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Senior Design Project Report

Design & Manufacturing of Automotive Tire Changing Mechanism

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Abstract

Essentially, most of cars use 4 to 5 lug nuts to fix wheels on cars. The traditional way to change a car's wheel tire is to unscrew the locking lug nuts one by one using a lug wrench. However, sometimes it can be so exhausting and time consuming. In this project, we have designed and manufactured an automotive tire changing mechanism using a gear train to unscrew lug nuts simultaneously that can be eventually efficient and time saving. The mechanism simply works by applying power on the driver gears causing all driven gears connected to spanners to move at the same time, and eventually unscrew the lug nuts fixed on the wheel. Additionally, our design has the capacity to unscrew five nuts of standard sedan cars in 11 seconds. Moreover, our project can be so useful and usable in many places such as workshops and tire manufacturing companies. In addition, this project's importance lies on the motto of "Every second counts."

Acknowledgments

In the name of Allah, the most gracious, all praise to Allah for his blessings in completing this project. We would like to thank all those who helped us to complete this project and achieve this project's objectives. Also, we would like to thank the Mechanical Engineering Department In our university for building up our engineering knowledge throughout different courses, which helped us completing this project successfully. This project wouldn't have been completed without the constant guidance and help of our advisor Dr. Muhammad Asad and co-advisor Dr. Nader Sawalhi, and for that we thank them and appreciate their help very much.

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List of Acronyms (Symbols) used in the report

Parameters	Symbol	Units
Pitch Circle Diameter	PCD	mm
Module	m	mm
Center Distance	C	mm
Teeth	N	Magnitude
Gear material	…	…
Nut sizes	…	mm
Speed	n	Rev/s
Power	P	KW
Torque	T	N.m
Catalog	C10	KN
Section modules	S	m
Polar moment of inertia	I	m
Max shear stress	τ_{max}	Pa
Stress	σmax	Pa
Desired life in hours	ζ_D	Revolution
Rating life in hours	ζ_R	Revolution
Safety of Factor	SOF	Ratio

Chapter 1: Introduction

1.1 Project Definition

This project is intended to design and manufacture an automotive tire changing mechanism. Initially, the general idea behind this mechanism was to have a power source that's connected through a shaft to a gear train that has a driver gear, and 5 driven gears that are connected with spanners to unscrew lug nuts simultaneously. But after we finalized the calculations, conceptual design and searched for the available materials in the market we changed the design completely and it will be shown and discussed in the next chapters. This project is very important to tire manufacturing companies and workshops, as it can be very efficient and time saving.

1.2 Project Objectives

When it comes to changing tires, most people find it exhausting and time consuming, because of the traditional way used for changing tires, which is using the tire lug wrench. Due to the difficulties that people face in changing tires, we came up with the idea of this project which is to make the procedure of changing tires much easier and time saving. This project has two main objectives, which are designing and manufacturing an automotive tire changing mechanism, reduce the time taken to change tires and optimizing the weight of the prototype.

1.3 Project Specifications

- 5 driven gears with a diameter of 71.2mm
- 3 driver gears with a diameter of 31.2mm
- Module of gears is 2.5mm
- 5 shafts with a diameter of 25mm
- Pitch Circle Diameter, PCD for wheel hub (mm): 114.3mm
- Torque (Nm): An impact wrench with a torque of 440N.m
- Power (W): An impact wrench with an output power of 710W.
- Speed (rpm): An impact wrench with load speed of 201 rpm.

1.4 Applications

Time is a very important aspect of life, and as engineers we always seek to come up with easy and efficient solutions for problems. Therefore, mainly, our project focuses on the aspect of reducing the amount of time taken in changing tires. This project can be used in a variety of places, such as workshops and tire manufacturing companies like Michelin, Continental, Bridgestone and Good Year. On one hand, there are many manufacturing companies, and workshops that use impact wrenches as a tool for changing tires, and they have to unscrew only one nut at a time, and that can be considered as a waste of time. On the other hand, our project can efficiently save time by unscrewing all nuts simultaneously in 11 seconds.

Chapter 2: Literature Review

2.1 Project background

The main purpose of using gears is to transfer power from a source to an application. Moreover, the modern technology of gears in its current form ages backs to only 100 years ago. Nevertheless, the oldest form of gears can be traced back to fourth century B.C. Greece. In addition, there are a lot of application that involves gearing systems in them such as, robotics, automotive and power transmissions. Moreover, there are different types of gears that can be used such us, bevel gears, helical gears and spur gears. In this project, the gear train that is being used is consisting of spur gears that are meshed in a way to achieve the aim of this project that is to design and manufacture an automotive tire changing mechanism.

2.2 Previous work

Gears transmit mechanical power and can be classified to parallel axis gears and non-parallel gears. One of the types of parallel axis gears is spur gears (Figure 2.1), which is considered to be the most suitable for machine transmission. Spur gears have straight teeth, and are mounted on parallel shafts and usually have 20 degree of pressure angle. This book includes details about spur gears design, specifications, and selection of gears. This project is based on a gear system where the materials provided in the book are considered to be a reference for gear systems. It helps to provide the formulas needed to calculate torque, forces acting on gears, and module. Moreover, it explains how different types of gears work such as epicycle. So, it is a basic need to design this project. [1]

Figure 2.1: Two spur gears in mesh

A bad selection for the motor used in this project leads to poor system performance and an increase of the cost of installation and maintenance in future. Therefore, engineers are required to avoid bad selections for design in their work. However, this article explains procedures in selecting the proper size of motors for the design, and shows an example illustrating load analysis. It also gives more information such as describing the methods of selecting other associated components. In this project, to select a motor, we have to find the torque needed to unscrew the 5 nuts at the same time. So, this article shows a good example of how to calculate the power needed to transmit torque and selecting the right motor for our system. [2]

The concepts and terminology of gears is a requirement to design any gear system. Gear terms and concepts are necessary to design, build and improve gear drive systems. To design and build a gear drive system, it is necessary to understand all concepts of gears and their mechanism. Moreover, ratio of gears depends on teeth of gears and tells the designer how much the driver gear rotates to complete one turn for the driven gear. For example, if the ratio for two gears is 1:3, this means that the driver gear must turn three times to get the driven gear to make one complete turn as shown in the figure below.

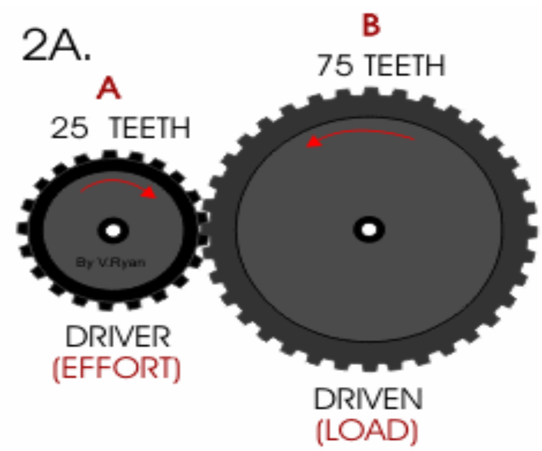


Figure 2.2: Two gears in mesh that have a ratio of 1:3

Another concept discussed in the article is the calculation of center to center. However, this source clarifies more about spur gears and how they are being used to design a gear system. [3]

2.3 Similar Mechanism

[6] Hammer drills have been used for a long time and they are using a rotating power with the help of vibration to pulverize the hard material into the surface. Moreover, sometimes the hammer drill's bit at the surface of material gets extremely hot, so the tip is made out of carbide steel to resist the heat.

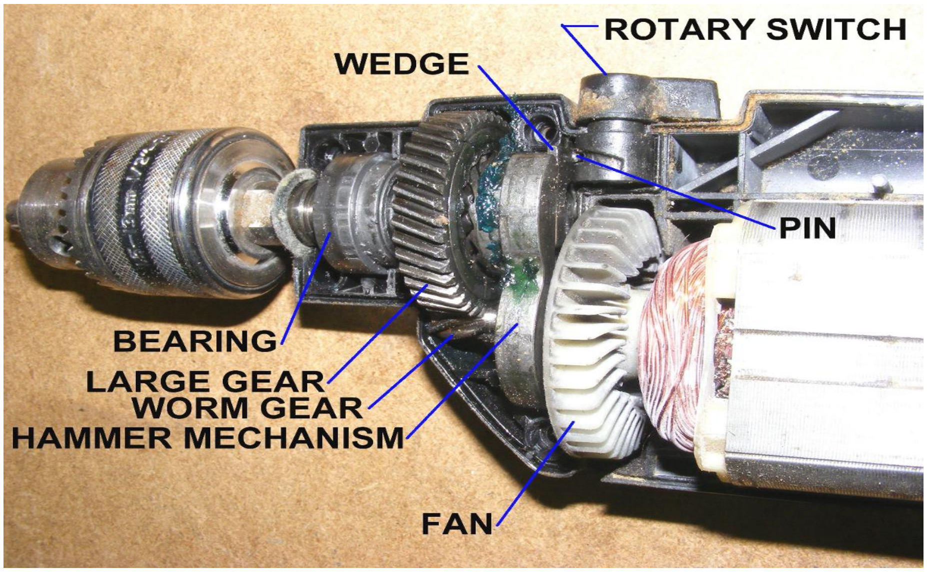


Figure 2.3: Components of hammer drill

In figure 2.3 above, its showing the main component of a drill hammer. First, the motor of the shaft is passing through the hammer body where there are bearings to support the shaft. While the shaft ends in the worm gear that transfers the rotational motion to the large gear. In the center of the large gear, there is a shaft that is attached to the chuck and drive it. The rotary switch is located on the top of the drill. It allows the users to select one of two modes of operation, which are counterclockwise and clockwise. Finally, while the drill is running, the wedge moves downward and forces the hammer mechanism forward. However, from this hammer mechanism, the design of impact wrenches was found.

[7] The impact wrench is known as impact gun, air wrench or torque gun. It is a socket wrench power tool that is designed to deliver torque. An impact wrench is an important tool for automotive repair work and designed to provide high torque at a medium speed.

Therefore, it is different from drill hammer which designed to provide rotational power at a relatively high speed. But our project is based on the idea of impact wrench which delivers torque to unscrew the nuts. Moreover, there are two major types of impact wrenches. There is a compressed air impact wrench known as pneumatic and an electric impact wrench which uses electrical power. They both deliver the same performance but air compressed has more power. In addition, their torque is around 100 Nm to 1400 Nm for heavy duty work. The only difference between them is that the electric impact can be used anywhere that electric power source is available. On the other hand, a pneumatic impact is hard to control and adjust the power. As a result of this high power the bolts can break if the user is not an expert. Moreover, a pneumatic impact wrench is most commonly used in workshops because it’s half cost the electrical impact and, also has a smaller size.

