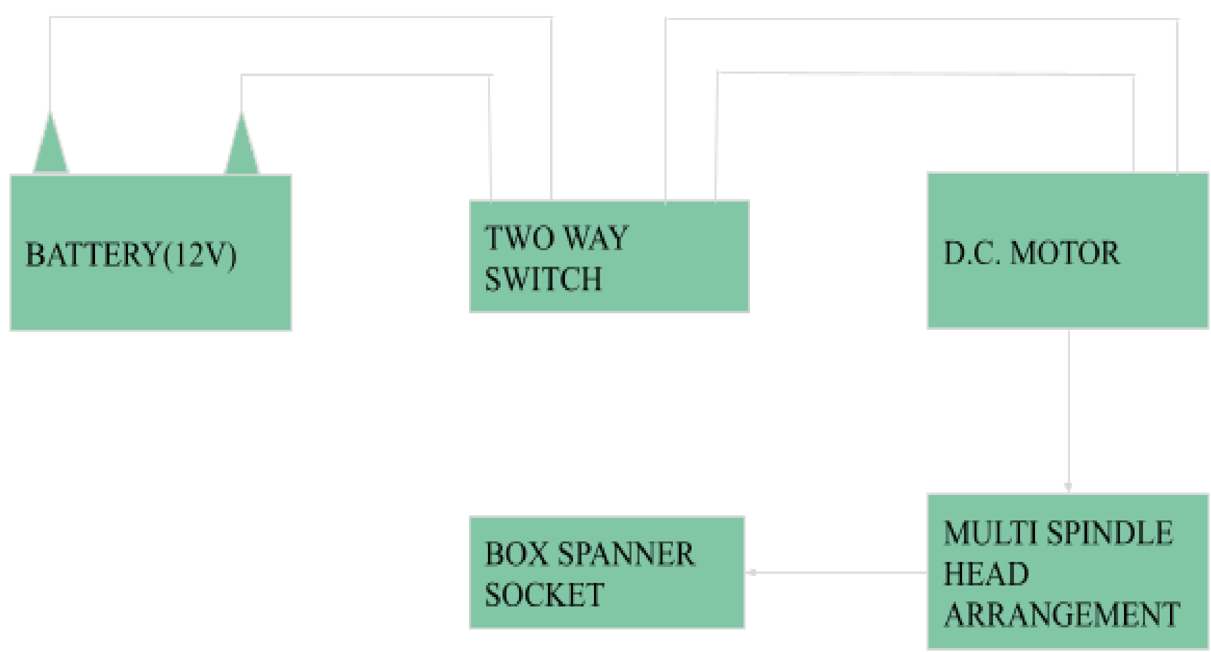

Fig 2.1. Block Diagram

CHAPTER 3

COMPONENTS

3.1. COMPONENTS

The Multi-spindle nut driver has the following components:

- Spur gear
- Driving motor
- Shaft
- Socket
- Battery
- Bearing
- Voltage regulator

3.1.1. SPUR GEAR

In this setup we are using five spur gears .The central spur gear is connected to the motor and thus it is driven by the motor and the other four spur gears are meshed with the central spur gear. Thus the central spur gear drives all four spur gears.

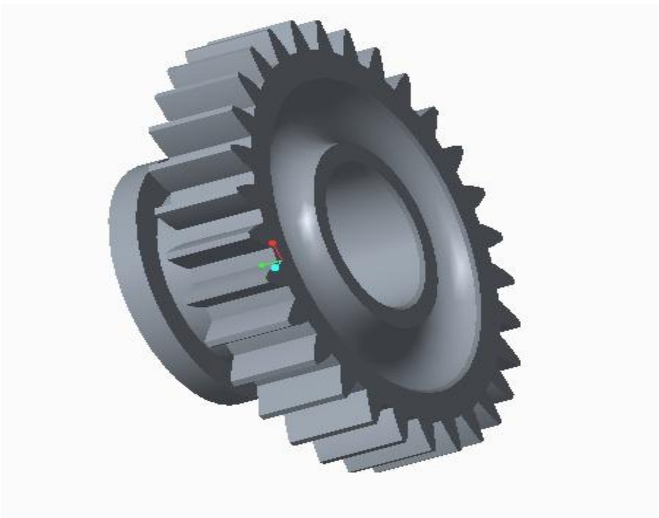

Fig 3.1 Spur gear

The spur gears in this setup is made according to the pitch circle diameter of the wheel which is 140 mm. So the corresponding diameter for the central spur gear and other four spur gears is taken as 70 mm with reference and the number of teeth for the spur gears are 30 respectively.

3.1.2. DRIVING MOTOR

A driving motor is used in driving the central spur gear. The central spur gear needs to be driven so that the all four spur gears meshed with the central spur gear also rotates. Thus for automatic rotation for the central spur gear a electric motor is connected with the central spur gear. A 12V DC motor of 60 RPM is used in this setup.

