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Presented by

BAIDJI Moussaab

DASSA Larbi

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Study and CAD of a Two-stage Speed Reducer with Bevel Gear

Jury :

Dr. SEDIRA Lakhdar	MCA University of Biskra	President
Dr. BEN MACHICHE Messaoud	MCA University of Biskra	Rapporteur
Dr.MOHAMDI Djemoui	MCA University of Biskra	Examiner

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بسم الله الرحمن الرحيم

Dedication

At the end of our university journey, the big thanks go to “Allah” who helped us to carry out this work.

We address our sincere thanks and deep gratitude to our supervisor “Dr BEN MACHICHE Messaoud” who agreed to supervise us and we thank him for his precious advices which was able to provide us, who helped us and followed judiciously during the realization of this work.

We would like to thank the members of the jury who agreed to do us the honor of examining and judge our work.

Our most sincere thanks go to our university “Mohamed Khieder University of Biskra” and all the teachers who contributed to our learning.

We would also like to express our sincere thanks to all the people who have contributed near or far to the realization of this work with the expression of our deep gratitude and perfect consideration.

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General Inroduction

Gear speed reducers and increasers, collectively labeled “gearboxes,” have probably been around for more centuries than any other machine. speed reducers perform duties in every industry today.

Gears are the core of speed reducers, they are one of the most fundamental mechanical devices in the world. Gears are particularly useful for the transferral and translation of rotary motion, and are able to manipulate speed, torque, and rotational axis within a given machine. Gears are so integral to our everyday lives that they can be found almost everywhere.

the transmission system in cars are one form of speed reducers, the one responsible of transmitting power from engine to wheels in vehicles.

This paper takes an in depth look at gear reducers and their use.

Objective

1. defenition, parts, history, function, applications of speed reducer
2. quick view on shafts and bearings
3. take deep view on the main component of speed reducers, the gears
4. talking about transmission as example ospeed reducer
5. making and studing a two-stage speed reducer with bevel gears by CAD (soliworks).

Chapter I
Speed Reducer

I.1. Defenition

A gear reducer is a mechanical system of gears in an arrangement such that input speed can be lowered to a slower output speed but have the same or more output torque. The operation of a gear reducer involves a set of rotating gears that are connected to a shaft with a high incoming speed, which is sent to a set of rotating gears where the speed or torque is changed. How many gears are in a gear reducer assembly is dependent on the speed requirements of the application.

The use of a gear reducer occurs when the drive gear is smaller and has fewer teeth than the driven gear. This is unlike the condition where the drive gear is larger with more teeth than the driven gear, which is referred to as overdrive.

Gear reducers are an essential component in cars and trucks where the high rotational speed of the engine is converted such that the slower motion of the tires can interpret and use the power safely. [1]

I.2. Features

Speed reducers have any number of different features, but by and large, they feature an input shaft, an output shaft, bearings, gears, gearboxes, and a gear motor.

Speed reducers accomplish the desired speed shift when the motor sends power to the reducer's input shaft, where it then converts said power into a lower output speed, so that the reducer can transfer it to the connected load through the output shaft. [2]

I.3. History

The first person to ever record a description of anything like a speed reducer was a Muslim polymath named Ismail al-Jazari. In a book that he wrote around 1206 AD, called The Book of Knowledge of Ingenious Mechanical Devices, al-Jazari talked about gearbox arrangements.

After that, no one really talked about or attempted to use gearboxes until the 19th century. This started in 1817, when a British manufacturing and engineering company called Watt & Boulton Engine designed a gearbox featuring two gears and a rotational speed governor. Around 60 years later, in 1881, engineers at de Dion-Bouton, a French company, started manufacturing gearboxes to be installed in steam-powered cars. Just seven years later, another set of Frenchmen, Emile Levassor and Louis-Rene Panhard, invented the gear and drive shaft assembly. Its goal was to generate the power needed for mechanical transmission.

In 1904, a set of American brothers, the Sturtevant brothers, invented what they called the "horseless carriage gearbox." What they invented was actually an early automatic power transmission speed reducer. Unfortunately, because they did not have access to adequate metal technology, the gearboxes could not thrive. Instead, they often broke down because they could not handle gear ratio shifts. In 1908, Henry Ford rolled out his Model T automobile. It shifted gears using planetary gearbox speed reducers.

For the first part of the 20th century, manufacturers mainly focused on developing speed reducer gears for use in the automotive industry. Over time, as technology evolved, this changed. Today, manufacturers produce speed reducers in a wide range of sizes for a wide range of applications, from sophisticated robotics to conventional bottling and beverage practices. Modern speed reducers boast high precision, energy efficiency, improved reduction ratios, complex design possibilities, and versatility. As the years go on, we expect engineers to only advance these qualities. [2]

I.4. function

Speed reducers primarily serve two functions. First, they take the torque created by the power source (the input) and multiply it. Second, speed reducers, much as the name implies, reduce the speed of the input so that the output is the correct speed.

A gear reducer is generally used for low-speed and high-torque transmission systems. The output gear of a speed reducer has more teeth than the input gear. So, while the output gear might rotate more slowly, reducing the speed of the input, the torque is increased. To sum up, the combination of large and small gears will reduce speed while increasing the torque.

The ratio of the number of rotations of a driver gear to the number of rotations of a driven gear is known as a gear ratio. By changing the torque/speed output, a machine (usually a motor or an engine) can be precisely controlled and better results attained. Torque output of a speed reducer can be calculated by multiplying the output torque of the motor and reduction ration (Note that the actual torque output of the speed reducer shall not exceed its rated torque). In decelerating the motor, gearboxes also reduce the reflected load inertia to the motor by a factor of the square of the gear ratio. [3] [4]

I.5. Process

I.5.1 Gear Ratio

The gear ratio is a way of measuring how different sizes of gears interact to transfer energy. The essential aspect of this calculation is the measurement of a circle, which is a major part of gears. The determination of the gear ratio can be understood by examining the circumference of a circle. A gear that makes two rotations to turn a larger gear once has a ratio of 2:1, which means that the output speed has been cut in half.

This example simplifies more complex gear reducers with several gear pairs in a series for converting revolutions per minute (RPMs) to torque. The example below presents a slightly more complex gear reducer with an idler gear between the small gear and the larger.

In determining the gear ratio, the only gears that influence the gear ratio are the drive gear and driven gear. Any gears inserted in between the two are not calculated in the gear ratio. An easy way to calculate the gear ratio is to count the number of teeth in the drive and driven gear. In the example, the drive gear has seven teeth while the driven gear has 30. The drive gear has to turn 4.3 times before the driven gear will turn. [1]

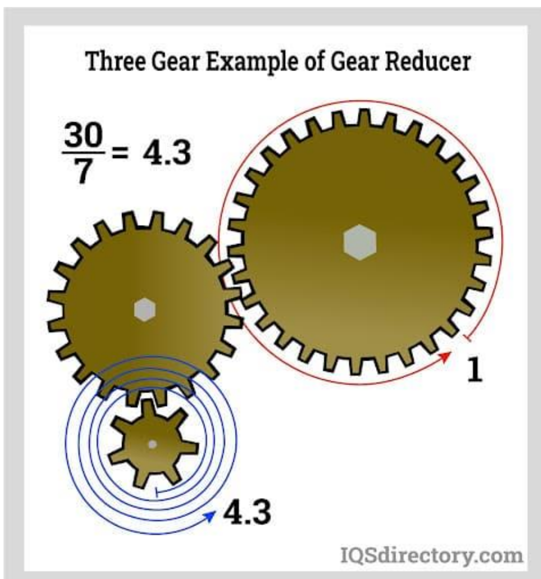

Figure I- 1 : three gear example of gear reducer

I.5.2 Gear Reducer Torque

Torque is a rotational force that is received by the gear reducer and changed into a different force and speed with the amount of power remaining the same. Gear reducers are a gear or series of gears designed to reduce the torque of a motor, which increases in direct proportion to the reduction of rotations per unit of time or revolutions per minute. This is accomplished by base mounted or shaft mounted gear reducers.

Gears are used to multiply or divide torque, which is determined by the size of the gears. The ratio of the gear sizes increases or decreases torque, which is the foundational aspect of the operation of a gear box. [1]

I.5.3 Drive Gear

Drive gears or gear drives are designed to change the speed, torque, or direction of a rotating shaft. In their simplest form they are a small gear that drives a larger gear connected to the output shaft. They are essential for providing variable output speed from a constant power source.

In the image below, the silver worm shaft with a worm gear is the drive gear for this two gear gear reducer. The driven gear is the brass colored worm wheel of the worm gear set. [1]

I.5.4 Driven Gear

The driven gear is connected to the output shaft and transfers the reduced power to the application. They are the larger of the gear set regardless of how many gears there are in the series and come in a variety of shapes. In the compound gear train example below, there are two driven gears connected to different shafts, B and C. The gear ratio for the driver gear for shaft B and the one for shaft C is the same. [1]

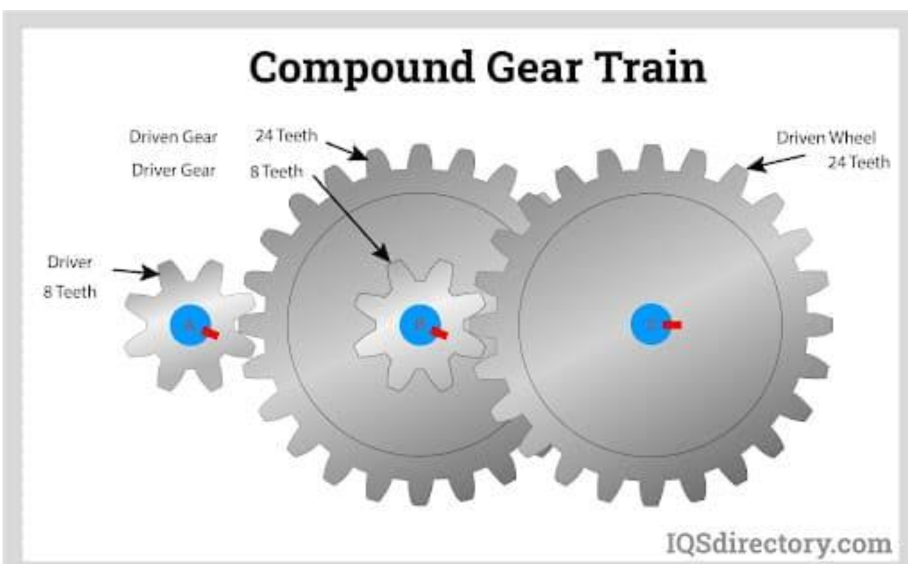

Figure I- 2 : compuned gear train

I.6. Design

Speed reducers service various devices, and they are offered with a variety of specific loads and torque capacities, though they are all made from strong, durable metals like steel.

I.6.1 Production

To make speed reducers, manufacturers must start by making the gears and gear shafts. They make gears using cutting and forming processes like blanking, broaching, form milling, and/or hobbing. They make gear shafts using metal forming processes including forging, extrusion, casting, and the like.

Once they have made the gears and gear shafts, manufacturers move on to the gear housings. Generally, they make these with CNC die casting equipment.

Next, they put together the gear motors, which are made up of a number of parts, including an electric power source (AC or DC). Then, they take all the parts and assemble them to make one speed reducer. As a final touch, manufacturers often add lubrication to the speed reducer to help it resist abrasion and corrosion from heat and friction. [2]

I.6.2 Materials

Manufacturers fabricate speed reducers using steel, hardened steel, or plastic. Steels are popular because of their durability, abrasion resistance, and corrosion resistance. Plastic is a good substitute for metal when a customer is looking to reduce the product's weight or cost. Plastic speed reducers also have the added benefits of low speed meshing and dirt tolerance. [2]

I.6.3 Considerations

When designing speed reducers, manufacturers consider a number of different application requirements and specifications, such as gear pitch, gear output, input and output torque capacities, and load capacities. Based on these, they can choose the details of product features, including its reduction ratio (the ratio of input speed to output speed), its size, and its total number of gears.