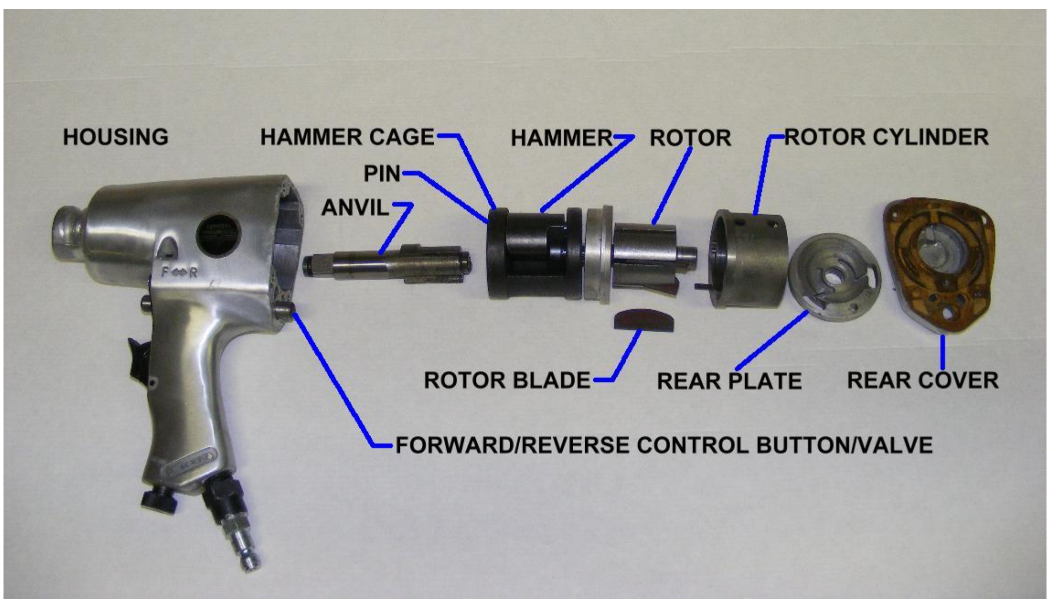


Figure 2.4: Components of impact wrench

[8] In figure 2.4, it shows the main components of pneumatic impact wrench. Firstly, adapter forces up the air through the handle. Then, the air is forced through channel to

rotor cylinder where air is compressed. After the air is compressed, it passes through the blades which convert the air compressed into kinetic energy. Then, the rotor turns by using centrifugal force which moves the rest of the blades partially out of the rotor where they are connected to rotor cylinder. In addition, rotor has a central shaft which passes through a bearing housing. Finally, there is a spline that forces a hammer cage and hammer to rotate with the rotor.

As known, one of the uses of impact wrenches is to change tires in workshops. Usually, the procedure takes around 1 min or more to change only one tire. Moreover, it is much faster than the traditional way with lug wrench. The lug wrench takes at least 15 minutes and sometimes the bolts are stuck and not easy to remove. In addition, lug wrench depends on an important factor to unscrew the bolts which is torque required to unscrew the lug nuts. Therefore, as the radius increases, the lower forces needed to unscrew the lug nuts. The main issue in using a lug wrench is that sometimes it takes so much effort to unscrew the nuts. Therefore, workshops use impact wrenches instead of normal lug wrench.

Detent pin anvil sizes of impact wrench come in different sizes because it depends on power of impact wrench too. As the torque increases, the Detent pin anvil diameter increases. So, heavy duty impact wrenches have larger detent pin anvil. Both electrical and pneumatic impact wrenches use standard sizes such as, 0.25-inch, 0.375-inch, 0.50-inch as shown in figure 2.5.

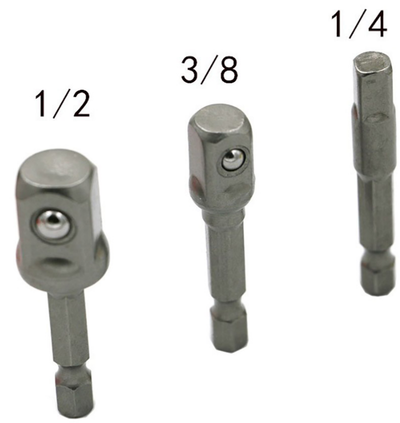


Figure 2.5: Most common sizes for detent pin anvil

2.4 Comparative Study

The objectives of the project [4] are to design a 4-nut removal mechanism and minimize the cost of it. This project uses one of most common types of gears, which is spur gears, to reduce the torque and force. The gear system is made of mild steel and has a 1:21.125 gear ratio and total weight of the product is 5.5 kg. The size of each nut is around 21mm and pitch circle diameter (PCD) of 114mm. Moreover, distance between nuts is 80mm. The gear system is supported by power window motor with a force of 2436 N to unscrew 4 nuts simultaneously. In addition, the torque required to unscrew one nut has been measured by using torque wrench and found the average torque to be around 140Nm. See table 2.1 [4]

Table 2.1: Torque measured at each nut for a normal used car

The torque measured at each nut (Nm)				
Tire	**Nut 1**	**Nut 2**	**Nut 3**	**Nut 4**
1	**138**	**143**	**140**	**135**
2	**150**	**147**	**135**	**136**
3	**140**	**134**	**142**	**160**
4	**135**	**133**	**134**	**138**
AVERAGE VALUE				

The project [5] is similar to the previous model, in the number of nuts and usage of spur gear to transmit motion to other gears. There are two type gears used, which are the primary gear (driver) and secondary gear (driven). In this model, the primary (driver) spur gear is connected to the motor by the shaft, which rotate to transmit power by using the motor. They used base plate made from cast iron to hold the gears and to withstand the forces from gears and the shaft extensions to hold the mechanism. This leads to stability and an increase of weight of mechanism. In addition, gears and the motor weren't covered and can be seen. Moreover, they claimed that their electrical motor has a power of 471 KW and minimum toque of 140 Nm, which seems to be too high for unscrewing lug nuts. The following figures show the design of their project from different views.

Figure 2.6: In the front view, the gear arrangement and the tool arrangement can be viewed.

Figure 2.7: In the back view, the motor arrangement can be seen. The motor is connected to the shaft which is connected to the primary gear.

Chapter 3: System Design

3.1 Design Constraints

3.1.1 Safety

Safety is considered to be an essential requirement for any project. Therefore, in this project, we will follow the international standards for choosing types of materials and parts being used that will lead to prevention of any failures caused by the mechanism.

3.1.2 Social & Economics

As we know, time is money. Therefore, using our project will save a lot of time, because it's fast and can screw or unscrew 5 lug nuts simultaneously. In addition, compared to the available mechanisms to change tires in workshops such as impact wrenches, our project is faster.

3.1.3 Engineering Standards

The project is consisting of many components, which are; gears, bearings, shafts, motor, and spanners. All of these components were selected based on existing standards such as SKF catalogue, and American Iron and Steel Institute.

3.1.4 Manufacturability

Our project can be manufactured easily, and it can be used in a wide range of applications such as tire manufacturing companies, workshops and portable using. On one hand, gears, bearings, and shafts will be manufactured based on their availability in the market. On the other hand, the motor will be selected based on the calculations of torque, horsepower and its availability in the market.

3.1.5 Time

As we all know, time is money, and our project is going to perform efficiently and save time by screwing and unscrewing all lug nuts simultaneously. Instead of using the normal way to unscrew nuts such as lug wrench, our prototype will allow the user to unscrew all 5 nuts in one move by using a gear train system to generate a torque to unscrew the five nuts simultaneously.

3.1.6 Quality

Quality of projects is a very important aspect of any design, and in our design we are making sure that the quality of materials used in the system and its parts is good and meets the standards.

3.2 Design Methodology

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. Also, in this phase we conduct the Gantt chart, where we divide the tasks and their time durations for the project. 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. Fourth phase is buying parts and manufacturing in market. Also, estimating the cost and the availability of parts in market whether there are gears, shafts, spanner and joints, because some parts need to be made in workshops. Finally, fifth phase includes welding, assembly of parts in workshops and testing our prototype.

3.3 Design, calculations and selections

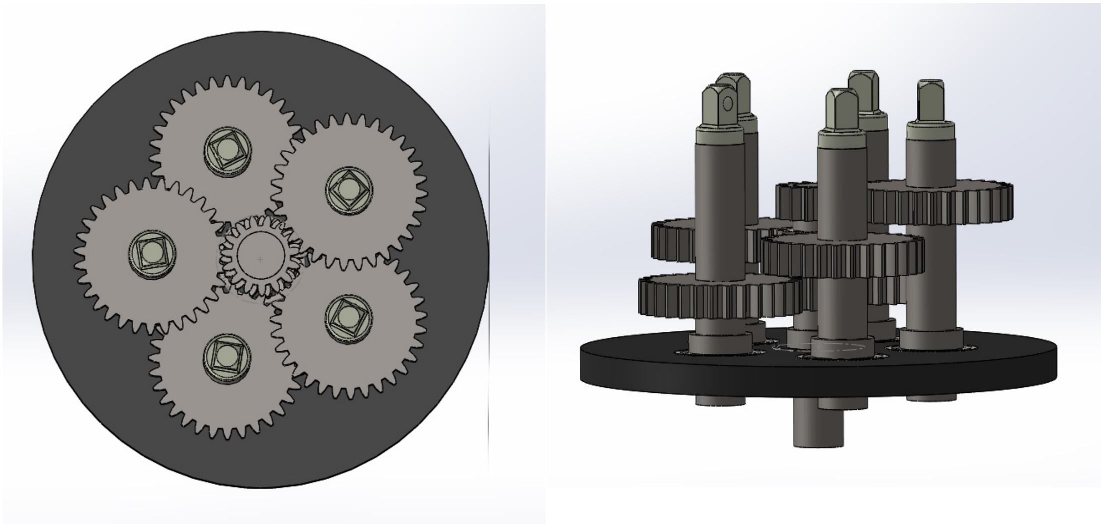
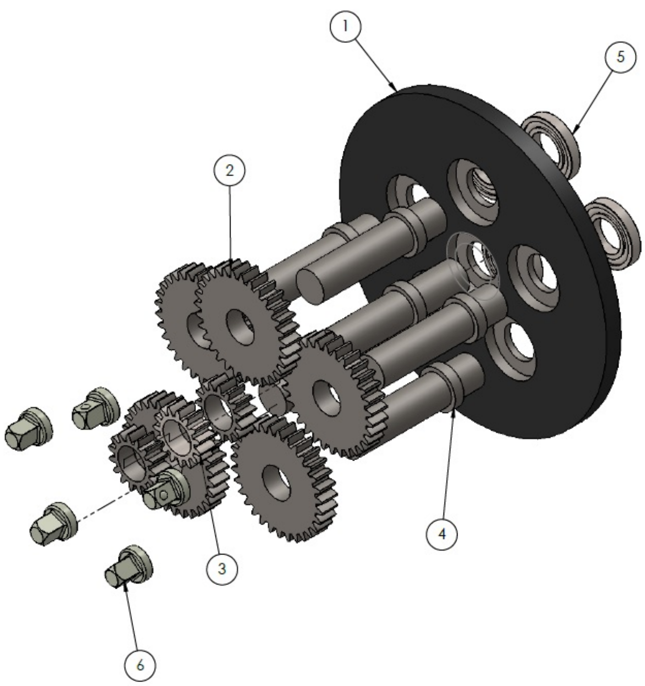


Figure 3.1: Assembly from different sides



ITEM NO.	PART NUMBER	QTY.
1	Disk	1
2	Metric - Spur gear	5
3	Metric - Spur gear	3
4	Shaft	6
5	Bearing	6
6	Joint	5

Figure 3.2: Exploded view of assembly

As shown in figures 3.1 and 3.2, our design has three levels because we couldn't design a different size of gears at the one level with a 114.3 PCD without avoiding gear interference. So, we started to build our design on an actual wheel hub, and we designed three levels to avoid the gear interference problem. See figure 3.3 below.