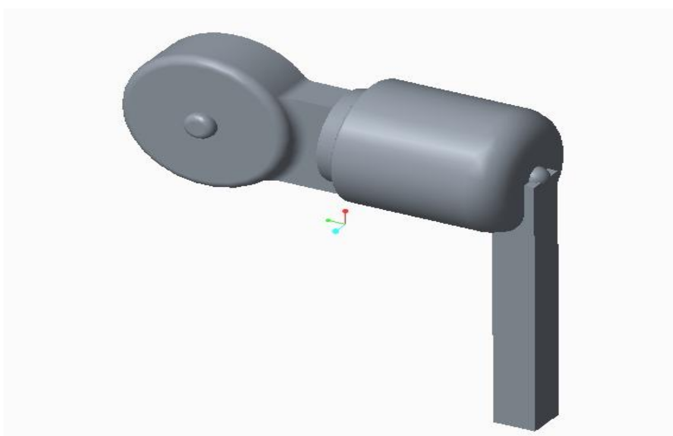

Fig 3.2 Driving Motor

3.1.3. SHAFT

A shaft for transferring torque is used to transfer the torque from the motor through the central spur gear to the sockets inorder to remove the nuts. Each driven gear is connected individually to the box socket. A shaft mounted at the central spur gear is used to transfer the motion from the central spur gear to the other spur gears.

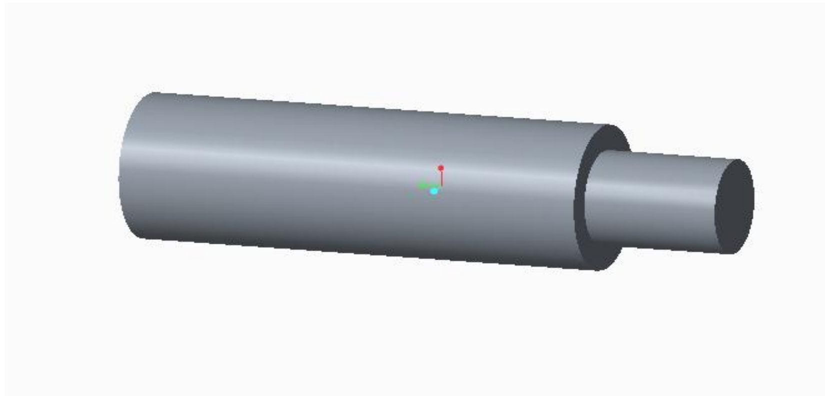

Fig 3.3 Shaft

3.1.4. SOCKET

A socket is a cylindrical type hexagonal fit which is fitted over the common hexagonal head of the nut. In this case the size of the socket is taken as 19 mm. The head of the socket wrench is completely the same as the nut / bolt head cover and the sense of the handle is not fixed. The socket is a hexagonal shape or size estimate which itself is either a square. This estimate, which fits into the appropriate size of the cavity or on the handle, can be used to apply force.

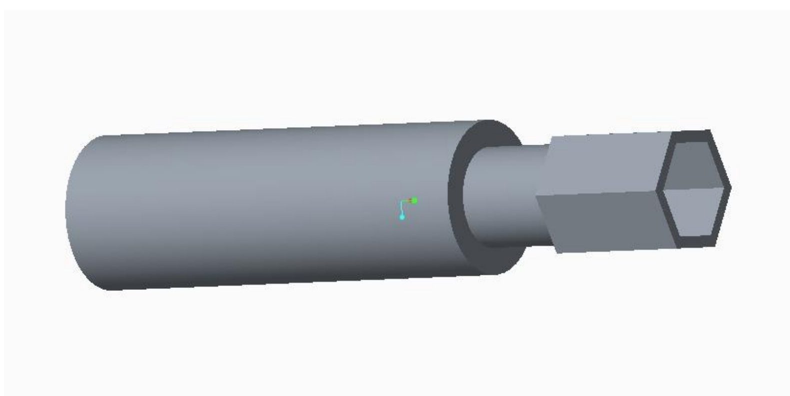

Fig 3.4 Socket

3.1.5. BATTERY

For driving the electric motor batteries are used. As it is a compact in nature it needs to be taken anywhere and worked thus the battery is used for the motor. Two 12V batteries are used for running the motor.The battery is placed with the setup.

3.1.6. VOLTAGE REGULATOR

A voltage regulator is a system designed to automatically maintain a constant voltage. A voltage regulator may use a simple feed-forward design or may include negative feedback. It may use an electromechanical mechanism, or electronic components.