To make your speed reducer work at optimum level for your application, manufacturers can customize it in a number of different ways. In addition to customizing your speed reducer size, reduction ratio and gear numbers, they may also outfit them with extra speed control elements, like sheaves, v-belts, sprockets, or chain drives. [2] [6]

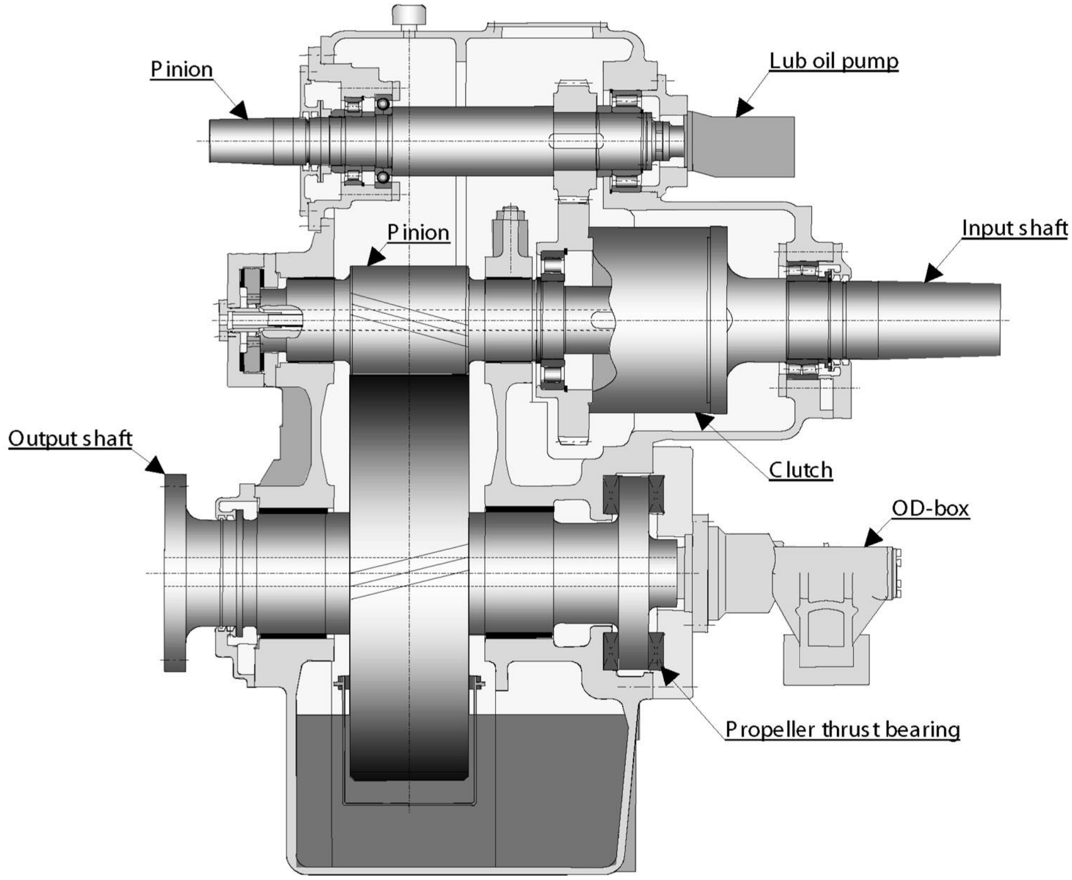

Figure I- 3 : components of speed reducer

I.7. Applications

Thanks to its compact structure, large range of power transmission, reliability, long life, high efficiency, simple use and maintenance, the speed reducer is widely used in various mechanical transmission systems as well as motion mechanisms from ships, automobiles, locomotives, heavy machinery used in construction, processing machinery and automated production equipment, to home appliances, clocks and watch, etc. Its applications cover reducer, food and light industry, electric machinery, construction machinery, metallurgical machinery, cement machinery, environmental protection machinery , Electronic appliances, road construction machinery, water conservancy machinery, chemical machinery, mining machinery, conveying machinery, building materials machinery, rubber machinery, petroleum machinery and other industries have strong demand for reducer products. [4]

I.8. Advantages

Customers use speed reducers for many reasons. Their many benefits include performance improvement, minimal energy loss, increased equipment lifespan, speed optimization, and flexible configuration options. Also, newer speed reducers require less fuel or electricity to work, furthering efficiency even more. As reduction ratios continue to reach new heights and designs become more complex, manufacturers are meeting new goals and creating greater power capacities. [2]

I.9. Failure

Mechanical failures are a great concern with any application and is a topic of conversation and study that is commonly broached. When a system is not operating, it ultimately results in lost productivity, and by extension, money. Maintenance teams, line workers, and other staff are all working tirelessly to get the system back on-line as quickly as possible, and during this time, no product is being manufactured. So what causes failures? Like all rotating equipment, there are many potential reasons for breakdowns and downtime, but it usually comes down to one of two issues: [5]

I.9.1 Poor system design

When it comes time to design a system with gear reducers, it's important that the proper research, time, and care be given in the process. Choosing the wrong reducer, failing to take into consideration all requirements or operating environments, or under sizing a reducer to save a small amount of money in the short term are all potential pitfalls. Therefore, it is important to do proper research before installing an entire system! "You can pay me now, or you can pay me later" – it is far better to put the proper resources into your application at the start and be set up for far more longevity, than to have unexpected downtime later resulting in extreme loss of productivity and income. [5]

I.9.2 Failure to maintain

You wouldn't buy a brand-new truck, drive it off the lot and say "this car is new. I'll never need to change the oil," would you? Of course not. Sure – for the first few months – perhaps even a year or so – everything would be fine. But eventually, that truck is going to need a new engine when parts start to warp, overheat, and wear out. Most gear reducers are the same – the oil within needs to be set to a specific level and needs to be changed regularly according to the manufacturer’s specifications. Every gear reducer should have a specified preventative maintenance plan in place, where the hardware is routinely checked for safe and correct operating conditions. Many companies also use automated systems to monitor the various parts of their applications, such as vibration sensors, or heat signatures, to give an early warning of problems that may appear .[5]

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Chapter II
Bearings and Shafts

II.1. Bearings

II.1.1 Defenition

A bearing is a mechanical part that allows linear or rotational movement and reduces friction between two objects. It eases the movement, reduces fatigue, and improves speed and efficiency between the parts.

As shafts that are required to rotate are used in different kinds of machines, bearings must be a feature to offer their great benefits. The mechanical part is widely used in automobiles, aeroplanes, electric generators, refrigerator, air-condition, vacuum cleaners as well as home appliances. With the list of this bearing applications, it seems we humans can’t do without them.[1]

II.1.2 Features

Bearings usually consist of the following components:

. Two rings or discs with raceways

. Rolling elements in the form of rollers or balls

. A cage which keeps the rolling elements apart and guides them [2]

Figure II- 1 : bearing features

II.1.3 Functions

Apart from making machines to work smoothly, bearing still accomplish the following two major functions.

. Friction reduction and ensuring ease rotation

As friction is a most occur event between two rotating shafts especially when lubrication is eliminated. Bearings are used between the parts to make the rotation smoother. Note that some bearings allow lubrication. Energy consumption is cut down since the friction is reduced.

. Bearing protect the part that supports the rotation and maintain the position of the shaft

Another primary purpose of the mechanical component is to withstand a large amount of force between the rotating shaft and the part that support the rotation. Bearings maintain the exact position of the rotating shaft. [1]

II.1.4 Types

We take a deeper look into the different types of bearings and their uses.

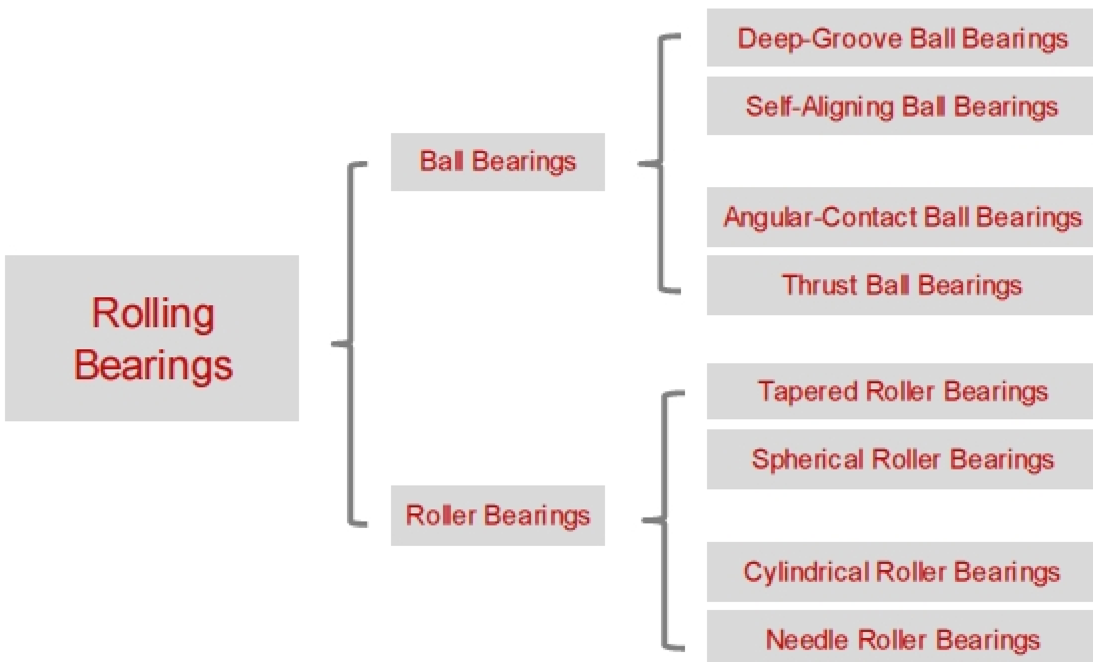

Figure II- 2 : main types of bearings

II.1.4.1 Ball Bearings

Ball Bearings are mechanical assemblies that consist of rolling spherical elements that are captured between circular inner and outer races. They provide a means of supporting rotating shafts and minimizing friction between shafts and stationary machine members. Ball bearings are used primarily in machinery that has shafts requiring support for low friction rotation. There are several configurations, most notably shielded or sealed. Ball bearings are standardized to permit interchangeability. Ball bearings are also known as rolling element bearings or anti-friction bearings. Considerations include

. First choice for high speeds or high precision apps

. Large range of standardized forms

. Handle radial and axial loads with specific configurations [2]

II.1.4.1.1 Types

. Deep-Groove Ball Bearings

. Angular Contact Ball Bearings

. Self-Aligning Ball Bearings

. Self-Aligning Ball Bearings [2]

Figure II- 3 : types of ball bearings

II.1.4.2 Roller Bearings

Roller Bearings are mechanical assemblies that consist of cylindrical or tapered rolling elements usually captured between inner and outer races. They provide a means of supporting rotating shafts and minimizing friction between shafts and stationary machine members. Roller bearings are used primarily in machinery with rotating shafts that require the support of heavier loads than ball bearings provide. Tapered roller bearings are often used to accommodate higher thrust loads in addition to the radial loads. Types range from cylindrical to spherical rollers. Roller bearings are standardized like ball bearings, albeit to a lesser degree. Considerations include

. Higher load capacities than ball bearings

. Can withstand high axial loads [2]

II.1.4.2.1 Types

. Spherical Roller Bearings

. Cylindrical Roller Bearings

. Tapered Roller Bearings

. Tapered Roller Bearings [2]

Figure II- 4 : types of roller bearings

II.1.4.3 Mounted Bearings

Mounted Bearings are mechanical assemblies that consist of bearings housed within bolt-on or threaded mounting components and include pillow blocks, flanged units, etc. They provide means of supporting rotating shafts and minimizing friction between shafts and stationary machine members. Mounted bearings are used primarily in machinery with exposed rotating shafting. They are used as take-up devices on the ends of conveyors and as flanged units along intermediate points. The bearings can be rolling element or journal bearing configurations. Mounted bearings are designed for bolt-on mounting and ease of replacement. Other varieties of mounted bearings include rod end bearings and cam followers. Considerations include