Figure 3.3: Car hub

The first level of our design has two driven gears and one driver gear. While the second level has two driven gears and one driver gear. Lastly, third level has one driven gear and one driver gear. Therefore, the total number of driven gears is five, and for the driver gears it's three. All driven and driver gears are held by 6 shafts. Moreover, gears and shafts are held by a circular plate and six ball bearings to reduce the rotational friction and support radial loads. Finally, in top of the shaft there is a wheel spanner to unscrew the lug nuts. Table 3.1 shows a summary of the design specification for gears, shafts, and the circular plate.

Table 3.1: A summary of design specification

	Driver Gear	**Driven Gear**	**Circular plate**	**Shaft**
No. of Teeth (mm)	15	31	-	-
PCD (mm)	15.624	35.624	114.3	-
Diameter (mm)	37	37.5	240	25
Module	2.5	2.5	-	-
Thickness (mm)	14	14	10	-
Pressure angle	20	20	-	-
Length (mm)	-	-	-	111

3.3.1 Gears Calculation

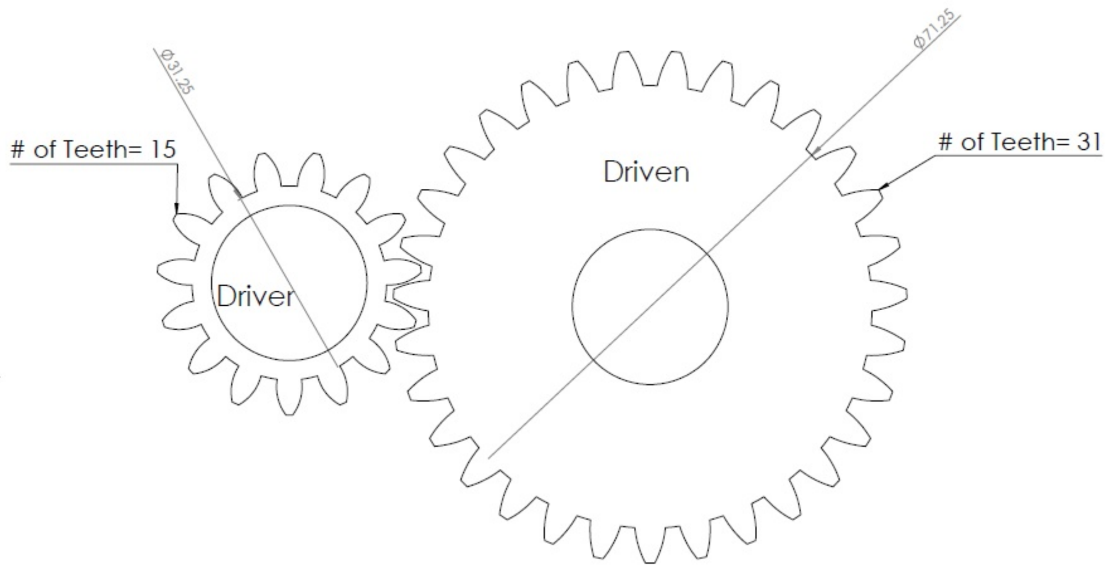


Figure 3.4: Driver and driven gears in mesh

Table 3.2: Driver and driven gears parameters

N_{driven}= 31	N_{driver}=15	D_{driven}=71.24	D_{driver}= 31.24

Module is calculated using Eq. 3.1

$$mo\square ule = \frac{d}{2} = \frac{71.24}{31} = 2.5\ mm \qquad \text{Eq. 3.1}$$

$-$ Based on the numbers of teeth the ratio is calculated using Eq. 3.1

$$Ratio\ = \frac{N.driven}{N.driver} = \frac{31}{15} = 2.066 \qquad \text{Eq. 3.2}$$

From the diameters of gears, we calculated the center distance Eq. 3.3

$$C = \frac{D.driven + D.driver}{2} = \frac{71.24+31.24}{2} = 51.24\ mm \qquad \text{Eq. 3.3}$$

3.3.2 Torque and Power Calculation

Based on standards for torque and specification to tighten one nut, we need at least is 59 Nm as shown in appendix B. The total torque to unscrew 5 nuts is 59 * 5 = 295 Nm. Then we can calculate estimate the torque and horsepower needed to unscrew the five nuts based on ratio of gears:

From the ration of gears, we calculated the torque on driver gears using Eq. 3.4

$$\frac{T.driven}{T.driver} = Ratio = \frac{295}{T.driver} = 2.1 \qquad \text{Eq. 3.4}$$

$$\rightarrow T = \frac{295}{2.1} = 140.5 \text{ N.m}$$

Speed at full load is 25 rpm, we calculated the power without full load using Eq. 3.5

$$\text{Power} = \frac{2n\pi T}{60} == \frac{2(201)(\pi)(140.5)}{60} = 2.9 \text{ KW} \qquad \text{Eq. 3.5}$$

Then we found horsepower using Eq. 3.5

$$1 \text{ hp} = 746 \text{ W} \rightarrow \frac{2900}{746} = 3.8 \text{ hp} \qquad \text{Eq. 3.6}$$

3.3.3 Material Selection

Table 3.3: Parameters for gears, shafts and materials

M_{31}= 453.527 grams	M_{15}= 61.525 grams	$D_{shaft=}$2.5 mm	Shear stress for steel 4140 = 327.5 Mpa	L_{shaft}=111mm

- **For all Shafts**

We calculated the maximum moment using Eq. 3.7

$Mmax = PL$= 4.45(.077) = 0.343 N Eq. 3.7

Section modulus was calculated by using Eq. 3.8

S =$\frac{\pi d3}{32}$=$\frac{\pi(0.025)\text{^}3}{32}$ = 1.534E-06 Eq. 3.8

Maximum stress was calculated using Eq. 3.9

$\sigma max = \frac{Mmax}{S}$ = 224 KPa Eq. 3.9

Maximum shear stress was calculated using Eq. 3.10

$\tau max = \frac{Tr}{J} = \frac{\frac{140.5(.0125)}{1}}{\frac{\pi(0.025)^4}{32}} = 45.8\ MPa$ Eq. 3.10

Safety factor was calculated using Eq. 3.11

SOF=$\frac{Max\ shear\ stress\ for\ material}{Max\ Shear\ stress} = \frac{327.5}{45.8} = 7.1$ Eq. 3.11

- **Bearing Calculation**

Catalog was calculated using Eq. 3.12

$$C_{10} = \left(\frac{\zeta Dn60}{\zeta R}\right)^{1/a} = \left(\frac{(5000)(200)(60)}{10^6}\right)^{1/3} = 3.9 \text{ KN} \qquad \text{Eq. 3.12}$$

From SKF website we determined the right bearing which will be provided in the implantation section. Table 3.4 shows the ball bearing specifications.

Table 3.4: Ball Bearing Specifications

Ball Bearing Specifications (KOYO, No.16005)

Inner diameter	25mm	Basic dynamic load rating	8.06 KN
Outer diameter	47 mm	Basic static load rating	4.75 KN
Thickness	8 mm	Fatigue load limit	0.212 KN
Mass bearing	0.055 kg	Limiting speed	20,000 rev/min