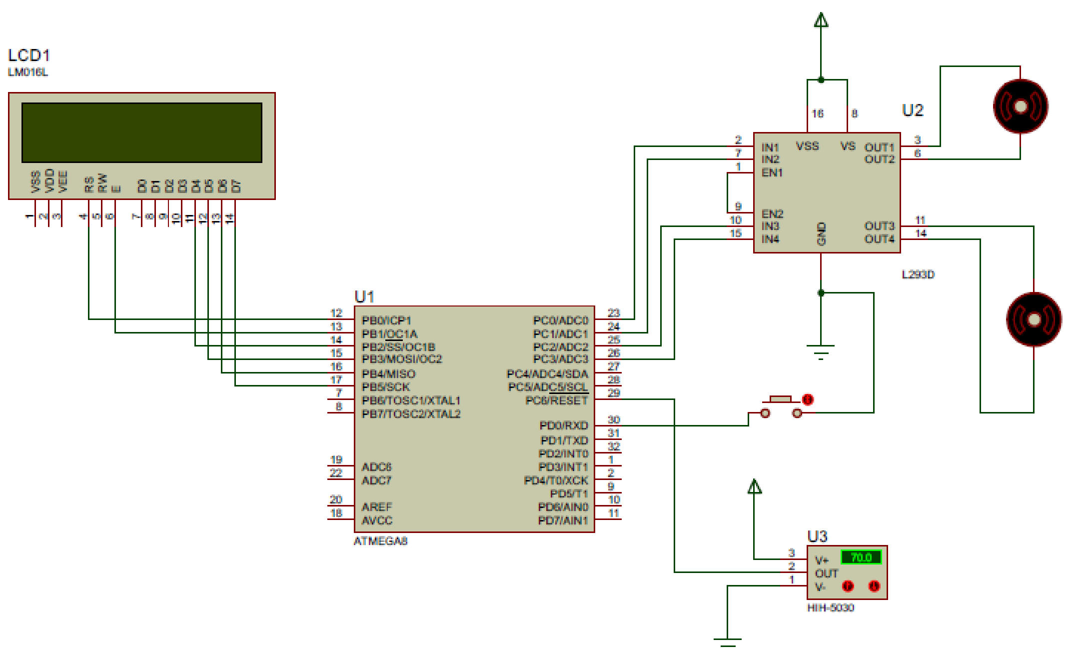

Fig 3.5. Voltage Regulator Circuit Diagram

CHAPTER 4

CAD ASSEMBLY

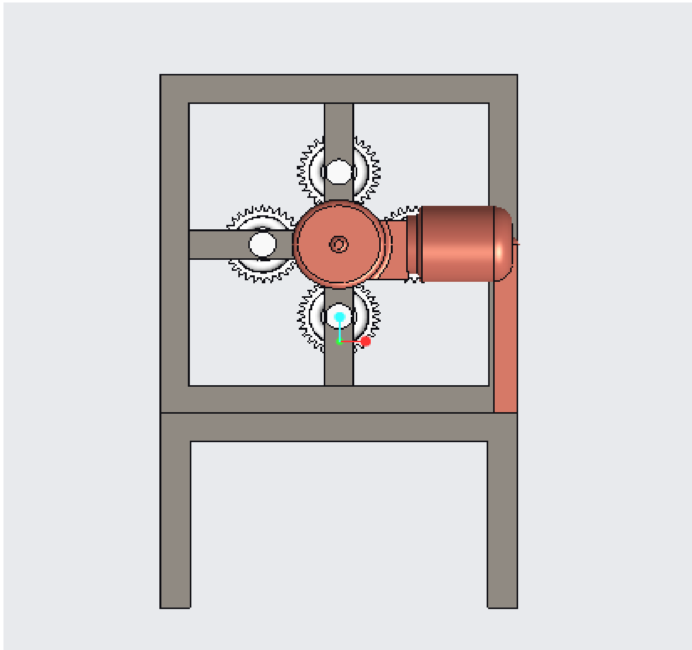

Fig 4.1 Front view

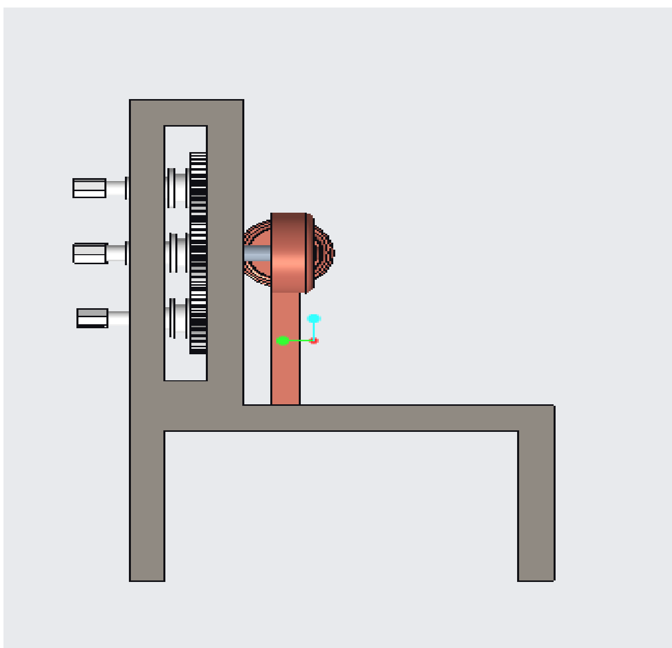

Fig 4.2 Side view

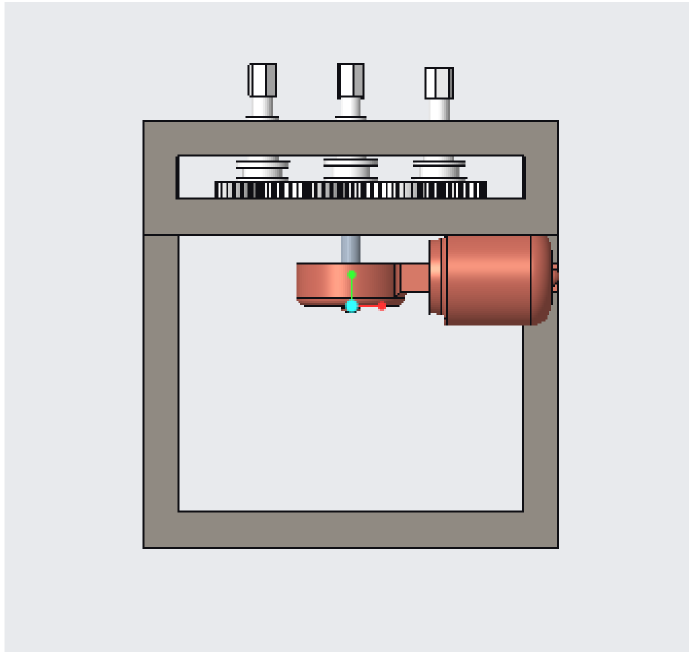

Fig 4.3 Top view

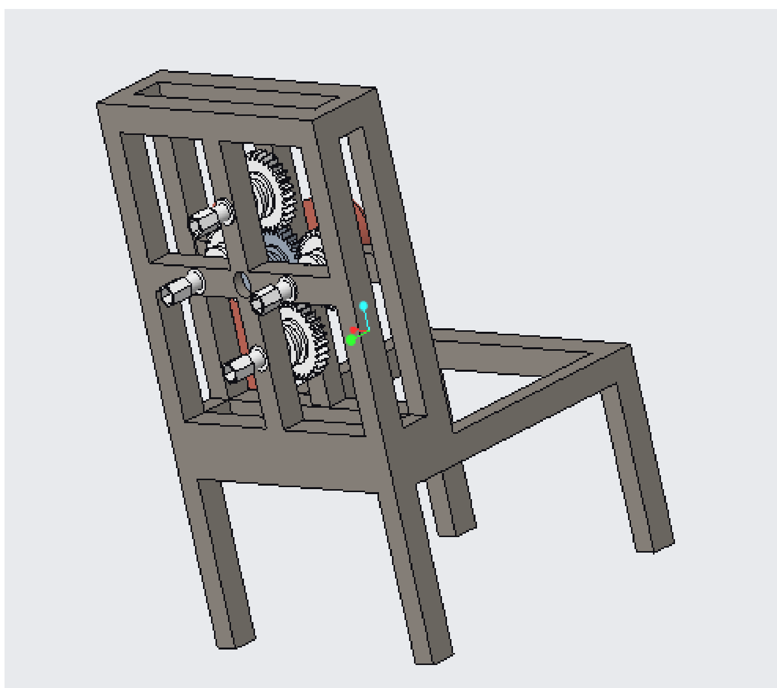

Fig 4.4 Isometric view

CHAPTER 5

DESIGN CALCULATIONS

5.1. DESIGN CALCULATION OF SPUR GEAR

"20 deg Full Depth Involute System"

System pressure angle = 20 degree

$8<b<12$, assume $b = 10$ mm

Centre distance between the gears = 65 mm

Two mating gears must have the same module.

Gear material selection

Spur gear = Grey Cast Iron (EN-GJL-200)

Basic terminology

Gear ratio = Np/Ng = 30/30 = 1

Addendum = 1m = 1*2.33 = 2.33 mm

Dedendum = 1.25*m = 1.25*2.33 = 2.9125 mm

Tooth thickness = 1.5708*2.33 = 3.6599 mm

Bottom clearance = 0.25*m = 0.25*2.33 = 0.5825 mm

Fillet radius at root = 0.4*m = 0.4*2.33 = 0.932 mm

Total depth = addendum + dedendum = 2.33 + 2.9125 = 5.2425 mm

5.1.1.DESIGN CALCULATION OF DRIVER GEAR

Pitch circle diameter (PCD) = 70 mm