. Housed units reduce mounting concerns, protection issues

. Cartridge designs ease replacement

. Shafts usually held in place with set screws

. Allow adjustment of the supported components

. Mainly used for low/mid speed applications [3]

Figure II- 5 : Mounted Bearings

II.1.4.4 Linear Bearings

Linear Bearings are mechanical assemblies that consist of ball or roller elements captured in housings and used to provide linear movement along shafts. Linear bearings are used primarily in machinery that requires linear movement and positioning along shafts. They also may have

secondary rotational features depending on the design. Considerations include

. Lower friction and higher accuracies compared with bushings

. Costlier and more complex than bushings [3]

II.1.4.5 Slide Bearings

Slide bearings are mechanical assemblies designed to provide free motion in one dimension between structural elements. Slide bearings are used primarily in the structural support of bridges as well as commercial and industrial buildings. These parts accommodate thermal movement, allow for end-beam rotation, and isolate components of the structure against vibration, noise, and shock. Other types of slide bearings include those used on truss base plates, heat exchangers, and process equipment. [3]

Figure II- 6 : Slide Bearings

II.1.4.6 Jewel Bearings

Jewel bearings are mechanical devices used in light rotating applications such as watches, meter movements, gyroscopes, etc. where loads are small and the supported rotating shafts are tiny. Jewel bearings are constructed from a range of synthetics, with ruby and sapphire being particularly common. [3]

Figure II- 7 : Jewel Bearings

II.1.4.6 Frictionless Bearings

Frictionless bearings are mechanical or electro-mechanical alternatives to conventional bearings that provide controllable shaft support through air, magnetic fields, etc. for critical, high precision applications. [3]

II.1.5 Applications

All bearings need to demonstrate low friction, guidance with minimum runout or play, quiet running, low lubricant requirements, little wear and a long service life.

In addition to this, different industry sectors, operating environments and applications have their own specific requirements. They include:

. Very high or low temperatures and/or differences in temperature

. Moisture

. Speeds/revolutions per minute

. Resistance to dirt

. Aggressive media such as acid and alkaline solutions

. Powdery media such as liquid gas and process dust

. Suitability for food contact [3]

II.2. Shafts

II.2.1 Defenition

A mechanical shaft is a mechanical power transmission element, usually circular in cross-section, either solid or hollow, which transmits torque and rotational motion from one device to another.

Machine elements such as gears, pulleys, flywheels, clutches, and sprockets are mounted on various shaft types and are used to transmit power from the driving device such as motor or engine. Vehicle crankshaft is a prime example of a mechanical shaft as shown in the above figure. [5]

II.2.2 Types

II.2.2.1 Transmission Shafts

The transmission shaft is one of the essential machine components that provides the axis of rotation, oscillation, and regulates the motion geometry; used to transmit power between the source and the machine absorbing power. e.g., countershafts, line shafts, and all factory shafts.[4] [5]

Figure II- 8 : Transmission Shafts

II.2.2.2 Machine Shafts

These shafts are an inherent element of the machine and are located inside the assembly. in another words they are an integral part of the machine itself. e.g., crankshaft [4] [5]

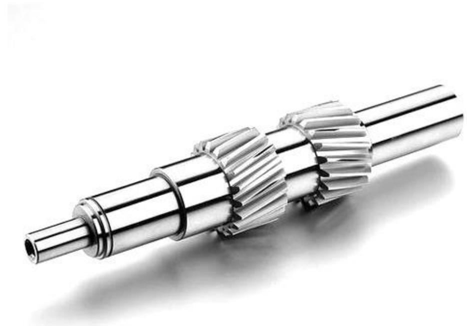

Figure II- 9 : Machine Shafts

II.2.2.3 Axle Shafts

is a non-rotating version of a shaft that supports elements such as rotating pulleys and wheels but carries no torque. An axle is a static beam and can be analyzed as one simply supported beam; used in vehicles. [4] [5]

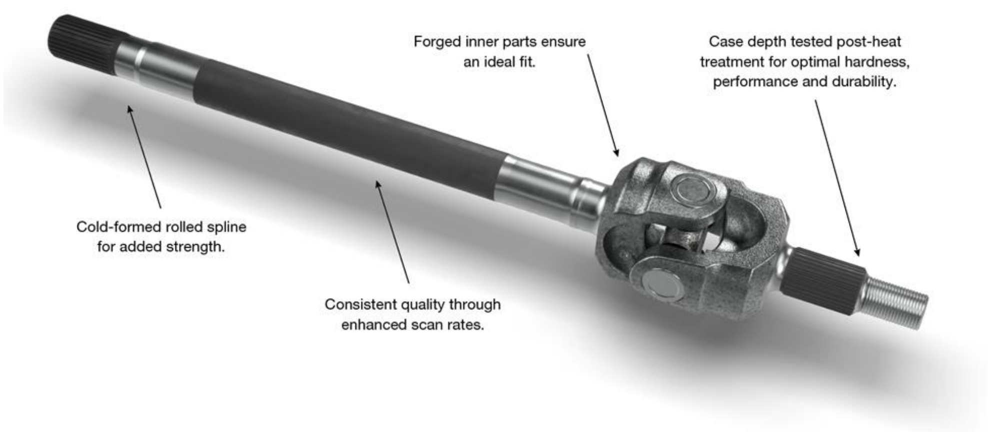

Figure II- 10 : Axle Shafts

II.2.2.3 A Spindle Shaft

is a revolving shaft with a fixture for retaining a tool (or workpiece in the case of milling, grinding, or drilling spindle) (in the case of a turning spindle). The spindle shaft acts as a tool or workpiece support, positioner, and rotational drive. [4] [5]

Figure II- 11 : Spindle Shaft

II.2.3 Standard Size

The standard sizes of transmission shafts are:

. 25 mm to 60 mm with 5 mm steps

. 60 mm to 110 mm with 10 mm steps

. 110 mm to 140 mm with 15 mm steps and

. 140 mm to 500 mm with 20 mm steps

. The standard length of the shafts is 5 m, 6 m, and 7 m.

The standard sizes of Machine shafts are:

. Up to 25 mm steps of 0.5 mm [4]

II.2.4 Design

II.2.4.1 Key Principles

During the design stage of the shaft, the following key principle should be taken into consideration by the product designer.

. Keep the shaft as short as possible and the bearing supports as close to the load vectors as possible. This will keep the shaft deflection and bending moments and also increase resonance and critical speed

. Place shaft stress concentration points away from stressed regions of the shaft. Add fillet radii, smooth surface finish

. Only use hollow shaft if weight is critical [5]

II.2.4.2 Consideration

. Form, fit, and function including tolerancing – Within the embodiment of the design during the

. Shaft material and treatment

. Shaft deflection and Rigidity – Deflection based calculation

. Shaft strength and stress – Strength bases calculation

. Frequency response and critical speed [5]

II.2.4.3 Materials

The material used for ordinary shafts is mild steel. When high strength is required, alloy steel such as nickel, nickel-chromium, or chromium-vanadium steel is used. Shafts are generally formed by hot rolling and finished to size by cold drawing or turning and grinding.

The material used for the shafts must have the following properties ; It should have :

. High strength.

. Good mechanization.

. A low-notch sensitivity factor.

. Good heat treatment properties.

. High wear-resistant properties. [5]

II.2.4.4 Process

. Material selection

. Geometric layout design

. Stress and strength

. Static strength

. Fatigue strength

. Deflection and rigidity

. Bending deflection

. Torsional deflection

. The slope at bearing and shaft supported elements.

. Shear deflection due to transverse loading of short shafts

. Vibrational due to natural frequency

. Manufacturing method [5]

II.2.4.5 Manufacturing

Shafts are usually produced by hot rolling and are prepared for shape by cold drawing or turning and grinding. Cold rolled shafts are stronger than hot-rolled shafts, but with higher residual stresses.

Residual stress can cause deformation of the shafts when it is mechanized, especially when slots or keys are cut. Shafts of larger diameter are usually forged and are shaped into a lathe. [4]

II.2.5 Advantages

. The shaft system is less likely to jam.

. Less maintenance than a chain system when a tube is attached to the drive shaft.

. A hollow shaft is a low weight than a solid shaft for the same torque transmission.

. In the hollow shaft, the internal shape is hollow so the materials required are less.

. The shaft is more strong and it has a low failure chance.

. High polar moment of inertia

. High torsional strength [6]

II.2.6 Disadvantages

. The power loss due to loose coupling.

. Shafts can vibrate during rotation.

. Produced a constant noise

. Maintenance and manufacturing costs were high.

. The manufacturing process is difficult.

. The downtime was longer due to mechanical problems.

. The use of flexible couplings, such as a leaf spring coupling, can cause a loss of velocity between shafts.

. Changing the speed was not so easy.

. Oil dripping from overhead shafting. [6]

II.2.7 Applications

Shafts are used in a number of different mechanical systems both used in industrial applications and appliances you may find around the home. Some of the most common places shafts are used are:

. Automotive industry

. Engines

. Inside gearboxes

. Linking gearboxes

. Clocks and watches

. Paper industry

. Pump drives

. Railway applications

. Conveyor systems

. Crane industry [6]

II.2.8 Failure

. Fatigue failure

. Force-induced elastic deformation failure

. Wear failure [5]

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Chapter III
Gears

III.1. Defenition

Gears are toothed, mechanical transmission elements used to transfer motion and power between machine components, and in this article, we discuss the different types of gears available and how gears work. Operating in mated pairs, gears mesh their teeth with the teeth of another corresponding gear or toothed component which prevents slippage during the transmission process. Each gear or toothed component is attached to a machine shaft or base component, therefore when the driving gear (i.e., the gear that provides the initial rotational input) rotates along with its shaft component, the driven gear (i.e., the gear or toothed component which is impacted by the driving gear and exhibits the final output) rotates or translates its shaft component. Depending on the design and construction of the gear pair, the transference of motion between the driving shaft and the driven shaft can result in a change of the direction of rotation or movement. Additionally, if the gears are not of equal sizes, the machine or system experiences a mechanical advantage which allows for a change in the output speed and torque (i.e., the force which causes an object to rotate).

Gears and their mechanical characteristics are widely employed throughout industry to transmit motion and power in a variety of mechanical devices, such as clocks, instrumentation, and equipment, and to reduce or increase speed and torque in a variety of motorized devices, including automobiles, motorcycles, and machines. Other design characteristics, including construction material, gear shape, tooth construction and design, and gear pair configuration, help to classify and categorize the various types of gears available. Each of these gears offers different behaviors and advantages, but the requirements and specifications demanded by a particular motion or power transmission application determine the type of gear most suitable for use. [1] [2] [3]

III.2. History

There is no literature reference concerning the origin of Gears. Who was the first person to use it or pioneered gear development. Ancient people probably fabricated gears by making notches or projection at external of wooden disk for farm work or to ladle water. We are able to find literature on gears to its origin when the author, Aristotle (Before Christ 384-322) had written Subject on Machine about 2,300 years ago.

A hundred years later that day, a Hellenistic mathematician Archimedes (287~212 B.C.) drew a diagram of a hoist that was driven with a set of worm and worm wheel.

Approximately 500 years ago, Leonardo da Vinci (1422-1519) had left several gear sketches. He drew almost all of the variety of gear currently used.