3.4 Product Subsystems and Components

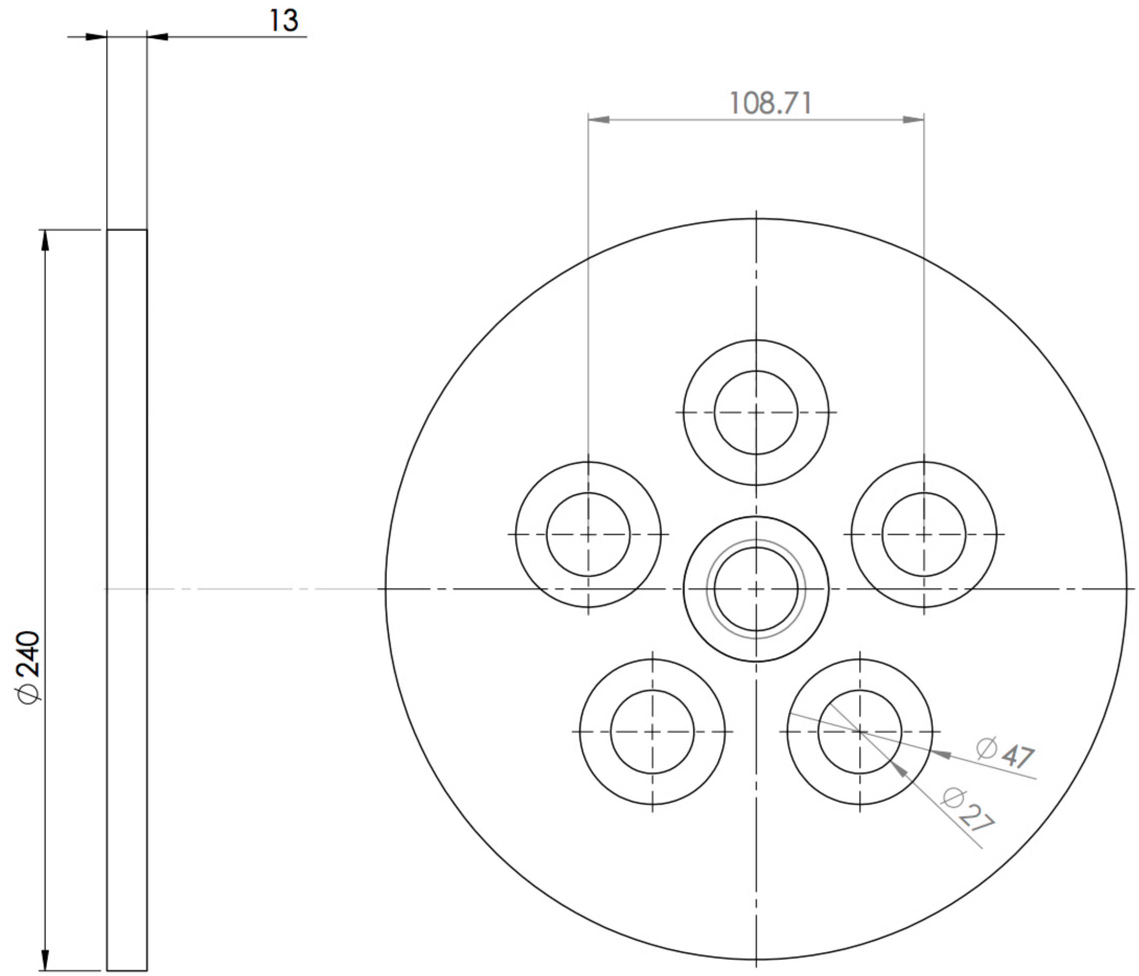


Figure 3.5: Plate

Figure 3.5 shows the plate used in our project which has 114.3 mm PCD that will hold the bearing, shafts, gears and spanners.

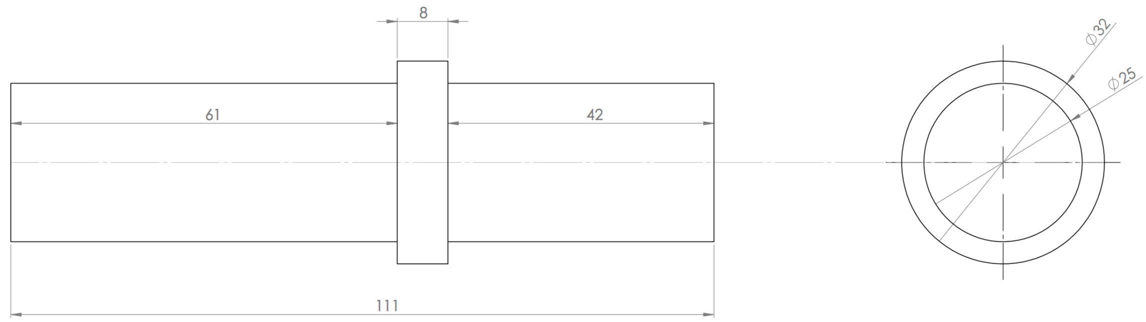


Figure 3.6: Shafts

Figure 3.6 shows the shafts used that will rotate and transfer the power to other shafts to unscrew the nuts.

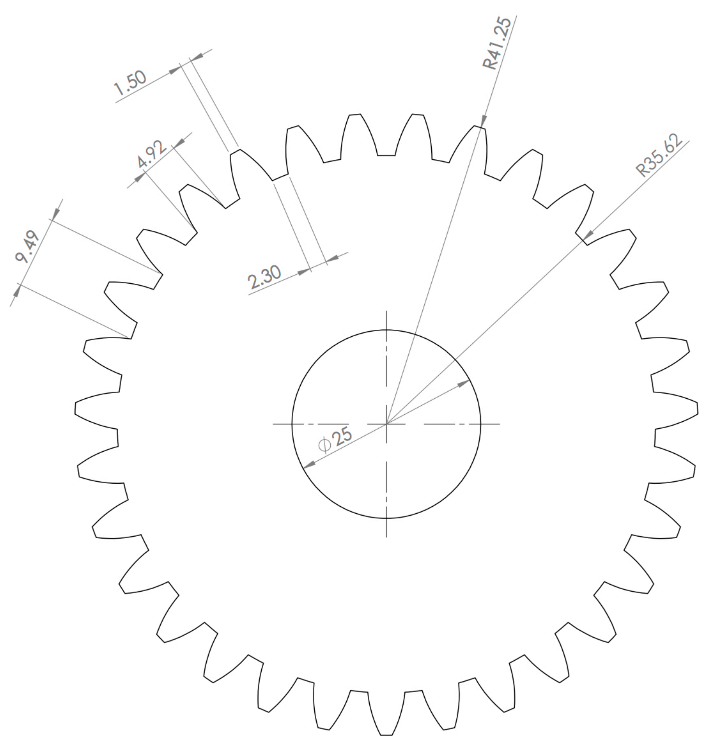


Figure 3.7: Driven Gears

Figure 3.7 shows the driven gears with 31 teeth will rotate and transmit the torque to other shafts to unscrew the bolts.

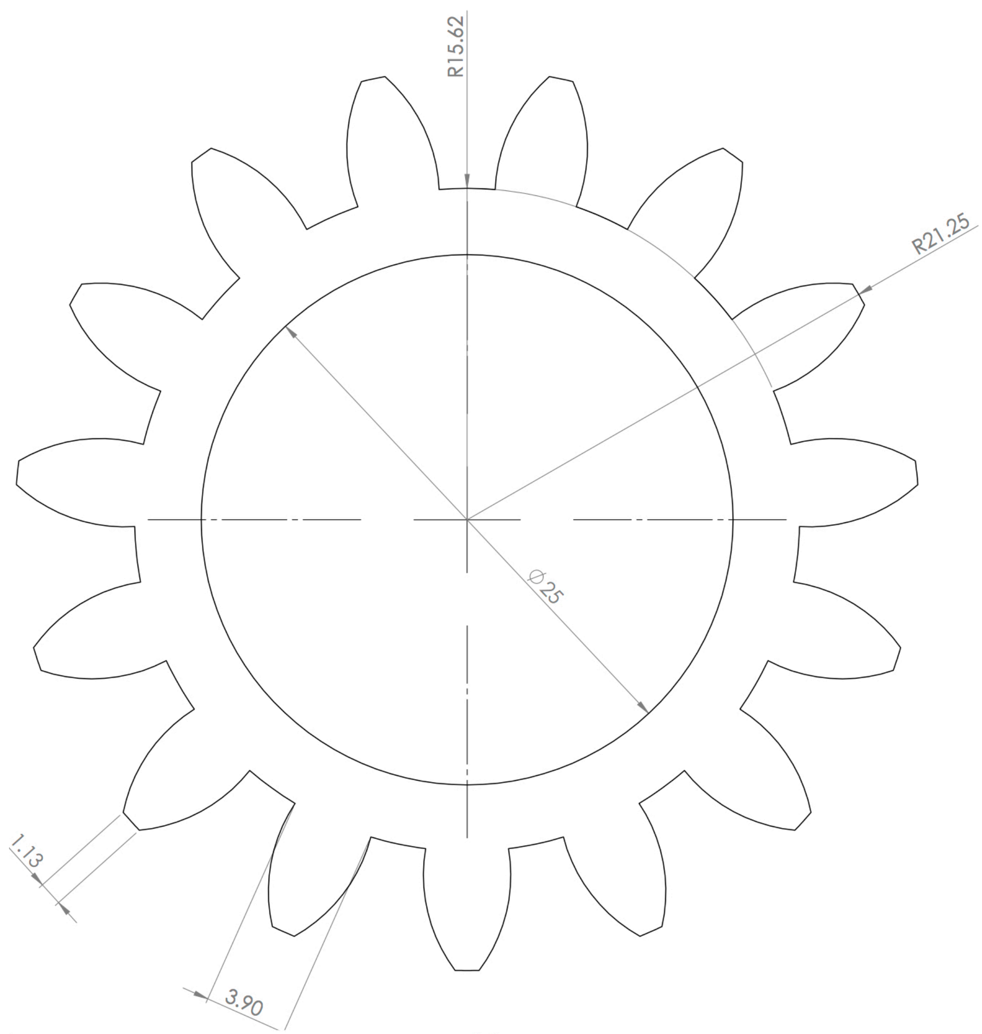


Figure 3.8: Driver Gears

Figure 3.8 shows the driver gears with 15 teeth will rotate and transmit the torque to other shafts to unscrew the bolts.

3.5 Implementation

Figure 3.9: Manufactured plate

Figure 3.9 shows the plate that is made from cast iron with 13 mm thickness. Each hole has a circle with 47 mm in diameter to hold the bearing from falling down.

Figure 3.10: Manufactured driven gears

Figure 3.10 shows driven gears with 31 teeth have a keyway to ensure that there is no relative rotation between two parts and it also enables torque transmission.

Figure 3.11: Manufactured shafts

Figure 3.11 shows the 25 mm diameter shafts have keyways to prevent relative rotation.

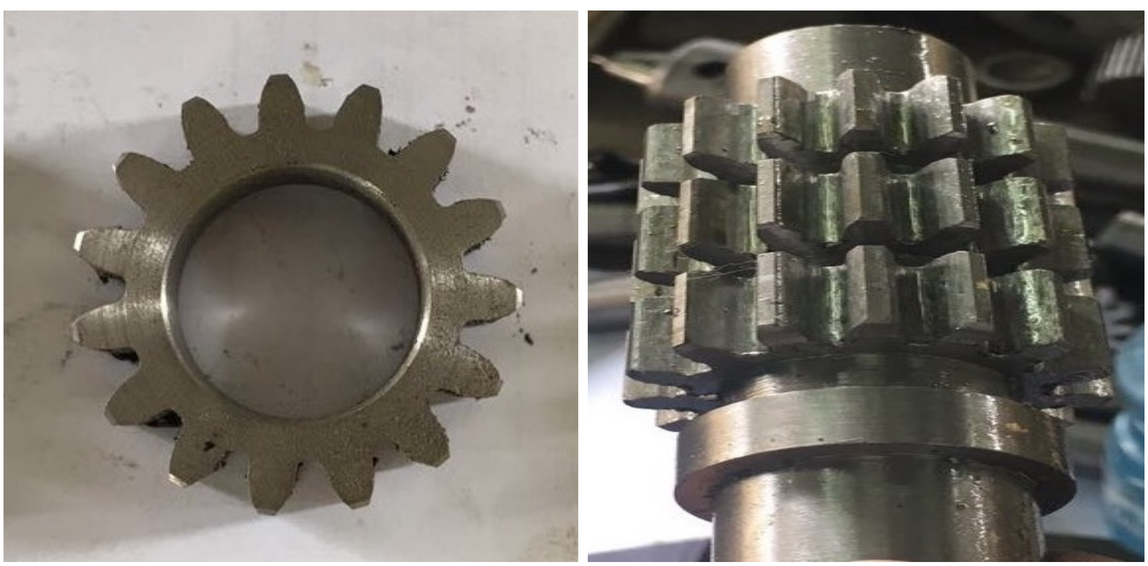


Figure 3.12: Manufactured driver gears

In figure 3.12, the picture on the left in figure 3.12 shows driver gears with 15 teeth. While the picture on the right shows the three gears attached to shafts after applying heat treatment to increase the hardness.