No of teeth, Np = 30

Diameter pitch = z/d = 30/70 = 0.42

Module , m = d/z = 70/30 = 2.33

Root diameter = PCD – dedendum = 70 – 2.9125 = 67.087 mm

Tip diameter = PCD + dedendum = 70 + 2.9125 = 72.9125 mm

5.1.2. DESIGN CALCULATION OF DRIVEN GEAR

Pitch circle diameter (PCD) = 70 mm

No of teeth, Np = 30

Diameter pitch = z/d = 30/70 = 0.42

Module , m = d/z = 70/30 = 2.33

Root diameter = PCD – dedendum = 70 – 2.9125 = 67.087 mm

Tip diameter = PCD + dedendum = 70 + 2.9125 = 72.9125 mm

5.1.3.DESIGN VALIDATION OF GEARS

Gear ratio = Ng / Np = 30 / 30 = 1

Velocity ratio = 1/ G.R. = 1/1 = 1

Normal force Fn = 500N

Radial force, $Fr = Fn(\sin 20°) = 500(\sin 20°) = 171.01N$

Tangential force, $Ft = Fn(\cos 20°) = 500(\cos 20°) = 468.84N$

Stress at the base of the involute profile, $\sigma(t) = Ft*Pd/F*J$

Geometry factor, $J = \sin(20)\cos(20) / 2*(G.R/G.R+1) = 0.0964$

$\sigma(t) = 468.84 * 0.45 / 500 * 0.0964 = 4.3772\ N/mm^2$

The permissible bending stress,

$\sigma(b) = \sigma(u) / 3$, $\sigma(u)$ = ultimate tensile strength of gear material