Here in Japan gears were in use in the Edo period (1603-1867) as a power source for flour milling in waterwheels. The gear was as large as one meter in diameter, and zelkova and oak trees were used as the material. [5] [6]

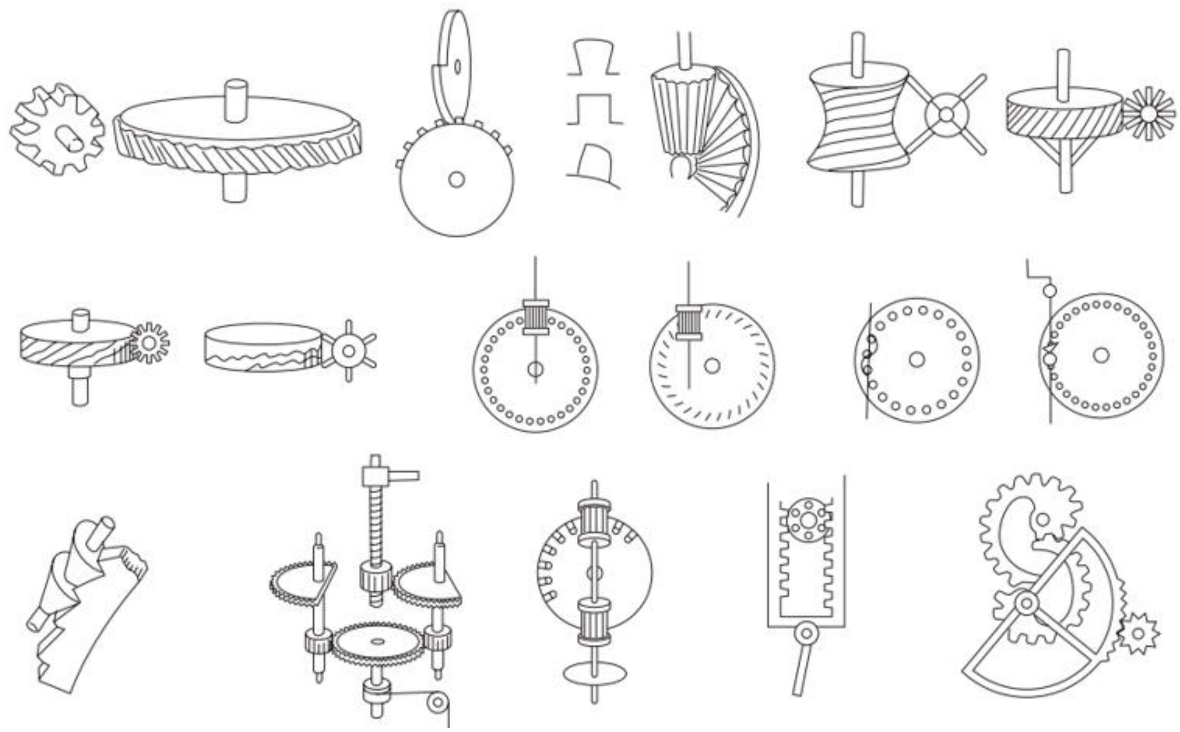
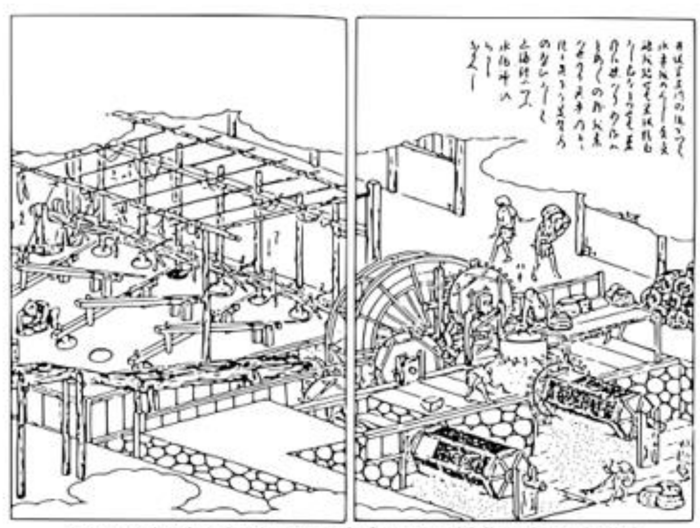


Figure III- 1 : Sketches og gears bu leonardo da vinci

Ancient gears at the Ctesiphon archeological site in Iraq



A waterwheel in the countryside from an old illustration (1786)

Figure III- 2 : ancient using of gears

III.3. Design

Gears are available in a variety of designs, constructions, and configurations to suit a wide range of industries and applications. These various characteristics allow gears to be classified and categorized in several different ways, which include:

III.3.1 Shape

Most types of gears are circular—i.e., the gear teeth are arranged around a cylindrical gear body with a circular face—but some non-circular gears are also available. These gears can feature elliptical, triangular, and square-shaped faces.

Devices and systems which employ circular gears experience constancy in the gear ratios (i.e., the ratio of the output to the input) expressed—both for rotary speed and torque. The constancy of the gear ratio means that given the same input (either speed or torque), the device or system consistently provides the same output speed and torque.

On the other hand, devices and systems which employ non-circular gears experience variable speed and torque ratios. Variable speed and torque enable non-circular gears to fulfill special or irregular motion requirements, such as alternatingly increasing and decreasing output speed, multi-speed, and reversing motion. Additionally, linear gears, such as gear racks, can convert the rotational motion of the driving gear into the translational motion (or a combination of translational and rotational motion) of the driven gear. [1]

III.3.2 Tooth Design And Construction

Gear teeth are also referred to as cogs, hence why a gear is also called by the somewhat archaic term of cogwheel. While in the previous section, gears were categorized based on the overall shape of the gear body, this section describes characteristics relating to their tooth (i.e., cog) design and construction. There are several common design and construction options available for gear teeth, including: [1]

III.3.2.1 Structure

Depending on the gear structure, gear teeth are either cut directly into the gear blank or inserted as separate, shaped components into the gear blank. For most applications, once a gear succumbs to fatigue, it can be replaced in its entirety. However, the advantage of employing gears with separate tooth components is the ability to individually replace the teeth as each becomes fatigued rather than replacing the whole gear component. This capability may help to reduce the overall cost of gear replacement over time as individual cogs are available at a lower cost compared to that of a complete gear. Additionally, it allows specialized, custom, or otherwise difficult to find gear bodies to be retained and preserved. [1]

III.3.2.2 Placement

Gear teeth are cut or inserted on the outer or inner surface of the gear body. In external gears, the teeth are placed on the outer surface of the gear body, pointing outward from the gear center. On the other hand, in internal gears, the teeth are placed on an inner surface of the gear body, pointing inward towards the gear center. In mated pairs, the placement of the gear teeth on each of the gear bodies largely determines the motion of the driven gear.

When both gears in a mated pair are of the external type, the driving gear and driven gear (and their respective shaft or base component) rotate or move in opposite directions. If an application requires the input and output to rotate or move in the same direction, an idler gear (i.e., a gear placed between the driving gear and driven gear) is typically employed to change the direction of rotation of the driven gear.

If one of the mated gear pair is an internal gear and the other is an external gear, both the driving gear and driven gear rotate in the same direction. This type of gear pair configuration removes the need for an idler gear in applications which require the same direction of rotation in the driving and driven gear. Additionally, configurations which employ an internal-external gear pair are suitable for limited- or restricted-space applications as the gears and their shaft or base components can be positioned closer together than is possible with a comparable external-only gear pair. [1]

III.3.2.3 Profile

The tooth profile of a gear refers to the cross-sectional shape of the gear's teeth and influences a variety of the gear's performance characteristics, including the speed ratio and experienced friction. While there are a large number of tooth profiles available for the design and construction of gears, there are three main types of tooth profiles employed—involute, trochoid, and cycloid.

Involute gear teeth follow a shape designated by the involute curve of a circle, which is a locus formed by the end point of an imaginary line tangent to the base circle as the line rolls along the circle's circumference. Throughout industry, the majority of gears produced employ the involute tooth profile both because of its ease of manufacturing and its smoothness of operation. Compared to some of the other profiles, the involute profile consists of fewer curves, making the manufacturing of involute gear teeth simpler and, consequently, the manufacturing equipment necessary cheaper, which reduces the overall cost of production. The advantage of involute gear teeth lies in their constancy of pressure angle throughout gear engagement and the ability to tolerate variation in the spacing of gear centers without impact to the constancy of the gear ratio for torque and speed. The constancy of pressure angle allows involute gears to run smoother than gears with other tooth profiles and the tolerance of variation allows for greater flexibility within the gear's design specifications.

Unlike an involute curve where the line rolls along the circumference of a circle, a trochoid curve is a locus formed by a point at a fixed distance (a) from the center of a circle with a given radius (r) as the circle rolls along a straight line. Trochoids are a general category of curves which include cycloids.

. If $a<r$, then the curve formed is known as a curtate cycloid

. if $a=r$, then the curve formed is a cycloid

. if $a>r$, then the curve formed is a prolate cycloid

Compared to the involute gear tooth profile, these profiles are rarely employed for gear design and construction except for use in specialized applications. For example, trochoidal gears are often employed in pumps and cycloidal gears in pressure blowers and clocks. Despite their limited applications, the trochoidal and cycloidal profiles offer a few advantages over the involute profile, including greater tooth durability and elimination of interference[1]

3.3 Axes Configuration

The axes configuration of a gear refers to the orientation of the axes—along which the gear shafts lay and around which the gears rotate—in relation to each other. There are three principal axes configurations employed by gears: [1]

III.3.3.1 Parallel

As indicated by the name, parallel configurations involve gears connected to rotating shafts on parallel axes within the same plane. The rotation of the driving shaft (and the driving gear) is in the opposite direction to that of the driven shaft (and driven gear), and the efficiency of power and motion transmission is typically high. Some of the types of gears which employ parallel configurations include spur gears, helical gears, internal gears, and some variants of rack and pinion gears. [1]

Figure III- 3 : Parallel gears

III.3.3.2 Intersecting

In intersecting configurations, the gear shafts are on intersecting axes within the same plane. Like the parallel configuration, this configuration generally has high transmission efficiencies. Bevel gears—including miter, straight bevel, and spiral bevel gears—are among the group of gears which employ intersecting configurations. Typical applications for intersecting gear pairs include changing the direction of motion within power transmission systems. [1]

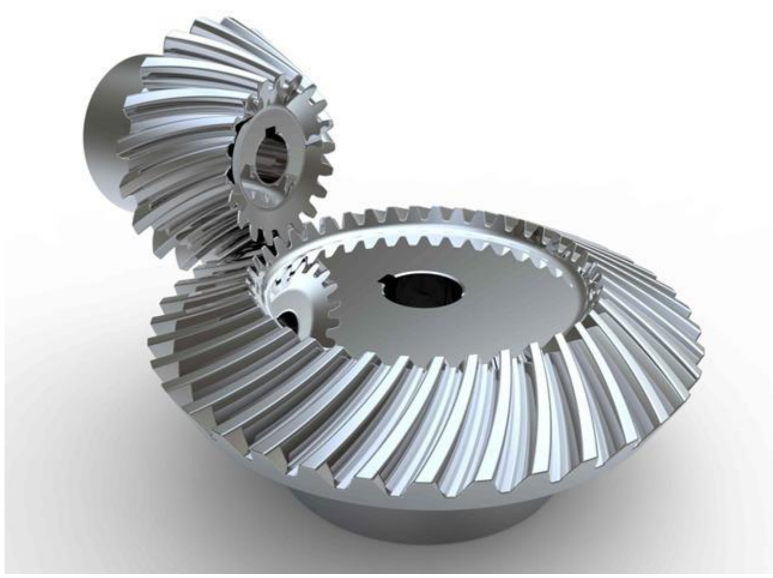


Figure III- 4 : Intersecting gears

III.3.3.3 Non-parallel, Non-intersecting

Gear pairs with a non-parallel, non-intersecting configuration have shafts existing on axes which cross (i.e., are not parallel) but not on the same plane (i.e., do not intersect). Unlike parallel and intersecting configurations, this configuration generally has low motion and power transmission efficiencies. Some examples of non-parallel, non-intersecting gears include screw gears, worm gears, and hypoid gears. [1]

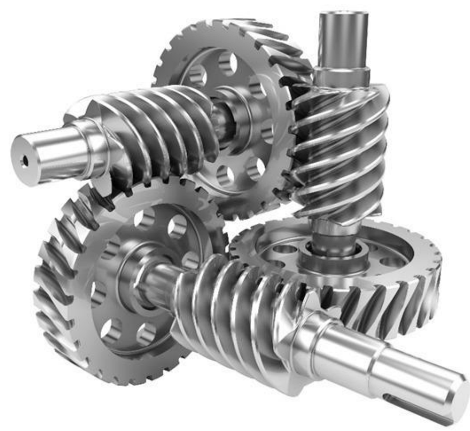


Figure III- 5 : Non-parallel, Non-intersecting gears

III.3.3.3.4 Additional Gear Design Characteristics

Beyond the design characteristics mentioned above, there are several other options an industry professional or procurement agent may consider when designing and selecting a gear for their particular application. Some of the other characteristics which may be considered include construction material, surface treatments, number of teeth, tooth angle, and lubricant type and lubrication method. [1]

III.4. Types

III.4.1 According to The Position of Shaft Axes

Gears may be classified according to the relative position of the axes of revolution. The axes may be:

. Parallel shafts

where the angle between driving and driven shaft is 0 degree. Examples include spur gears, single and double helical gears.