Figure 3.13: Lock washers

In figure 3.13, the purpose of using lock washers is to keep bearing from coming loose.

Figure 3.14: Head of Ratchet

In figure 3.14, the purpose of using the head of ratchet wrench is the continues rotatory motion. It allows only one direction while preventing motion in the opposite direction. We welded on the top so we can adjust the head wheel spanner to fix lug nuts.

Figure 3.15: socket wrench

In figure 3.15, it’s a small tool for tightening and loosening nuts of different sizes.

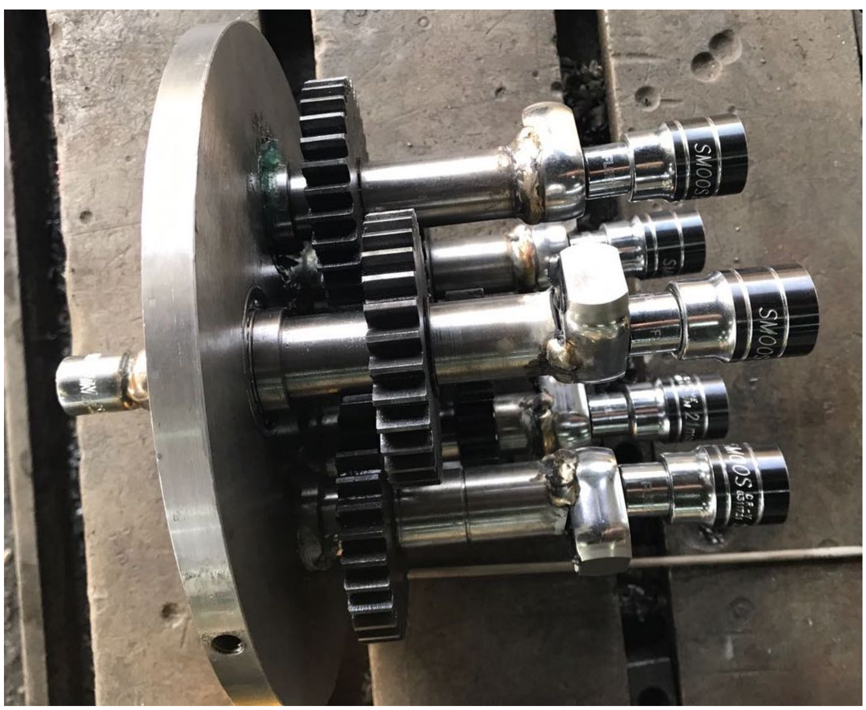


Figure 3.16: The final prototype (top view)

In figure 3.16, it shows the final prototype from the top view.

Figure 3.17: The final prototype (front view)

In figure 3.17, it shows the final prototype from the front view.

Chapter 4: System Testing and Analysis

4.1 Subsystem 1

We used DW292 1/2" Impact Wrench with Detent Pin Anvil, which can deliver a powerful forward and reverse torque, which is operated by electrical power. See figure 4.1 The main reason we chose the impact wrench is because it can provide a high torque with high RPM.

Figure 4.1: An impact wrench

Table 4.1: Specifications of impact wrench

Specifications			
Amps	**7.5 Amps**	**Weight:**	**3.2 kg**
Max Torque	**440 N.m**	**Length:**	**292 mm**
No load Speed	**2200 rpm**	**Height:**	**216 mm**
Impacts per Minute:	**2700 ipm**	**Voltage**	**220V**
Power output=	**370 Watts**		
Power input=	**710 Watts**		

After installing the impact wrench with the prototype, we tested the speed by using a digital tachometer and found it to be 201 RPM as shown in figure 4.2. The speed was less than total speed of impact wrench without load because of the high weight of prototype which is approximately 10 Kg.

Figure 4.2: Calculation of speed using a tachometer

4.2 Overall Results, Analysis and Discussion

Each car has its own sizes of nuts that are fixed in the wheel, and there are standards provided from manufacturing companies for tightening nuts. So, the torque to unscrew the nuts is different from a car to another, because the torque to tighten depends on several points:

- Geometry of lug nuts.
- Materials used in manufacturing the nuts such as Aluminum alloys or steel.

We did our tests on standard nuts as shown in table 4.2 below

Table 4.2: Dorman 611-299 Nuts Specification

	
Length	27 mm
Type	Acorn
Material	Chrome
Thread Size	M12-1.50 mm
Hex Size	21mm

So, to fit with the nuts size we bought a socket wrench with 21 mm hex size. But the size of socket is bigger to fit with the ratchet wrench. Therefore, we installed ratchet adaptor with 21 mm size of detent pin anvil to provide the size needed to fit with the socket wrenches as shown in figure 4.3.

Figure 4.3: After installing the adaptor to the ratchet wrench

Socket wrench can be replaced with different sizes but only M12 thread size. To sum up, the mechanism doesn’t work with all types of nuts especially the lug nuts larger than 21 mm hex size.

Figure 4.4: Back view of prototype

After completing the prototype, we did two main tests. First, we applied a force on the main shaft to make sure the mechanism works very well before installing the impact wrench as shown in figure 4.2. The result was that the gears didn't interfere with each other. Then we installed the impact wrench to test the mechanism on the nuts of the wheel.

Table 4.3: The time taken to unscrew nuts in seconds

Type of mechanism	Unscrew one nut	Unscrew five nuts
Lug wrench	50	250
Impact wrench	10	50
Our design	-	11

As a result, our project managed to unscrew all 5 lug nuts simultaneously in 11 seconds. Therefore, we achieved our objective of saving time, and it's better than the other mechanisms which are the lug wrench and impact wrench.

Chapter 5: Project Management

5.1 Project Plan

Table 5.1 shows the project's plan and the tasks required from us to finish the project successfully from the day we started working on it until the last day of the semester. Moreover, it helped us to manage our time perfectly, because we also had other courses that required us to do other projects. In addition, we had the advantage of working together equally in each task, and that made the work easier for us. So, in the end we managed to go through and finish the tasks mentioned in our Gantt chart successfully in time.

Table 5.1: Project's Gantt chart

No	Task	Assigned to	Start Date	End Date	# Of Workdays	%Completed
1	Meeting with Advisor	All members	16-Feb-17	18-Feb-17	2	**100%**
2	Meeting with group members (Brainstorming)	All members	18-Feb-17	21-Feb-17	3	**100%**
3	Assigning Tasks to team Members	All members	19-Feb-17	20-Feb-17	1	**100%**
4	Sketch the prototype (includes the parts such as, gears, bearings and shafts)	All members	21-Feb-17	25-Feb-17	4	**100%**
5	Searching for workshops & shops to find the required	All members	24-Feb-17	25-Feb-17	1	**100%**

	parts and their costs					
6	Start writing the first and second chapters of the report	All members	24-Feb-17	3-Mar-17		**100%**
7	Second meeting with team members	All members	3-Mar-17	3-Mar-17	1	**100%**
8	Completing 1st & 2nd chapters	All members	3-Mar-17	8-Mar-17	5	**100%**
9	Working on calculation	All members	10-Mar-17	20-Apr-17	40	**100%**
10	Looking for material of gears & shafts in workshop	All members	15-Mar-17	17-Mar-17	2	**100%**
11	Sketching parts, assembly in SolidWorks	All members	17-Mar-17	23-Mar-17	6	**100%**
12	Completing the conceptual design for the prototype	All members	23-Mar-17	26-Mar-17	3	**100%**
13	Testing the prototype using SolidWorks	All members	27-Mar-17	30-Mar-17	3	**100%**
14	Making 2D drawings for the parts	All members	30-Mar-17	2-Apr-17	3	**100%**
15	Determine the materials needed to manufacture gears & shafts	All members	3-Apr-17	9-Apr-17	6	**100%**

16	Completing chapter 3	All members	10-Apr-17	14-Apr-17	4	**100%**
17	Preparing for mid presentation	All members	18-Apr-17	24-Apr-17	6	**100%**
18	Midterm presentation	All members	25-Apr-17	25-Apr-17	1	**100%**
19	Manufacturing of parts and assembly	All members	25-Apr-17	5-May-17	10	**100%**
20	Testing the prototype	All members	6-May-17	8-May-17	2	**100%**
21	Completing chapter 4	All members	5-May-17	6-May-17	7	**100%**
22	Completing chapter 5	All members	6-May-17	8-May-17	2	**100%**
23	Completing chapter 6	All members	8-May-17	10-May-17	2	**100%**
24	Completing chapter 7	All members	10-May-17	12-May-17	2	**100%**
25	Submission day for the first final draft of final report		15-May-17	15-May-17	1	**100%**
26	Preparing for the final presentations	All members	13-May-17	19-May-17	6	**100%**
27	Revise the feedback given and modified our report	All members	19-May-17	24-May-17	5	**100%**

28	Submission date for updated corrected draft	28-May-17	28-May-17	1	**100%**
29	Oral Presentation and prototype summary Brochure and Stand	29-May-17	29-May-17	1	**100%**
30	Portfolios	29-May-17	5-Jun-17	1	**100%**

5.2 Contribution of Team Members

Table 5.2 shows the contribution of each team member of our group in completing this project's tasks.

Table 5.2: Contribution of team members

Team member	Contribution percentage
Mohammad Al-Otaibi (Leader)	25%
Yousef Naffaa	25%
Saeed Al-Ghamdi	25%
Abdullah Al-Zahrani	25%

5.3 Project Execution Monitoring

- Meeting with advisor and co-advisor:

We met with our advisor Dr. Muhammad Asad and co-advisor Dr. Nader Sawalhi several times during the semester to get their feedback and guidance.

- Meeting with team members:

We had weekly meetings with all members of our group to complete the required tasks. Additionally, we did all the tasks with an equal contribution of each member that helped us in progressing fast and complete the project.

- Testing:

After completing the manufacturing of our prototype, we tested it on an actual wheel to screw and unscrew all lug nuts simultaneously.