$\sigma(b) = 565 / 3 = 188.33\ N / mm^2$

Effective loading on gear tooth (Feff),

$Feff = ka * km * Ft / kv$

Combined shock and fatigue factor $ka = 1.25$

Load distribution factor $km = 1.2$

Dynamic factor $kv = (Fd + Ft) / Ft$

Dynamic load ,

$Fd = Ft + 21v (bc +Ft) / 21v + (bc + Ft)^{0.5v} = (3.14) * d * N / 60$

(Assume humans can turn the central spur gear at the rate of 30 rpm)

$v = 3.14 * (40 * 10^{-3}) * 30 / 60 = 62.83 * 10^{-3}\ m/ s$

From PSG DB Pg 8.53 ,

Correction factor, c = 11860e

Error factor, e = 0.038

c = 450.68

$Fd = 468.84 + ((21*62.83*10^{-3})(10*450.68+468.84))$ /

$((21*62.83*10^{-3})+(10*450.68+468.84)^{0.5})$

Fd = 560.2095 N

kv = (Fd + Ft) / Ft = (560.2095 + 468.84) / 468.84

kv = 2.1944 = 2.22 (approx.)

Feff = 1.25 * 1.2 * 468.84 / 2.22 = 316.788 N

Beam strength ,

Fb = m * b * Y * σ(b)

b = face width = 10 mm

Y = form factor = 0.308 (from PSG DB Pg 8.53)

Fb = 2.33 * 10 * 0.308 * 188.33 = 1351.531 N

Wear load ,

Fw = d * b * Q * kw

Q = 2i / i +1 = 2zg / zp + zg = 1.2

kw = 2.553

Fw = 70 * 10 * 1.2 * 2.553 = 2144.52 N

5.2.FACTOR OF SAFETY

FOS = Fb / Feff = 1351.531 / 316.788 = 4.3 > 1.5 (Design is safe)

(FOS)bending = Fb / Fd = 1351.531 / 560.2095 = 2.412 > 1.5

Therefore , the design is safe.

(FOS)pitting = Fw / Fd = 2144.52 / 560.2095 = 3.828 > 2

Therefore, the design is safe.

Check for beam strength (or tooth breakage) :

Fb > Fd. It means the gear tooth has adequate beam strength and it will not fail by breakage. Therefore the design is satisfactory.

Check for wear :

Fw > Fd. It means the gear tooth has adequate wear capcity and it will not wear out . Therefore the design is satisfactory.

5.3.DESIGN SPECIFICTION OF DRIVING MOTOR

12 V, 60 RPM DC motor is chosen.

Operating voltage : 12 V

Speed : 60 RPM

5.4.DESIGN CALCULATION OF SHAFT

Power transmitted by the central spur gear ,

Psg = 2 * (3.14) * nsg * Tsg / 60,

nsg – speed of central spur gear ; Tsg – Torque transmitted by the central spur gear and shaft

Assume average humans can rotate the central spur gear at the 30 rpm.

Average torque required for removing the four nuts of the wheel = 480 Nm

Psg = 2 * (3.14) * 30 * 480 / 60 = 1507.9644 W

Weight of the spur gear (Wsg) = 0.00118Tsg * b * m * 2 = 0.00118 *480 *10 * 1 * 2 = 11.33 N

W.K.T,

Gear ratio, G.R = nsg / ng = dg / dsg = Tg / Tsg

Tg = Tsg * G.R = 480 * 1 = 480 Nm

$T = t*(3.14/16)*(d^3)$

$t = \sigma(u)/(FOS)bending = 565 / 2.412 = 234.245\ N/mm^2$

$480*10^3 = (234.245)*(314/16)*(dsg^3)$

$dsg^3 = 9942.8994\ mm^3$

dsg = 21.5 mm =22 mm(approx.)

Diameter of shaft = 22 mm

CHAPTER 6

ANALYSIS

6.1 ABOUT ANSYS

ANSYS develops and markets engineering simulation software for use across the product life cycle. ANSYS Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow and other attributes.

ANSYS is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, ANSYS software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste or how to design a slide that uses less material without sacrificing safety.

Most ANSYS simulations are performed using the ANSYS Workbench system, which is one of the company's main product. Typically. ANSYS users break down larger structures into small components that are each modelled and tested individually.

A user may start by defining the dimensions of an object and then adding weight, pressure, temperature and other physical properties. Finally, the ANSYS software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.

6.2. STATIC STRUCTURAL ANALYSIS OF MULTI-SPINDLE NUT DRIVER

6.2.1. BOUNDARY CONDITION

The lower side of the frame is fixed to the ground. A pressure of 1000 Mpa is applied at the teeth of the spur gear.