. Intersecting shafts

where there is some angle between driving and driven shaft. Examples include bevel and miter gear.

. Non-intersecting and non-parallel shafts

where the shafts are not coplanar. Examples include the hypoid and worm gear. [8]

III.4.2 According to Peripheral Velocity

Gears can be classified as:

. Low velocity

if their peripheral velocity lies in the range of 1 to 3 m/sec.

. Medium velocity

if their peripheral velocity lies in the range of 3 to 15 m/sec.

. High velocity

if their peripheral velocity exceeds 15 m/sec. [8]

III.4.3 According to Type of Gears

Gears can be classified as external gears, internal gears, and rack and pinion.

. External gears

the bigger one is called “gear” and the smaller one is called “pinion”.

. Internal gears

the larger one is called “annular” gear and the smaller one is called “pinion”.

. Rack and pinion

converts rotary to linear motion or vice versa. There is a straight line gear called “rack” on which a small rotary gear called “pinion” moves. [8]

III.4.4 According to Teeth Position

Gears are classified as straight, inclined and curved.

. Straight gear teeth

are those where the teeth axis is parallel to the shaft axis.

. Inclined gear teeth

are those where the teeth axis is at some angle.

. Curve gear teeth

are curved on the rim’s surface. [8]

Based on the design characteristics indicated above, there are several different types of gears available. Some of the more common types of gears employed throughout industry include:

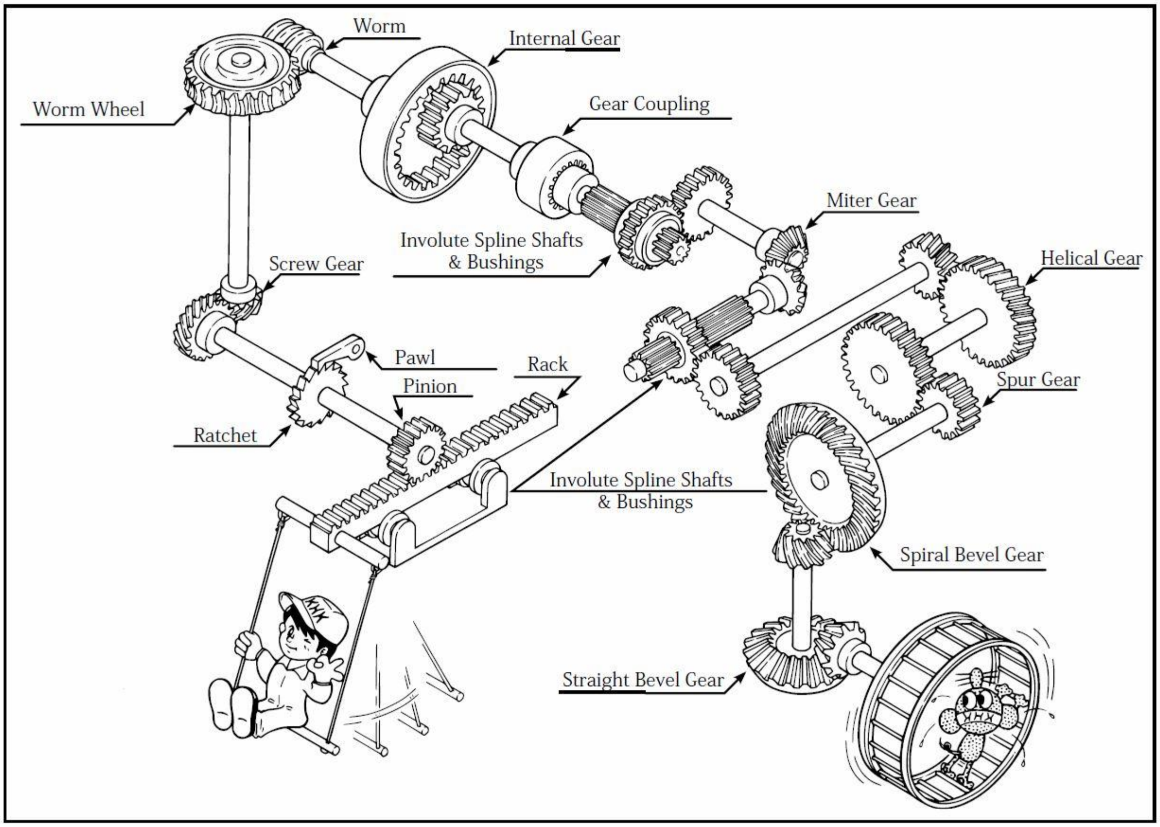


Figure III- 6 : types of gears

III.5. Spur Gears

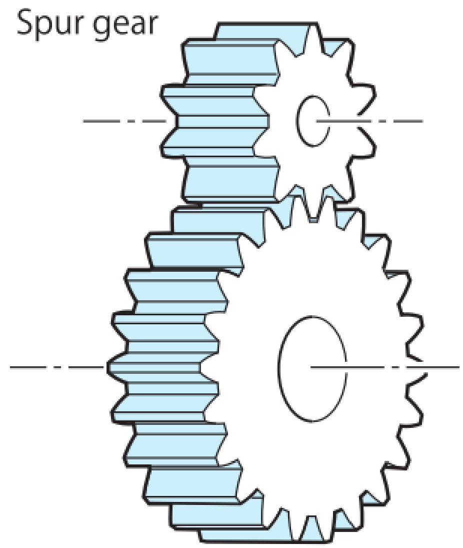


Figure III- 7 : Spur Gears

The most common type of gears employed, spur gears are constructed with straight teeth cut or inserted parallel to the gear's shaft on a circular (i.e., cylindrical) gear body. In mated pairs, these gears employ the parallel axes configuration to transmit motion and power. Depending on the application, they can be mated with another spur gear, an internal gear (such as in a planetary gear system), or a gear rack (such as in a rack and pinion gear pair).

The simplicity of the spur gear tooth design allows for both a high degree of precision and easier manufacturability. Other characteristics of spur gears include lack of axial load (i.e., the thrust force parallel to the gear shaft), high-speed and high-load handling, and high efficiency rates. Some of the disadvantages of spur gears are the amount of stress experienced by the gear teeth and noise produced during high-speed applications.

This type of gear is used for a wide range of speed ratios in a variety of mechanical applications, such as clocks, pumps, watering systems, power plant machinery, material handling equipment, and clothes washing and drying machines. If necessary for an application, multiple (i.e., more than two) spur gears can be used in a gear train to provide higher gear reduction. [1] [6]

III.5.1 Characteristics

. Simplest and most economical type of gear to manufacture.

. Speed ratios of up to 8 (in extreme cases up to 20) for one step (single reduction) design; up to 45 for two step design; and up to 200 for three-step design.

. The most common type of gear [4] [8]

III.5.2 Limitations

. Not suitable when a direction change between the two shafts is required.

. Produce noise because the contact occurs over the full face width of the mating teeth instantaneously. [8]

III.5.3 Applications

. Transmission components[7]

III.6. Helical Gears

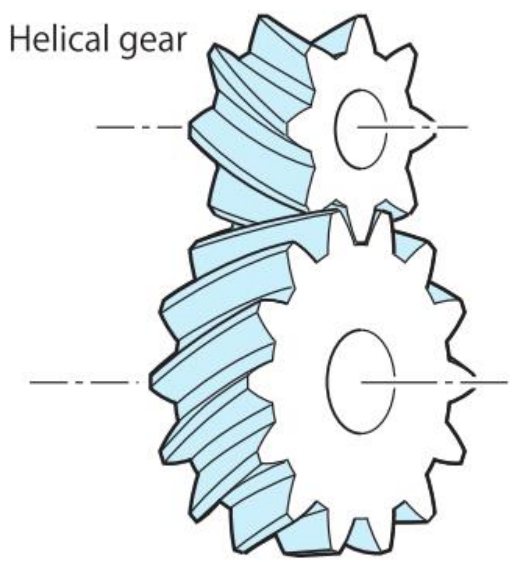


Figure III- 8 : Helical Gears

Similar to spur gears, helical gears typically employ the parallel axes configuration with mated gear pairs, but, if aligned properly, they can also be used to drive non-parallel, non-intersecting shafts. However, unlike spur gears, these gears are constructed with teeth which twist around the cylindrical gear body at an angle to the gear face. Helical gears are produced with right-hand and left-hand angled teeth with each gear pair comprised of a right-hand and left-hand gear of the same helix angle.

The angled design of helical teeth causes them to engage with other gears differently than the straight teeth of spur gears. As properly matched helical gears come in contact with one another, the level of contact between corresponding teeth increases gradually, rather than engaging the entire tooth at once. This gradual engagement allows for less impact loading on the gear teeth and smoother, quieter operation. Helical gears are also capable of greater load capabilities but operate with less efficiency than spur gears. Further disadvantages include the complexity of the helical tooth design, which increases the degree of difficulty in its manufacturing (and, consequently, the cost) and the fact that the single helical gear tooth design produces axial thrust, which necessitates the employment of thrust bearings in any application which uses single helical gears. This latter necessity further increases the total cost of using helical gears.

As helical gears are also capable of handling high speeds and high loads, they are suitable for the same types of applications as spur gears, such as pumps and generators. Their smoother, quieter operation also suits them for automobile transmissions where spur gears are typically not used. [1] [6]

III.6.1 Single or Double Helical Gear Design

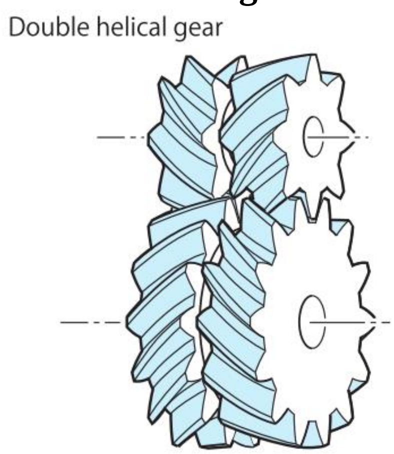


Figure III- 9 : Double Helical Gear

Helical gears are available in single helical and double helical designs. Single helical gears consist of a single row of angled teeth cut or inserted around the perimeter of the gear body, while double helical gears consist of two mirrored rows of angled teeth. The advantage of the latter design is its greater strength and durability (than the single helical design), and the elimination of axial load production. [1] [6]

III.6.1.1 Screw

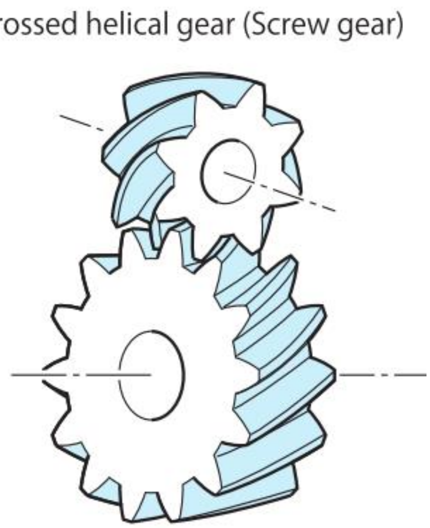


Figure III- 10 : Screw

Screw gears, also called crossed helical gears, are helical gears which are used for non-parallel, non-intersecting configurations. Unlike the helical gears used for parallel configurations, screw gears employ same-hand pairs rather than a right-hand and left-hand gear per pair. These gears have relatively low load capacities and efficiency rates and are not suitable for high power transmission applications. [1] [6]

III.6.1.1.1 Characteristics

. Can be used as a speed reducer or as a speed increaser

. Due to sliding contact, has higher friction

. Not suitable for transmission of high horsepower[4]

III.6.1.1.2 Applications

. Driving gear for automobile. Automatic machines that require intricate movement

III.6.2 Characteristics

The longer teeth cause helical gears to have the following differences from spur gears of the same size:

. Tooth strength is greater because the teeth are longer than the teeth of spur gear of equivalent pitch diameter.