5.4 Challenges and Decision Making

- Material selection:

As we were making our conceptual design of the project, we made our calculations based on the available manufacturing materials in SolidWorks. Therefore, when we finished our design, we went to the local market to search for that specific material which is AISI 4340, but we couldn't find it, but eventually we found an alternative in the market, which is AISI 4140 and remade our calculations from scratch.

5.5 Project Bill of Materials and Budget

Table 5.3 shows the project bill of materials and budget. Mainly, the manufacturing of this project was expensive because of two main reasons. Firstly, it’s a prototype that is not manufactured for large quantities. Secondly, we couldn’t find gears in the local market, so we manufactured them in a workshop that costed us 5000 SR in total.

Table 5.3: Project bill of materials and budget

#	Item	Description	Quantity	Price
1	Bearings	Koyo 16005 Deep groove ball bearings	6	120 SR
2	Heads of wheel spanners	21mm	5	75 SR
3	Circular plate	240mm in diameter	1	550 SR
4	Spur gears	2.5M 31T 20PA 14FW	5	3500 SR
5	Spur gears	2.5M 15T 20PA 14FW	3	1500 SR
6	Shafts	111mm in length 25mm in diameter	6	750 SR
7	Motor (Impact wrench)	DW292-220	1	1376 SR
8	Adaptor	3/8”F – 1/2”M AD3812 Japan	5	62.5 SR
9	Socket wrench		5	175 SR
10	Washers		6	24 SR
11	Coupler		1	15 SR
		TOTAL		**8147.5 SR**

Chapter 6: Project Analysis

6.1 Life-long Learning

We chose this project due to its many applications in many different places such as workshops and tire manufacturing companies. While working on this project, we have gained a lot of experience, skills and knowledge that enhanced our abilities to find solutions for engineering problems. Moreover, in our project, we used PMU E-Resources and Google Scholar for gaining more knowledge regarding different aspects of our project. Additionally, our advisor and co-advisor provided us with constant guidance and useful knowledge that we used in our project throughout the semester that led eventually to the success of completing it.

6.1.1 Teamwork

Working in a team of four actually helped us gaining many skills that led to the success of this project such as communication skills, time management and knowing the strengths and weaknesses of each member, so the tasks can be divided accordingly. Moreover, working in a team enabled us to accomplish all the tasks efficiently, and complete the project successfully in time. Additionally, working in a team helped us to share different ideas and skills from all team members and combine them to generate the design of this project. Also, teamwork enabled us to gain and develop new skills that we haven't had before such as the skill of leadership. The skill of leadership was very important because you learn to lead all team members to complete difficult tasks and motivate them to share their opinions freely. Lastly, as we all know, a group of people working together may solve a difficult problem that an individual cannot.

6.1.2 Project and time management

In any project that a group of team members are working on, they will face some obstacles that may affect their work negatively. Therefore, time management skill was gained by doing a Gantt chart at the beginning of the semester to write the tasks that has to be done to finish this project and their time durations. In our Gantt chart that we have developed, tasks and their time durations were divided among the team members. Also, all team members have other courses to study for and require doing projects and assignments that may take a long time to finish. Therefore, time management skill helped managing each member's time efficiently and accurately. In addition, time management skill helped us gaining the skill of creating an effective working environment by setting of priorities, that helped us finishing the most important tasks at the beginning and then proceed to the less important ones to finish the project successfully in time.

6.1.3 Engineering skills and software

In this project, we learned a lot about the topics that we have already studied in courses such as Mechanical Engineering Design I & III, Mechanics of Solids and Manufacturing courses in a practical way. For example, we did calculations related to torque, gears, bearings and material selection and applied them to our design to make this project's prototype successfully. Moreover, Computer Aided Design course benefited us a lot in making and designing our project. Moreover, our project was designed using SolidWorks software due its many advantages of using it. Firstly, it helped us producing accurate designs of the parts and their assembly. Secondly, we used it to produce 2D drawings of the design to make the measurements clear to understand and to be applied in the manufacturing phase. Lastly, it helped us Producing animated videos of the motion, assembly, and disassembly of the design to see the mechanism of it clearly.

6.2 Impact of Engineering Solutions

Our project has many impacts on tire-manufacturing companies and workshops, as it will benefit them in many ways:

1. It will make the tire changing process a lot easier and save a lot of effort for the user, while other available changing tire mechanisms such as using lug wrench are difficult to use and takes so much effort.
2. It will save time, because as mentioned before, using our project will save time for changing tire process, and as for other available mechanisms it takes a lot of time. For example, customers at workshops don’t have to wait for long time if the workshop used our project, and the procedure will be easier.

6.3 Contemporary Issues Addressed

All over the world, when it comes to tire changing process, the first thing that comes to one’s mind that it’s tiring and takes time and effort. While as mentioned above, our design will make the process of changing tires easier and save time and effort for users. Therefore, large tire manufacturing companies such as Michelin, Continental, Bridgestone and Good Year will benefit from using this project.

Chapter 7: Conclusions and Future Recommendations

7.1 Summary and conclusions

To sum up, we successfully managed to design and manufacture an automotive tire changing mechanism that can unscrew 5 lug nuts of a wheel simultaneously. In addition, this project can be used in a variety of applications such as tire manufacturing companies and workshops. Moreover, while working on this project during the semester, we have gained a lot of skills. For example, we used the theoretical knowledge that we have gained from mechanical engineering courses and apply it in our project practically to design and manufacture our prototype. Additionally, this project wouldn't have been completed, without the equal contribution of each team member in completing the tasks. Finally, working on this project taught us how to work under pressure, especially that this semester was short.

7.2 Future Recommendations

Before finalizing the final design for the project, we recommend to search for the available parts and materials in the market, and find alternatives if the needed materials or parts are not available. In addition, sometimes you can't find the needed parts in the local market, so you have to order them online. Therefore, you have to order them early because sometimes it takes a lot of time to be delivered and it will affect your project's execution plan. Additionally, we recommend sticking to the tasks' time durations provided in Gantt chart to avoid any delay in completing the project.

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Felipe De La Cruz, Milton Hidalgo Ceotto

Appendix A: Bill of Materials

Project Bill of Materials and Budget

Table A: Project Bill of Materials and Budget

#	Item	Description	Quantity	Price
1	Bearings	Koyo 16005 Deep groove ball bearings	6	120 SR
2	Heads of wheel spanners	21mm	5	75 SR
3	Circular plate	240mm in diameter	1	550 SR
4	Spur gears	2.5M 31T 20PA 14FW	5	3500 SR
5	Spur gears	2.5M 15T 20PA 14FW	3	1500 SR
6	Shafts	111mm in length 25mm in diameter	6	750 SR
7	Motor (Impact wrench)	DW292-220	1	1376 SR
8	Adaptor	3/8"F – 1/2"M AD3812 Japan	5	62.5 SR
9	Socket wrench		5	175 SR
10	Washers		6	24 SR
11	Coupler		1	15 SR
		TOTAL		**8147.5 SR**

Appendix B: Tables

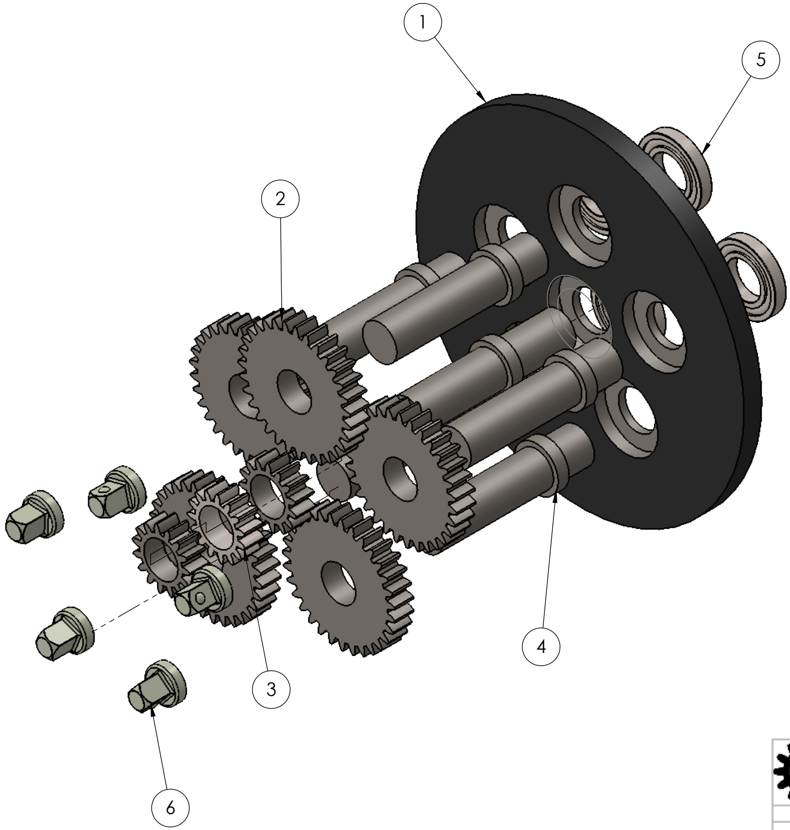
Table B.1: Specified torque for standard bolts

SERVICE SPECIFICATIONS – STANDARD BOLT

SPECIFIED TORQUE FOR STANDARD BOLTS

Class	Diameter mm	Pitch mm	Specified torque					
			Hexagon head bolt			Hexagon flange bolt		
			N·m	kgf·cm	ft·lbf	N·m	kgf·cm	ft·lbf
4T	6	1	5	55	48 in.·lbf	6	60	52 in.·lbf
	8	1.25	12.5	130	9	14	145	10
	10	1.25	26	260	19	29	290	21
	12	1.25	47	480	35	53	540	39
	14	1.5	74	760	55	84	850	61
	16	1.5	115	1,150	83	–	–	–
5T	6	1	6.5	65	56 in.·lbf	7.5	75	65 in.·lbf
	8	1.25	15.5	160	12	17.5	175	13
	10	1.25	32	330	24	36	360	26
	12	1.25	59	600	43	65	670	48
	14	1.5	91	930	67	100	1,050	76
	16	1.5	140	1,400	101	–	–	–
6T	6	1	8	80	69 in.·lbf	9	90	78 in.·lbf
	8	1.25	19	195	14	21	210	15
	10	1.25	39	400	29	44	440	32
	12	1.25	71	730	53	80	810	59
	14	1.5	110	1,100	80	125	1,250	90
	16	1.5	170	1,750	127	–	–	–
7T	6	1	10.5	110	8	12	120	9
	8	1.25	25	260	19	28	290	21
	10	1.25	52	530	38	58	590	43
	12	1.25	95	970	70	105	1,050	76
	14	1.5	145	1,500	108	165	1,700	123
	16	1.5	230	2,300	166	–	–	–
8T	8	1.25	29	300	22	33	330	24
	10	1.25	61	620	45	68	690	50
	12	1.25	110	1,100	80	120	1,250	90
9T	8	1.25	34	340	25	37	380	27
	10	1.25	70	710	51	78	790	57
	12	1.25	125	1,300	94	140	1,450	105
10T	8	1.25	38	390	28	42	430	31
	10	1.25	78	800	58	88	890	64
	12	1.25	140	1,450	105	155	1,600	116
11T	8	1.25	42	430	31	47	480	35
	10	1.25	87	890	64	97	990	72
	12	1.25	155	1,600	116	175	1,800	130