6.2.2. ANALYSIS RESULT

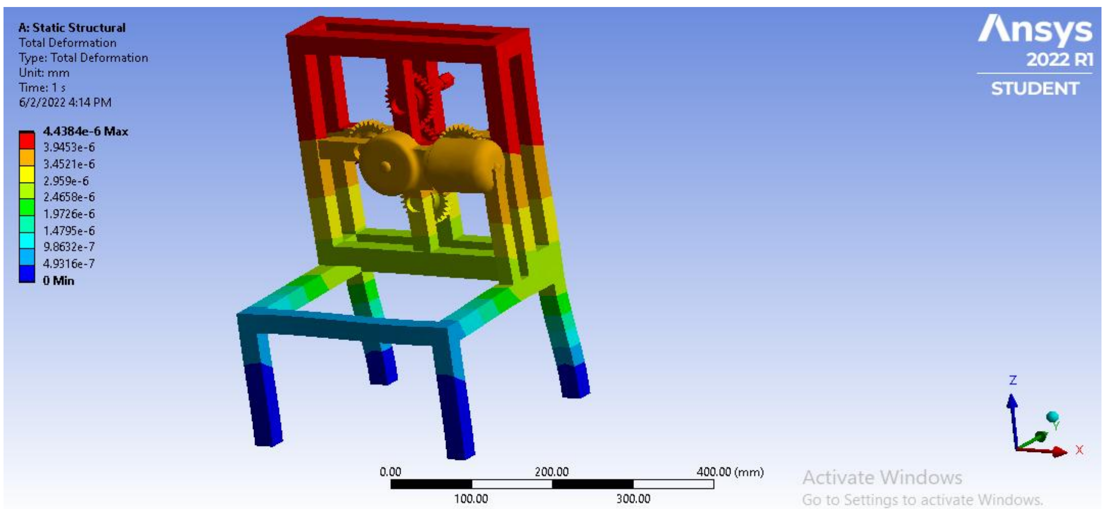

Fig 6.1. Total deformation

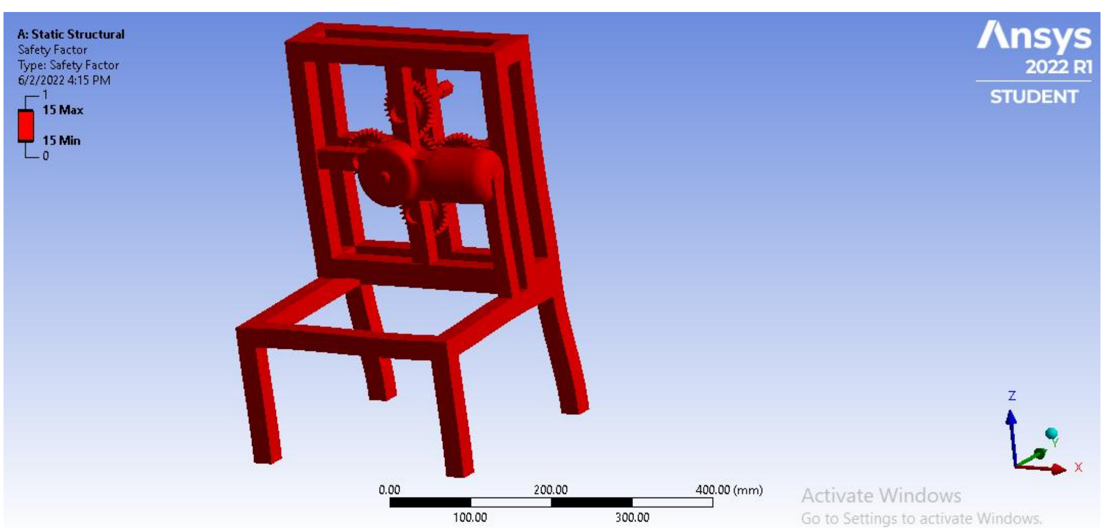

Fig 6.2. Safety factor

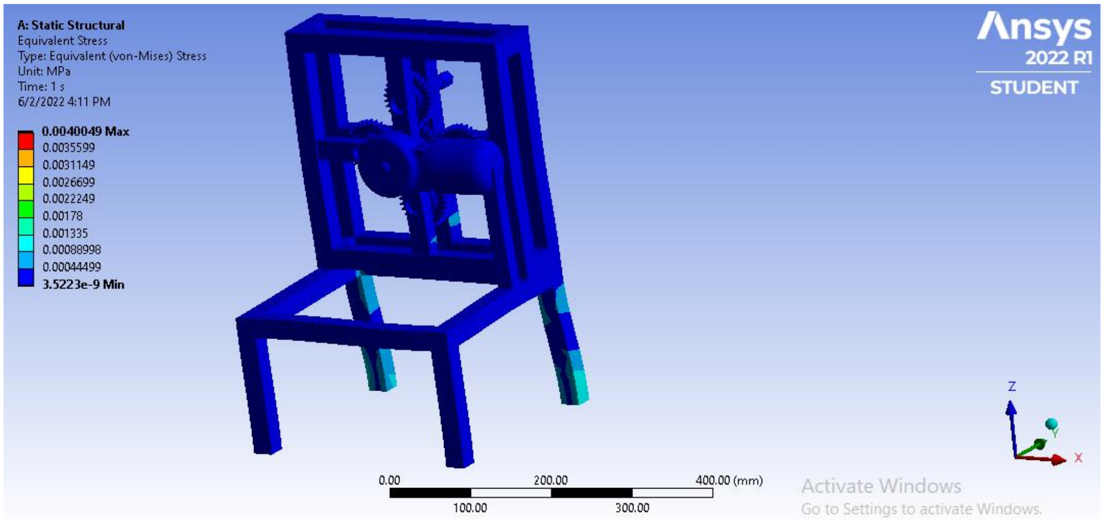

Fig 6.3. Von-Mises stress

Mesh size	- 33.044 mm (Default)	-
Total Deformation	- 4.4384 x 10^{-6} mm	
Factor of Safety	- 15 (min)	
Maximum Von-Mises stress	- 0.0040049 Mpa	