. Can carry higher loads than can spur gears because of greater surface contact on the teeth.

. Can be used to connect parallel shafts as well as non-parallel, non-intersecting shafts.

. Quieter even at higher speed and are durable. [8]

III.6.3 Limitations

. Gears in mesh produce thrust forces in the axial directions.

. Expensive compared to spur gears. [8]

III.6.4 Applications

. Transmission components, automobile, speed reducers, etc. [7]

III.7. Bevel Gears

Bevel gears are cone-shaped gears with teeth placed along the conical surface. These gears are used to transmit motion and power between intersecting shafts in applications which require changes to the axis of rotation. Typically, bevel gears are employed for shaft configurations placed at 90-degree angles, but configurations with lesser or greater angles are also manageable.

There are several types of bevel gears available differentiated mainly by their tooth design. Some of the more common types of bevel gears include straight, spiral, and Zerol® bevel gears.[1] [6]

III.7.1 Straight Bevel Gears

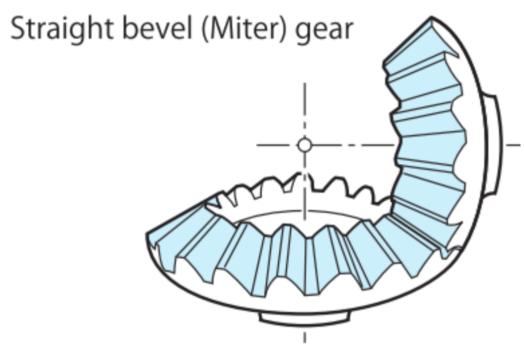


Figure III- 11 : Straight Bevel Gears

The most commonly used of the bevel gear tooth designs due to its simplicity and, consequently, its ease of manufacturing, straight bevel teeth are designed such that when properly matched straight bevel gears come into contact with one another, their teeth engage together all at once rather than gradually. As is the issue with spur gears, the engagement of straight bevel gear teeth results in high impact, increasing the level of noise produced and amount of stress experienced by the gear teeth, as well as reducing their durability and lifespan.[1] [6]

III.7.1.1 Angular straight bevel gear

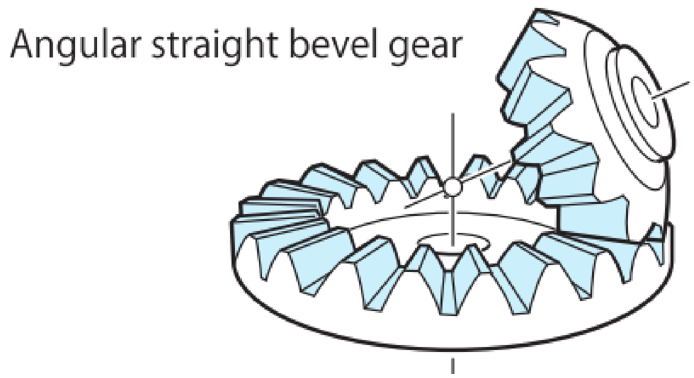


Figure III- 12 : Angular straight bevel gear

Angular straight bevel gear which does not have shaft angle of 90°[1] [6]

III.7.1.2 Characteristics

. Relatively easy to manufacture

. Provides reduction ratios up to approx. 1:5 [7]

III.7.1.3 Applications

. Machine tools, printing presses, etc. Especially suitable for use as a differential gear unit[7]

III.7.1.4 Miter

are bevel gears which, when paired, have a gear ratio of 1:1. This gear ratio is a result of pairing two miter gears with the same number of teeth. This type of bevel gear is used in applications which require a change only to the axis of rotation with speed remaining constant.

III.7.1.3.1 Characteristics

. They provide a steady ratio; other characteristics are similar to bevel gears.

. They are used as important parts of conveyors, elevators and kilns. [8]

III.7.1.3.2 Limitations

. Gear ration is always 1 to 1 and therefore not used when an application calls for a change of speed[8]

III.7.2 Spiral Bevel Gears

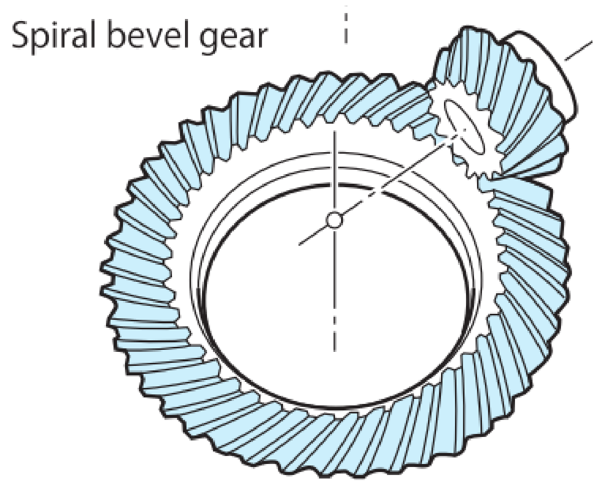


Figure III- 13 : Spiral Bevel Gears

In spiral bevel gears, the teeth are angled and curved to provide for more gradual tooth engagement and more tooth-to-tooth contact than with a straight bevel gear. This design greatly reduces the vibration and noise produced, especially at high angular velocities (>1,000 rpm). Like helical gears, spiral bevel gears are available with right-hand or left-hand angled teeth. As is also the case with helical gears, these gears are more complex and difficult to manufacture (and, consequently, more expensive), but offer greater tooth strength, smoother operation, and lower levels of noise during operation than straight bevel gears. [1] [6]

III.7.2.1 Angular spiral bevel gear

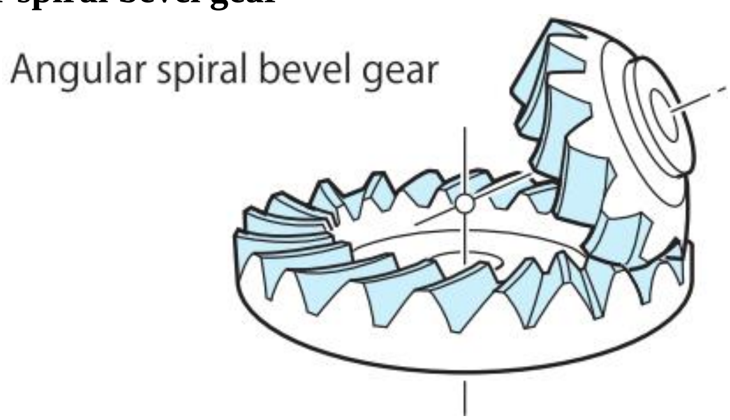


Figure III- 14 : Angular spiral bevel gear

Angular spiral bevel gear does not have shaft angle of 90°.[1] [6]

III.7.2.2 Characteristics

. Has higher contact ratio, higher strength and durability than an equivalent straight bevel gear

. Allows a higher reduction ratio

. Has better efficiency of transmission with reduced gear noise

. Involves some technical difficulties in manufacturing[7]

III.7.2.3 Applications

. Automobiles, tractors, vehicles, final reduction gearing for ships. Especially suitable for high-speed, heavy load drives[7]

III.7.3 Zerol® Bevel Gears

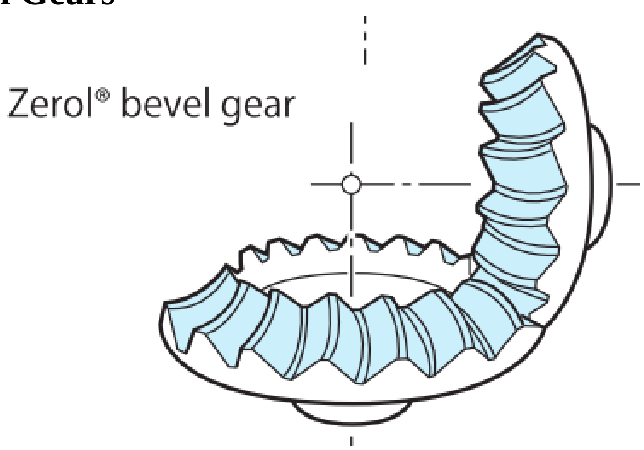


Figure III- 15 : Zerol® Bevel Gears

Zerol® bevel gears (a registered trademark of the Gleason Co.) incorporate the design characteristics of both straight and spiral bevel gears with curved teeth placed straight on the conical surface. As the teeth on Zerol® bevel gears are placed as those on straight bevel gears, Zerol® bevel gears can be used in the same as applications as those of straight bevel gears. However, compared to straight bevel gears, Zerol® bevel gears are quieter and experience less friction. Like spiral bevel gears, Zerol® bevel gears are also available in right-hand and left-hand designs, but, unlike spiral bevel gears, Zerol® bevel gears can rotate in both directions since the teeth are not placed at an angle. [1] [6]

III.7.4 Additional Bevel Gear Designs

Other than the types mentioned above, there are several other designs of bevel gears available including miter, crown, and hypoid gears.

III.7.4.1 Crown

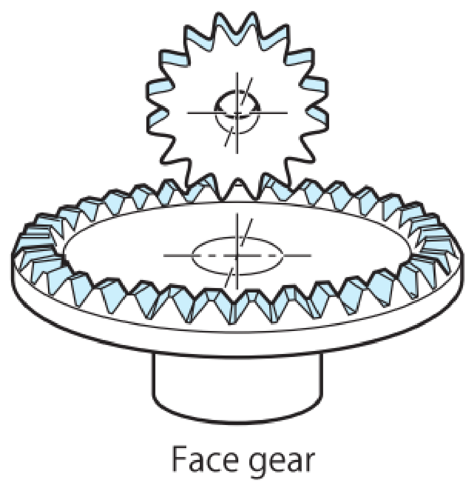


Figure III- 16 : Crown gear

also referred to as face gears, are cylindrical (rather than conical) bevel gears with teeth cut or inserted perpendicular to the gear face. Crown gears can be paired either with other bevel gears or, depending on the tooth design, spur gears. [1] [6]

III.7.4.2 Hypoid

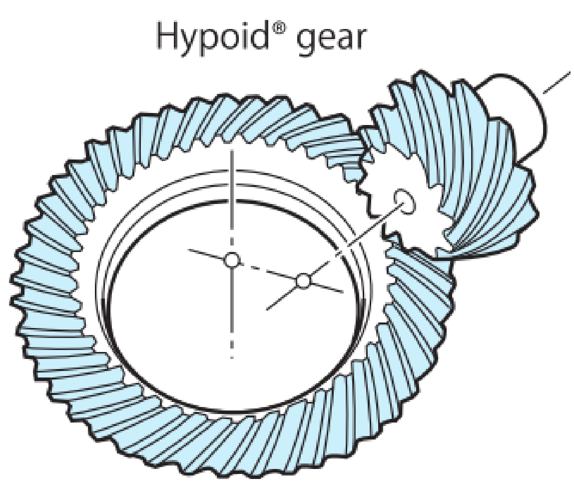


Figure III- 17 : Hypoid

Hypoid gears are a modification of the spiral bevel gear with the axis offset. The distinguishing feature of hypoid gears is that the shafts of the pinion and ring gear may continue past each other, never having their axis intersecting.