Appendix C: SolidWorks Drawings



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Disk		1
2	Metric - Spur gear	2.5M 31T 20PA 14FW ---S31N75H50L25N	5
3	Metric - Spur gear	2.5M 15T 20PA 14FW ---S15N75H50L25N	3
4	Shaft	Lenght= 11.1mm - Diameter=25mm	6
5	Bearing	SKF - 16005 - 14,SI,NC,14_68	6
6	Joint		5

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Project Advisors:
Advisor: Dr. MUHAMMAD ASAD
Co-Advisor: Dr. NADER SAWALHI

STUDENT NAME	ID
Mohammad Al-Otaibi	201202606
Saeed Al-Ghamdi	201101066
Yousef Naffaa	201201700
Abdullah Al-Zhrani	201101872

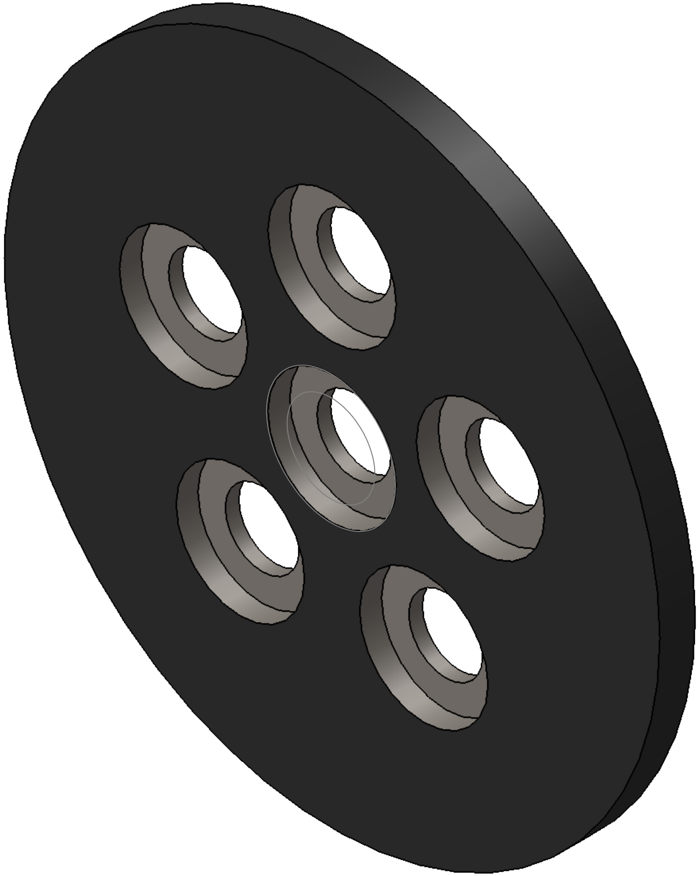
MATERIAL:

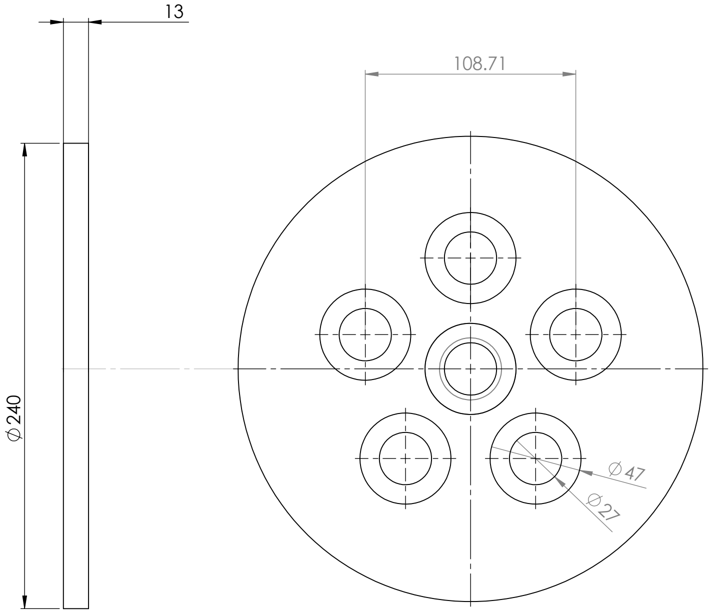
Learning Outcome Asse. III/ ME_110

Design & Manufacturing of Automotive Tire Changing Mechanism

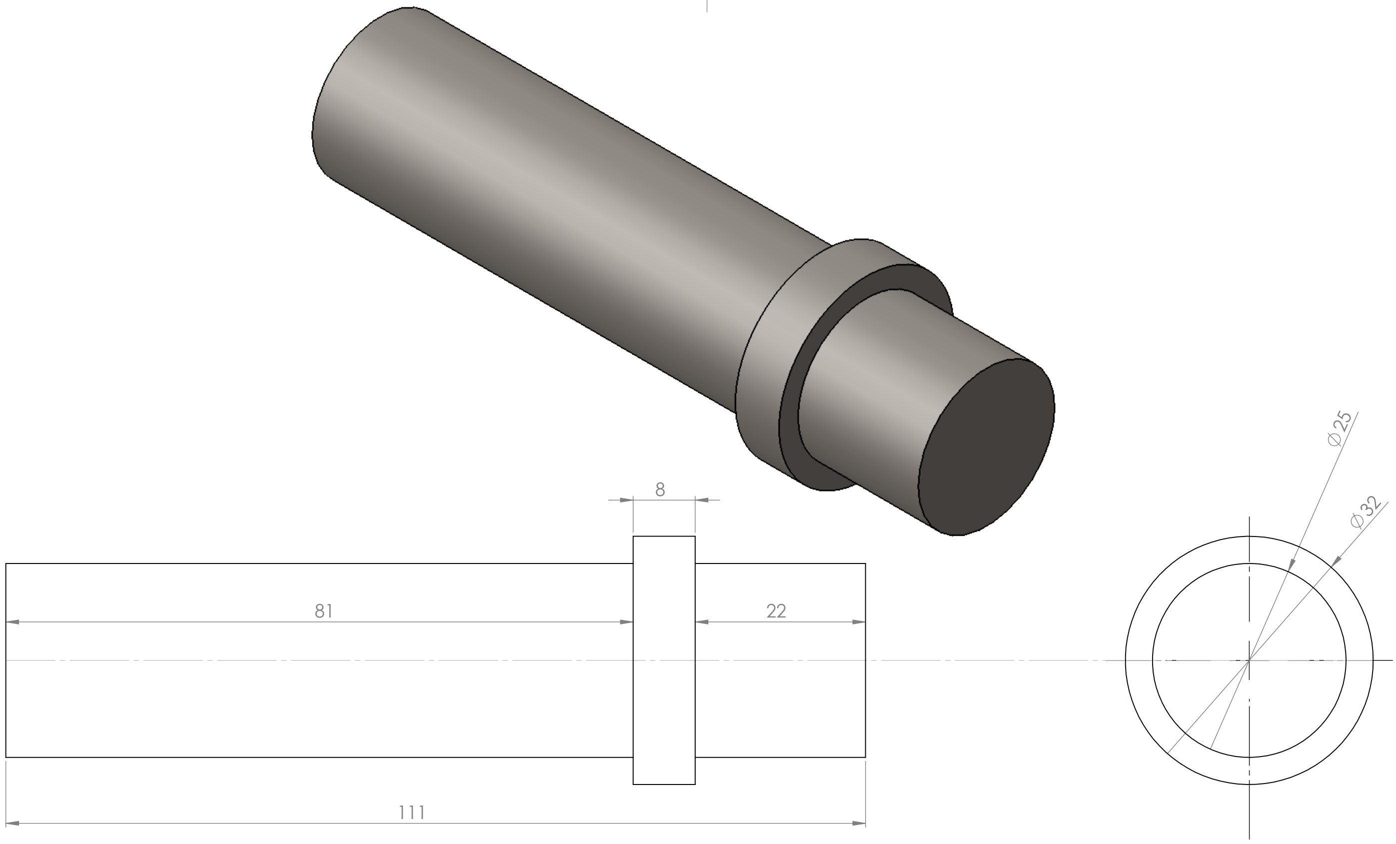
DWG NO.
Exploded View

SCALE:1:5
SHEET 1 OF 1





Project Advisors: Advisor: Dr. MUHAMMAD ASAD Co-Advisor: Dr. NADER SAWALHI			Learning Outcome Asse. III/ ME_110
STUDENT NAME	ID		Design & Manufacturing of Automotive Tire Changing Mechanism
Mohammad Al-Otaibi	201202606		
Saeed Al-Ghamdi	201101066		
Yousef Naffaa	201201700	MATERIAL: Cast Iron	DWG NO. Circular plate
Abdullah Al-Zhrani	201101872		