CHAPTER 7

FABRICATION

7.1. MATERIAL SELECTION

7.1.1. FRAME

Material – Mild Steel (Grade A Corten)

Description

Corten Steel (grade A) is also known as weathering steel or atmospheric corrosion resistant steel and is specified to EN 10025-5. Corten is a cost-effective choice for structures that are exposed to extremes of weather. The surface of Corten oxidises to give it a distinctive brown/ orange colour; this does not just look great, it also protects the metal. The oxidisation develops and regenerates the surface as it is exposed to weather and air pollution.

Table 7.1. Physical properties of Grade A Corten Steel

PHYSICAL PROPERTY	VALUE
Density	8000 kgm^{-3}
Melting point	1370-1400°c
Modulus of Elasticity	190-210 Gpa
Electrical resistivity	0.7 μΩm
Thermal conductivity	42.7W/m.K
Thermal expansion	16-17 μm/m-k

Table 7.2. Mechanical properties of Grade A Corten Steel

MECHANICAL PROPERTY	VALUE
Yield Strength	345 N/mm2
Tensile Strength	485 N/mm2
Hardness	105 vickers HV
Elongation	20% minimum

Table 7.3. Chemical composition (% of weight)

C	Si	Mn	P	S	Al	Cu	Cr	Ni	Fe
0.15 max	0.25-0.75	0.2-0.5	0.07-0.15	0.03 max	0.015-0.06	0.25-0.55	0.5-1.25	0.65 max	Balance

Machinability

Corten is suitable for drilling and machining. You can reduce wear and damage to tools by reducing the fabrication speeds necessary on other mild steels. Drilling speeds can be reduced to 2/3 of standard mild steel speeds and to 3/7 of the speed for machining.

Cutting

Corten can be cut in the same way as standard steel products by using shears or gas / flame cutting techniques.

Welding

Weathering steel is suitable for manual and mechanical welding, but, there are couple of pointers you need to remember. The weather resistance of Corten means that any welding consumables you choose need to have similar corrosion resistance and preferably be a good colour match too. On a single pass weld, mild steel electrodes can be used because the pick up from the base metal will help to get the desired colour match. If you are doing multiple pass welds, it is better to use low alloy electrodes to make sure you get a good colour and corrosion resistant match.

7.1.2. GEAR

Material – Grey Cast Iron (EN-GJL-200)

Description

Gray iron, or grey cast iron, is a type of cast iron that has a graphite microstructure. It is named after the gray color of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material based on weight.

Table 7.4. Physical properties of Grey cast iron EN-GJL-200

PHYSICAL PROPERTY	VALUE
Density	7150 kgm^{-3}
Thermal conductivity	48 W/m.K
Thermal expansion	13 µm/m-k

Table 7.5. Mechanical properties of Grey cast iron EN-GJL-200

MECHANICAL PROPERTY	VALUE
Yield Strength	130-195 N/mm^2
Tensile Strength	200-300 N/mm^2
Hardness	180-220 Brinell HB
Elongation	0.3-0.8 %

Table 7.6. Chemical composition (% of weight)

C	Si	Mn	P	S	CE
3.10-3.40	1.90-2.30	0.6-0.9	0.15 max	0.15 max	3.90-4.15

Machinability

Grey cast iron is characterized by its graphitic flakes that give the material its grey appearance. It has lower toughness than steel; however, it has good resistance to plastic deformation and is therefore widely used for housing components, such as cylinder blocks and gearbox cases. Most of the designations are based on SAE J431, which is related to the material's hardness.

7.2. FRAME

7.2.1. Specifications

Table 7.7. Frame Specifications

PARAMETER	VALUE
Type	Square tube
Material	Grade A Corten
Width	305 mm
Height	480 mm
Thickness	25 mm

7.2.2. Flame Cutting

CORTEN is suitable for flame cutting provided proper operating methods are used. At temperatures below 5°C a sufficiently wide zone on either side of the intended cut should be preheated. If flame cut edges are to undergo cold forming, the hardening effect should be prevented by preheating.

7.2.3. Welding

CORTEN can be welded both manually and mechanically, provided the general rules of welding practices are observed. A prerequisite for obtaining identical mechanical properties in the weld and in the base material is the application of suitable welding consumables and the choice of appropraite welding conditions. Recommendations for welding of metallic materials-. Lime basic electrodes, inert-gas welding wire, and wire/power combinations equivalent to the tensile strength of corten is used as welding consumables. For unprotected use care must be taken that the welded joint is also weather resistant. This is possible by using welding consumables matching the base material. If due to design or building specification stress relieving is required, it should be performed in the range temperature from about 530°C to 580°C.