The major advantages of the hypoid gear design are that the pinion diameter is increased, and it is stronger than a corresponding bevel gear pinion. The increased diameter size of the pinion permits the use of comparatively high gear ratios and is extremely useful for non-intersecting shaft requirements such as automotive applications where the offset permits lowering of the drive shaft. [1] [6]

III.7.5 Characteristics

. Designed for the efficient transmission of power and motion between intersecting shafts. A good example of bevel gears is seen as the main mechanism for a hand drill. As the handle of the drill is turned in a vertical direction, the bevel gears change the rotation of the chuck to a horizontal rotation.

. Permit a minor adjustment during assembly and allow for some displacement due to deflection under operating loads without concentrating the load on the end of the tooth. [8]

III.8. Worm Gears

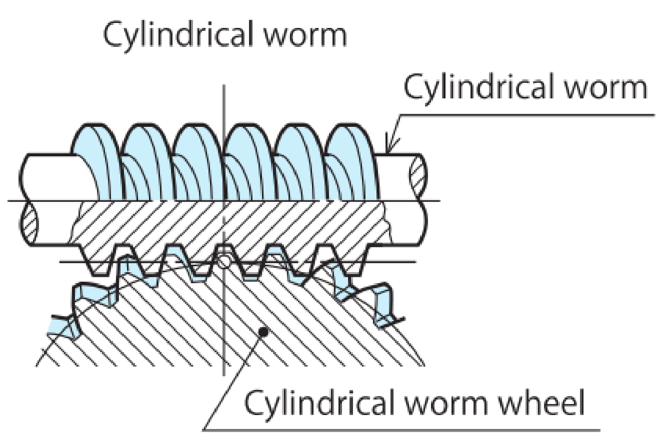


Figure III- 18 : Worm Gears

Worm gear pairs are comprised of a worm wheel—typically a cylindrical gear—paired with a worm—i.e., a screw-shaped gear. These gears are used to transmit motion and power between non-parallel, non-intersecting shafts. They offer large gear ratios and capabilities for substantial speed reduction while maintaining quiet and smooth operation.

One distinction of worm gear pairs is that the worm can turn the worm wheel, but, depending on the angle of the worm, the worm wheel may not be able to turn the worm. This characteristic is employed in equipment requiring self-locking mechanisms. Some of the disadvantages of worm gears are the low transmission efficiency and the amount of friction generated between the worm wheel and worm gear which necessitates continuous lubrication. [1] [6]

III.8.1 Characteristics

. Meshes are self-locking. Worm gears have an interesting feature that no other gear set has: the worm can easily turn the gear, but the gear cannot turn the worm. This is because the angle on the worm is so shallow that when the gear tries to spin it, the friction between the gear and the worm holds the worm in place. This feature is useful for machines such as conveyor systems, in which the locking feature can act as a brake for the conveyor when the motor is not turning.

. Worm gear is always used as the input gear, i.e. the torque is applied to the input end of the worm shaft by a driven sprocket or electric motor.

. Best suited for applications where a great ratio reduction is required between the driving and driven shafts. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater. [8]

III.8.2 Limitations

. Yield low efficiency because of high sliding velocities across the teeth, thereby causing high friction losses.

. When used in high torque applications, the friction causes the wear on the gear teeth and erosion of the restraining surface. [8]

III.8.3 Applications

. Speed reducers, antireversing gear devices making the most of its self-locking features, machine tools, indexing devices, chain blocks, portable generators, etc. [7]

III.9. Rack and Pinion Gears

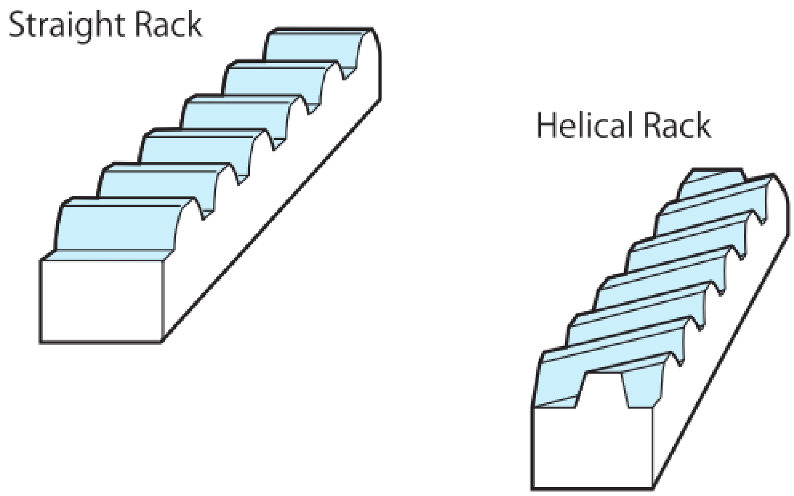


Figure III- 19 : Racks

Rack and pinion gears are a pair of gears comprised of a gear rack and a cylindrical gear referred to as the pinion. The gear rack can be considered as a gear of infinite radius (i.e., a flat bar) and is constructed with straight teeth cut or inserted on the bar's surface. Depending on the type of pinion gear with which it is mated, the gear rack's teeth are either parallel (when mated with spur gears) or angled (when mated with helical gears). For either of these rack designs, rotational motion can be converted into linear motion or linear motion can be converted into rotational motion.

Some of the advantages of a rack and pinion gear pair are the simplicity of the design (and the low cost of manufacturing) and high load carrying capacities. Despite the advantages of this design, gears which employ this approach are also limited by it. For example, transmission cannot continue infinitely in one direction as motion is limited by the designated length of the gear rack. Additionally, rack and pinion gears tend to have a greater amount of backlash (i.e., additional space between mated gear teeth) and, consequently, the teeth experience a significant amount of friction and stress.

Some of the common applications of rack and pinion gear pairs include the steering system of automobiles, transfer systems, and weighing scales.

(Note: whereas in rack and pinion gears, the term "pinion" refers to the gear which meshes with the gear rack, in pairs of other types of gears, the term "pinion" refers, when applicable, to the gear with the smallest number of teeth) [1] [6]

III.9.1 Straight Rack

It is thought that radius of spur gear grew infinite to become a straight line. It can be matched with Spur gear to convert between the rectilinear motion and the rotary motion. [6]

III.9.2 Helical Rack

It is thought that radius of Helical gear grew infinite to become a straight line and Tooth trace is also straight line. It can be matched with Helical gear to convert between the rectilinear motion and the rotary motion. [6]

III.9.3 Characteristics

. Racks with machined ends can be joined together to make any desired length.

. Changes a rotary motion into a rectilinear motion and vice versa[8]

III.9.4 Applications

. A transfer system for machine tools, printing presses, robots, etc.

. The most well-known application of a rack is the rack and pinion steering system used on many cars in the past. The steering wheel of a car rotates the gear that engages the rack. The rack slides right or left, when the gear turns, depending on the way we turn the wheel. Windshield wipers in cars are powered by a rack and pinion mechanism. [7]

III.10. Internal Gears

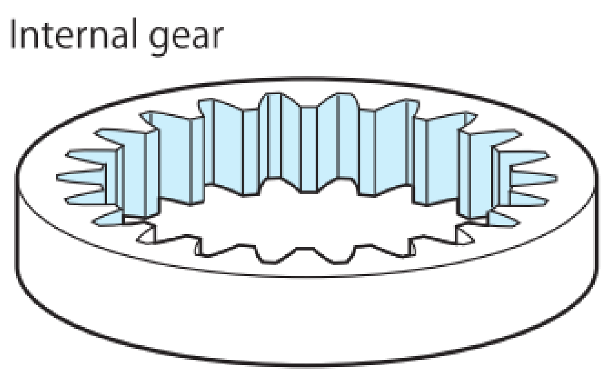


Figure III- 20 : internal gear

Internal gears have their teeth cut parallel to their shafts like spur gears, but they are cut on the inside of the gear blank. The properties and teeth shape are similar as the external gears except that the internal gears have different addendum and dedendum values modified to prevent interference in internal meshes. [1] [6]

III.10.1 Characteristics

. In the meshing of two external gears, rotation goes in the opposite direction. In the meshing of an internal gear with an external gear the rotation goes in the same direction.

. The meshing arrangement enables a greater load carrying capacity with improved safety (since meshing teeth are enclosed) compared to equivalent external gears.

. Shaft axes remain parallel and enable a compact reduction with rotation in the same sense. Internal gears are not widely available as standard.

. When they are used with the pinion, more teeth carry the load that is evenly distributed. The even distribution decreases the pressure intensity and increases the life of the gear.

. Allows compact design since the center distance is less than for external gears. Used in planetary gears to produce large reduction ratios.

. Provides good surface endurance due to a convex profile surface working against a concave surface. [7]

III.10.2 Limitations

. Housing and bearing supports are more complicated because the external gear nests within the internal gear.

. Low ratios are unsuitable and in many cases impossible because of interferences.

. Fabrication is difficult and usually special tooling is required. [8]

III.10.3 Applications

. Planetary gear drive of high reduction ratios, clutches, etc. [7]

III.11 Difference Between Gear and

III.11.1 Sprocket

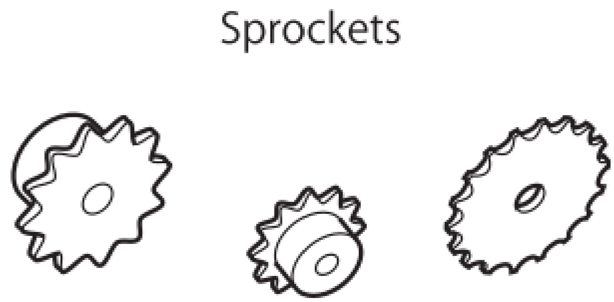


Figure III- 21 : Sprocket

Simply said, a gear meshes with another gear while a sprocket meshes with a chain and is not a gear. Aside from a sprocket, an item that looks somewhat like a gear is a ratchet, but its motiion is limited to one direction. [6]

III.11.2 Ratchet gear

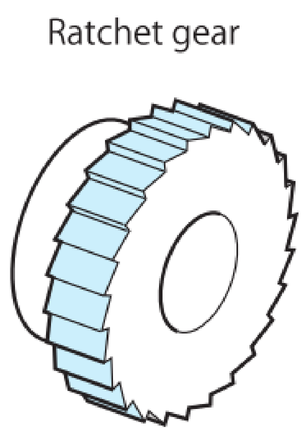


Figure III- 22 : Ratchet gear

This is Ratchet gear, which looks like the teeth of saw formed at external wheel used for positioning (indexing) and preventing inversion. [6]

III.11.3 Timing Pulley

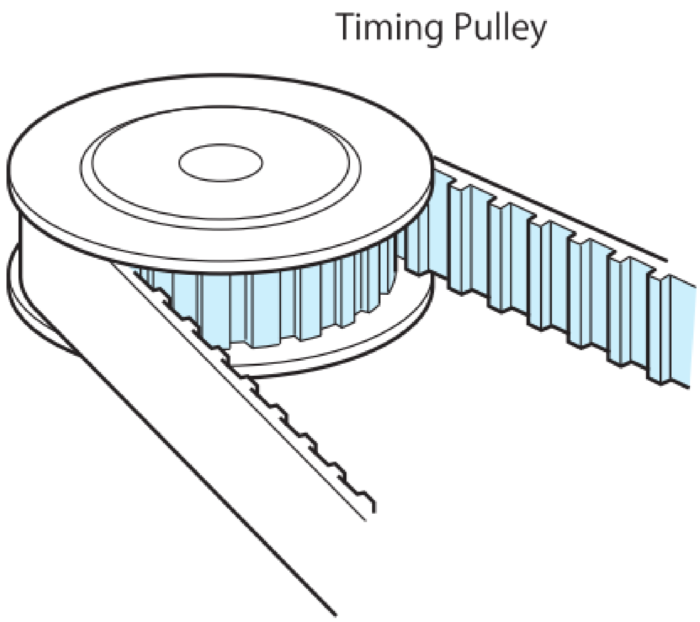


Figure III- 23 : Timing Pulley

This is Timing pulley using matching timing belt (belt with teeth). Usage is for transmitting power over long distance between axes. [6]