Project Advisors:
Advisor: Dr. MUHAMMAD ASAD
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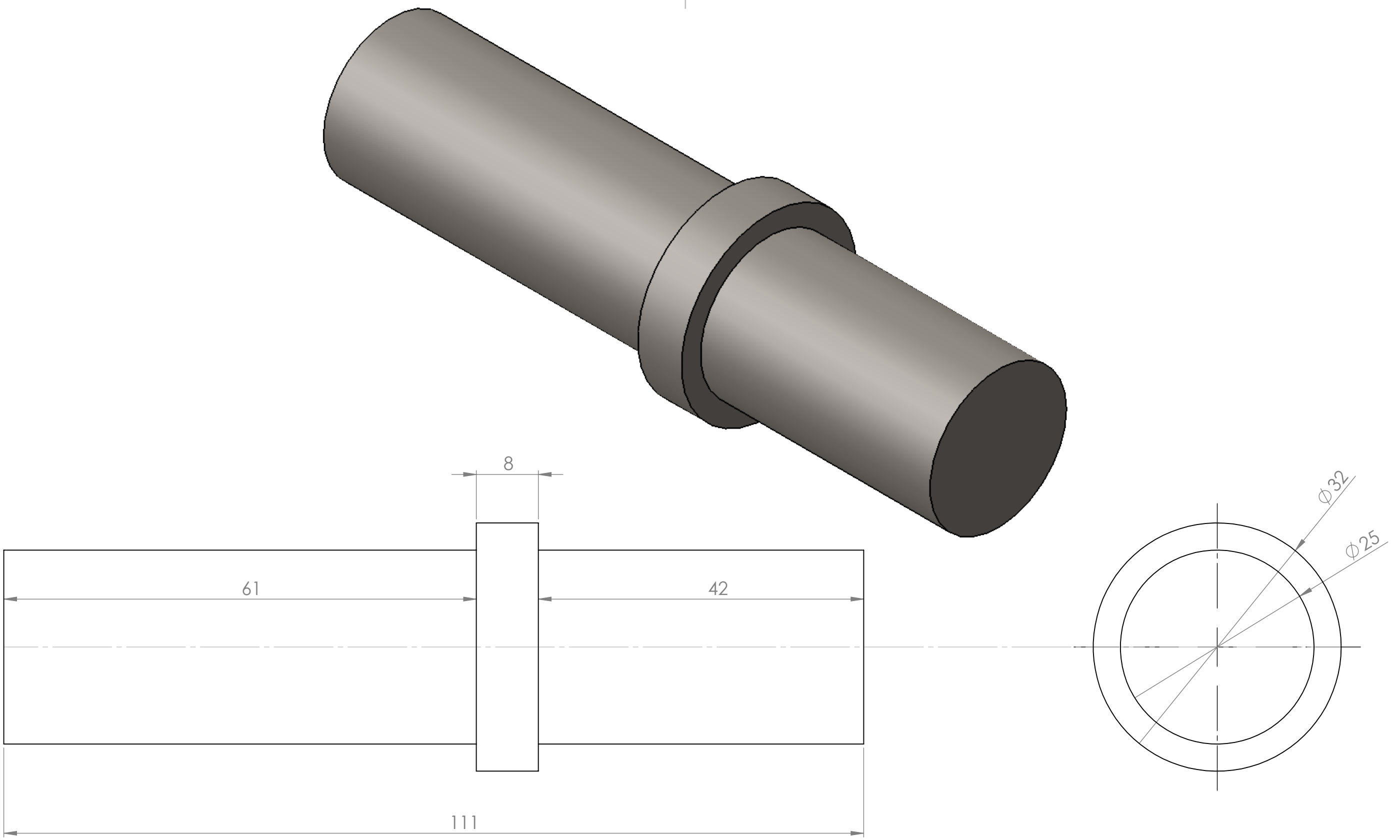
Learning Outcome
Asse. III/ ME_110

STUDENT NAME	ID
Mohammad Al-Otaibi	201202606
Saeed Al-Ghamdi	201101066
Yousef Naffaa	201201700
Abdullah Al-Zhrani	201101872

Design & Manufacturing of Automotive Tire Changing Mechanism

MATERIAL: AISI 4140

DWG NO. Shaft

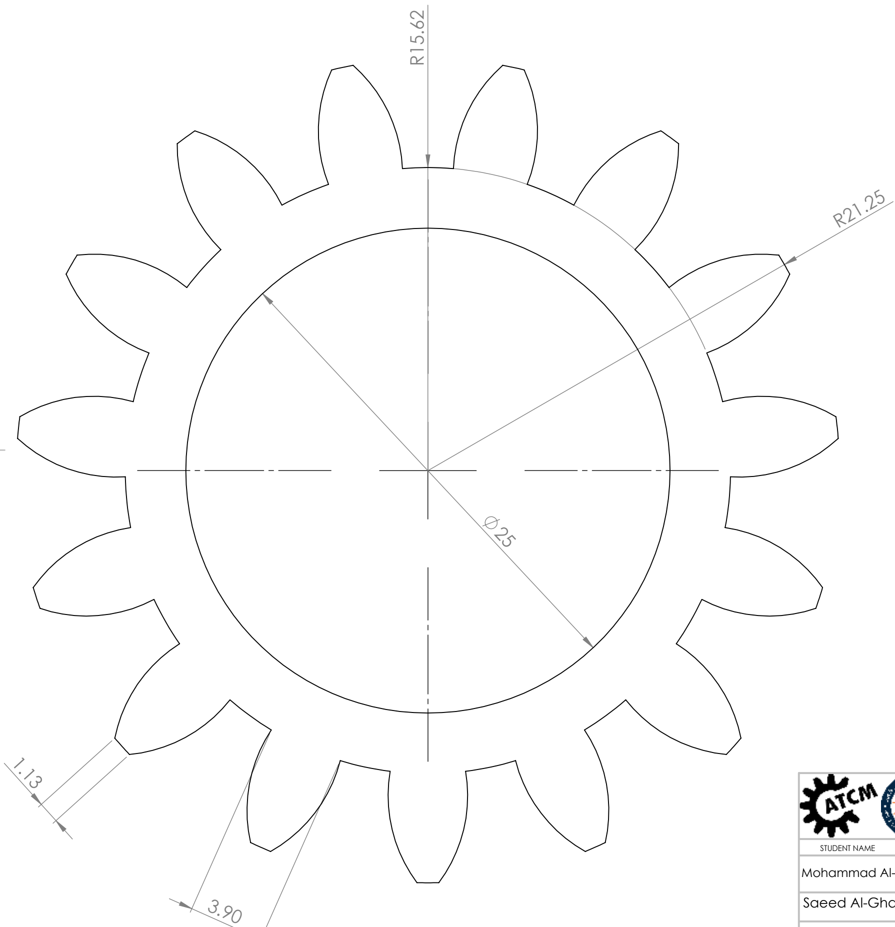


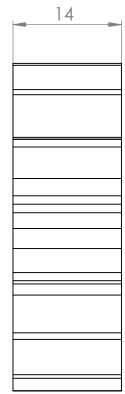
Project Advisors:		
Advisor: Dr. MUHAMMAD ASAD		
Co-Advisor: Dr. NADER SAWALHI		
STUDENT NAME	ID	
Mohammad Al-Otaibi	201202606	
Saeed Al-Ghamdi	201101066	
Yousef Naffaa	201201700	MATERIAL: AISI 4140
Abdullah Al-Zhrani	201101872	

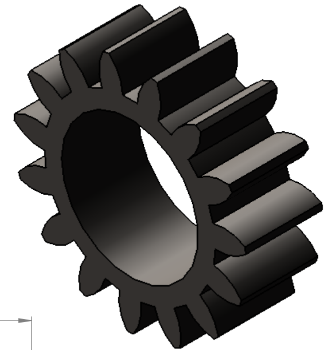
Learning Outcome
Asse. III/ ME_110

Design & Manufacturing of Automotive Tire Changing Mechanism

DWG NO.
Sun gear shaft







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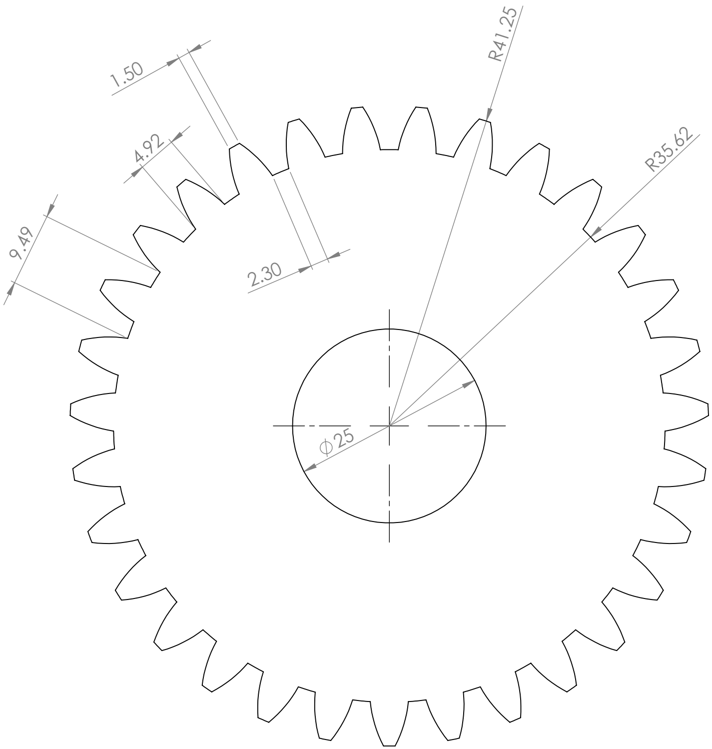
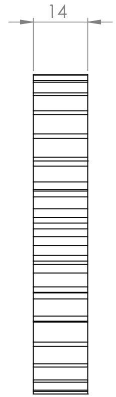
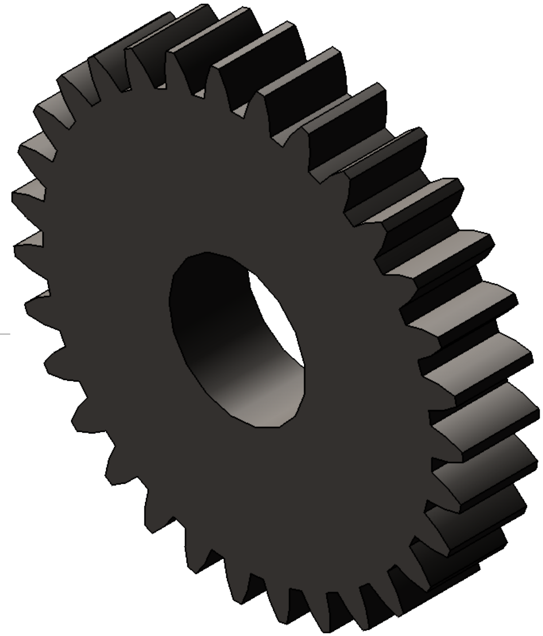
STUDENT NAME	ID		Design & Manufacturing of Automotive Tire Changing Mechanism
Mohammad Al-Otaibi	201202606		
Saeed Al-Ghamdi	201101066		
Yousef Naffaa	201201700	MATERIAL: AISI 4340	DWG NO. Spur gears 2.5M 15T 20PA 14FW
Abdullah Al-Zhrani	201101872		







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ATCM

Project Advisors:

Advisor: Dr. MUHAMMAD ASAD
Co-Advisor: Dr. NADER SAWALHI

Learning Outcome Asse. III/ ME_110

Design & Manufacturing of Automotive Tire Changing Mechanism

STUDENT NAME	ID
Mohammad Al-Otaibi	201202606
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Abdullah Al-Zhrani	201101872

MATERIAL: AISI 4340

DWG NO. Spur gears 2.5M 31T 20PA 14FW