7.2.4. Boring

Boring is a machining process in which internal diameters are generated in true relation to the centerline of the spindle by means of single-point cutting tools. The elements are composition and hardness of workpiece metal, cutting fluid, speeds and feeds, and methods for piloting and supporting tools in boring applications.

7.3. SHAFT AND SOCKETS

7.3.1. Shaft Specifications

Table 7.8. Shaft Specifications

PARAMETER	VALUE
Type	Cylindrical rod
Material	Grade A Corten
Outer Diameter	23 mm
Inner Diameter	15 mm
Length	90 mm

7.3.2. Socket Specifications

Table 7.9. Socket Specifications

PARAMETER	VALUE
Type	Cylindrical rod
Material	Grade A Corten
Outer Diameter	23 mm
Inner Diameter	15 mm
Length	110 mm

7.3.3. Turning

A single-point turning tool moves axially, along the side of the workpiece, removing material to form different features, including steps, tapers, chamfers, and contours. These features are typically machined at a small radial depth of cut and multiple passes are made until the end diameter is reached.

7.4. TIG WELDING

7.4.1. Description

Mild steel is a steel alloy with a low carbon content, typically 0.3 percent or less. As a result, mild steel is also known as low-carbon steel. It is widely used in fabrication because it is less expensive than other steel alloys and is simple to weld. Mild steel can be welded with tungsten inert gas (TIG) welding techniques, producing a clean and precise weld.

7.4.2. Machine settings

Because the TIG welding process uses a non-consumable tungsten electrode, a separate welding rod or wire is used as filler material when welding mild steel. The E60XX and E70XX lines are the most commonly used welding rods for mild steel.

Table 7.10 Weilding parameters

Diameter	0.90 mm
Ampere	50 – 70 A
Volts	10 – 12 V
Shielding gas	100% Argon

7.4.3. Welding process

The TIG process necessitates more concentration and finesse than MIG or oxy-acetylene torch welding. All workpiece, including the welding rod, are cleaned before welding mild steel, as particulates can cause the weld to weaken. Filler material may not be required for thinner sheets. The weld puddle is created by striking an arc and holding the electrode at a 10 to 15 degree angle from vertical at the start of the weld. The molten metal is pushed forward by moving the electrode and the arc forward. The electrode, workpiece and filler rod are all held to a tight tolerance, with neither the filler rod nor the workpiece touching the electrode.

7.4.4. Safety configuration

Although the light produced by TIG welding is not as intense as that produced by other welding procedures, TIG welding emits a higher amount of UV light than other methods, requiring to take extra precautions to cover their work areas from pedestrians. A No. 10 lens can be used in the helmet to offer proper eye protection while maintaining visibility. To protect the skin from burns gloves, an apron, or coveralls, are used as with any welding process.

7.4.5. Welding Electrode

Electrode – ER70S-2

Description

ER70S-2 is a copper-coated solid wire designed for welding carbon and carbon-manganese steels with tensile strength up to 610 MPa. Additional manganese and silicon present in this wire enhances deoxidation when welding over light rust and mill scale. It is also suitable for welding thin, galvanized or electro-galvanized material with very limited spatter.

Diameter : 0.035”

Welding positions : All positions

Welding guidelines : Preheat and PWHT are not required

Table 7.11. Mechanical properties of ER70S-2

PARAMETER	VALUE
Ultimate Tensile Strength	520 MPa
Yield Strength	440 MPa
Percent Elongation	28%

Table 7.12. Deposition composition

Al	C	Cu	Mn	P	Si	S	Ti	Zr
0.10	0.06	0.15	1.10	0.012	0.50	0.012	0.10	0.09

7.5. FABRICATED PRODUCT

Fig 7.1. Isometric view of fabricated product

Fig 7.2. Top view of fabricated product

7.6. COST ESTIMATION

Table 7.13. Cost Estimation of Product

S.NO.	COMPONENTS	QUANTITY	PRICE
1	Spur gear	5	1250
2	DC Motor	1	750
3	Frame	-	1500
4	Welding rod and cutting wheel	-	200
5	Voltage controller circuit	-	4000
Total			**7700**

CHAPTER 8

CONCLUSION

An automated multi spindle nut driver for car tyres (with 140 PCD) was developed. The design and analysis of the automated multi spindle nut driver was completed, and the analysis clearly shows that the device can conveniently remove and tighten four-wheel nuts of car tyres with little application of force and time spent. Hence, the machine can be operated with ease.

The project is economical, and it sustains all the required feasibility. Automated multi spindle nut driver is a perfect tool for assembling and dismantling a wheel in a four wheeler. A detailed feasibility study is however recommended to find alternative materials that are lighter in weight to further reduce the weight of the device. Also, this study should be further subjected to improvement and modification by inculcating a free wheel to each of the socket wrench. This will overcome the challenges of one nut tightening faster than the rest. Provision for an adjustable gear arrangement system will also make the wheel nuts to fit in perfectly into the socket wrench.

Thus the design and analysis of automated multi spindle nut driver is successfully done. Automated multi spindle nut driver is a perfect tool for assembling and dismantling a wheel in a four wheeler.

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