III.12. Gear Terminology

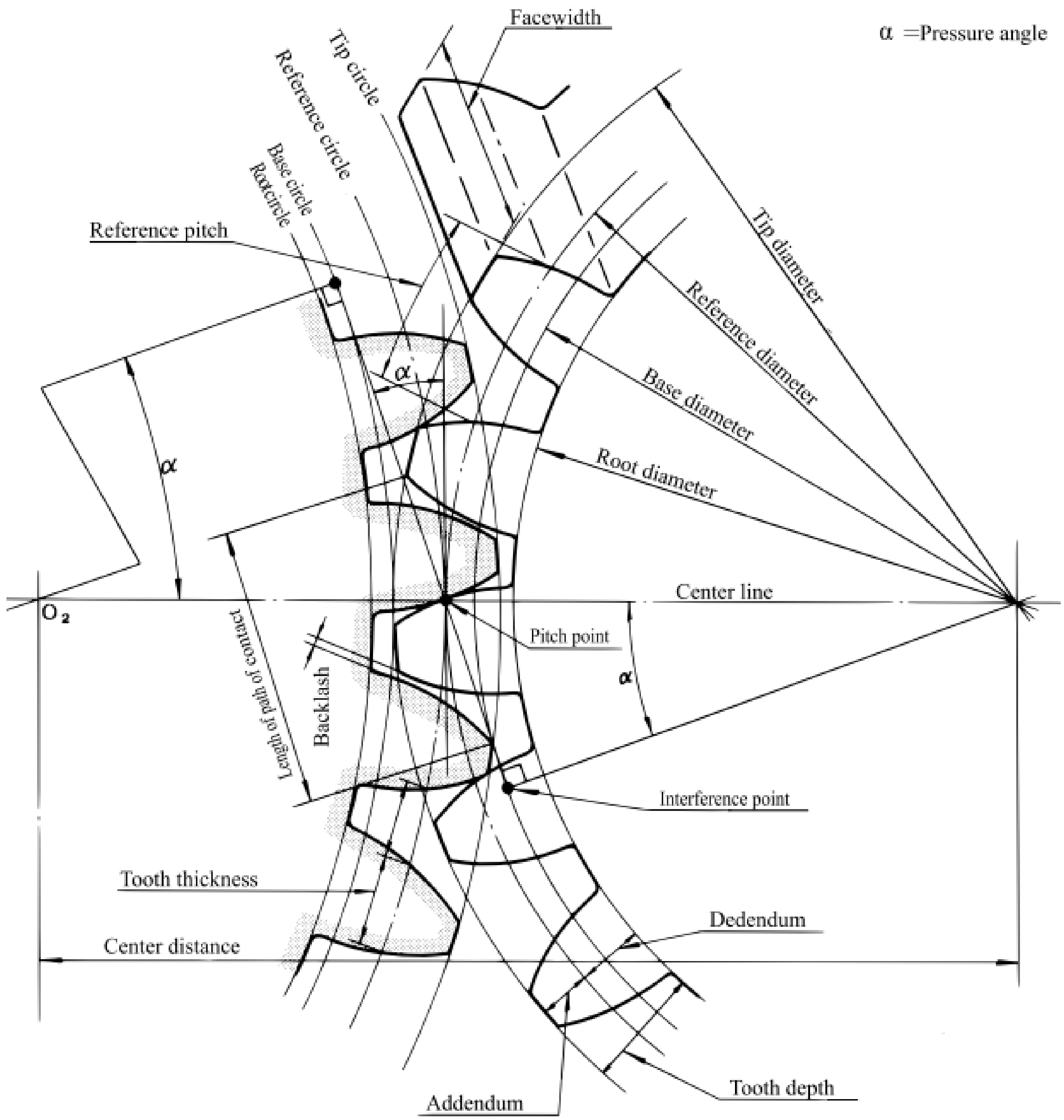


Figure III- 24 : Gear Terminology 1

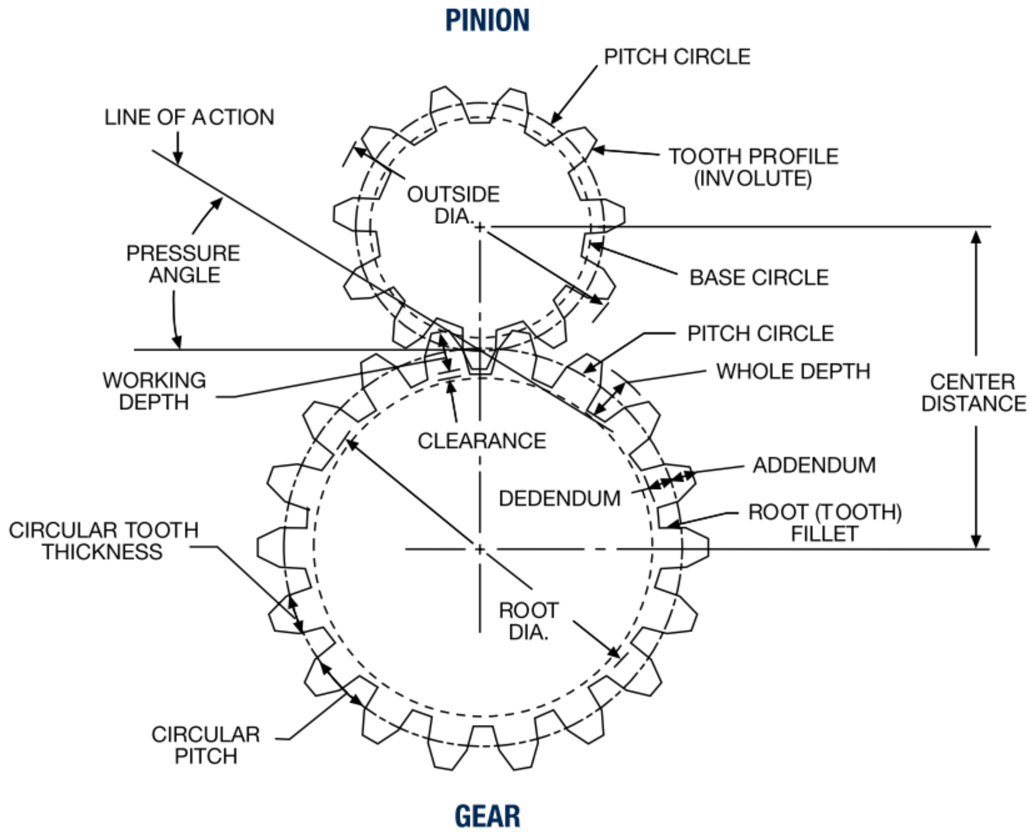


Figure III- 25 : Gear Terminology 1

Fundamental formulas

Spur gears

Pitch diameter	$D = \frac{N}{P_d} = \frac{N - p_c}{\pi}$
Circular pitch	$p_c = \frac{\pi}{P_d} = \frac{\pi D}{N}$
Diametral pitch	$P_d = \frac{\pi}{p_c} = \frac{N}{D}$
Number of teeth	$N = DP_d = \frac{\pi D}{p_c}$
Outside diameter	$D_o = D + \frac{2}{P_d} = \frac{N+2}{P_d}$
Root diameter	$D_R = D - 2b$
Base circle diameter	$D_b = D\cos\phi$
Base pitch	$p_b = p_c \cos\phi$
Tooth thickness at standard pitch diameter	$T\,\text{std} = \frac{p_c}{2} = \frac{\pi D}{2N}$
Addendum	$a = \frac{1}{P_d}$
Center distance	$C = \frac{D_1 + D_2}{2} = \frac{N_1 + N_2}{2} = \frac{p_c(N_1 + N_2)}{2\pi}$
Contact ratio	$m_p = \frac{\sqrt{R_o^2 - R_b^2} + \sqrt{r_o^2 - r_b^2} - C\sin\phi}{p_c\cos\phi}$
Backlash (linear)	$B = 2(\Delta C)\tan\phi$
Backlash (linear)	$B = \Delta T$
Backlash, linear along line-of-action	$B_{LA} = B\cos\phi$
Backlash, angular	$B_a = 6880\frac{B}{D}$ (arcmin)
Minimum number of teeth for no undercutting	$N = \frac{2}{\sin^2\phi}$

Worm meshes

Pitch diameter of worm	$d_w = \frac{n_w p_{cn}}{\pi\sin\lambda}$
Pitch diameter of worm gear	$D_g = \frac{N_g p_{cn}}{\pi\cos\lambda}$
Lead angle	$\lambda = \tan^{-1}\frac{n_w}{P_d d_w} = \sin^{-1}\frac{n_w p_{cn}}{\pi d_w}$
Lead of worm	$L = n_w p_c = \frac{n_w p_{cn}}{\cos\lambda}$
Normal circular pitch	$p_{cn} = p_c\cos\lambda$
Center distance	$C = \frac{d_w + D_g}{2}$
Center distance	$C = \frac{p_{cn}}{2\pi}\left(\frac{N_g}{\cos\lambda} + \frac{n_w}{\sin\lambda}\right)$
Velocity ratio	$Z = \frac{N}{n_w}$

Bevel gearing

Velocity ratio	$Z = \frac{N_1}{N_2}$
Velocity ratio	$Z = \frac{D_1}{D_2}$
Velocity ratio	$Z = \frac{\sin \gamma_1}{\sin \gamma_2}$
Shaft angle	$\Sigma = \gamma_1 + \gamma_2$

Helical gearing

Normal circular pitch	$p_{cn} = p_c \cos \psi$
Normal diametral pitch	$P_{dn} = \frac{P_d}{\cos \psi}$
Axial pitch	$P_a = p_c \cot \psi = \frac{P_{cn}}{\sin \psi}$
Normal pressure angle	$\tan \phi_n = \tan \phi \cos \psi$
Pitch diameter	$D = \frac{N}{P_d} = \frac{N}{P_{dn} \cos \psi}$
Center distance (parallel shafts)	$C = \frac{N_1 + N_2}{2P_{dn} \cos \psi}$
Center distance (crossed shafts)	$C = \frac{1}{2P_{dn}}\left(\frac{N_1}{\cos \psi_1} + \frac{N_2}{\cos \psi_2}\right)$
Shaft angle (crossed shafts)	$\theta = \psi_1 + \psi_2$

Symbol nomenclature and definition

B	backlash, linear amount along pitch circle
B_{LA}	backlash, linear amount along line of action
B_a	backlash in minutes
C	center distance
D	pitch diameter, gear (D_g)
D_b	base circle diameter
D_o	outside diameter
D_R	root diameter
L	length, general; also lead of worm
N	number of teeth, usually gear (N_g)
P_d	diametral pitch
P_{dn}	normal diametral pitch
R	pitch radius, gear or general use
R_b	base circle radius, gear
R_o	outside radius, gear
T	tooth thickness, gear
Z	mesh velocity ratio
a	addendum
b	dedendum
d	pitch diameter, pinion
d_w	pitch diameter, worm
m_p	contact ratio
n_w	number of threads in worm
p_a	axial pitch
p_c	circular pitch
p_{cn}	normal circular pitch
r	pitch radius, pinion
r_b	base circle radius, pinion
r_o	outside radius, pinion
γ	pitch angle, bevel gear
θ	rotation angle, general
λ	lead angle, worm gearing
ϕ	pressure angle
ϕ_n	normal pressure angle
ψ	helix angle
Σ	shaft angle, bevel gearing

Figure III- 26 : gears fundamental formulas

Refernces of chapter III

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Chapter IV
Transmission

IV.1. Defenition

The first thing to know is what your transmission is. This is the part of the vehicle that connects to the back of the engine offering power from the engine to the wheels. The transmission uses the power created in the engine to keep the wheels spinning and keep the engine within a certain revolutions per minute range. Each car is different in the range required, so the transmission needs to be tuned to your vehicle. The arrangement of the transmission and where it sits is dependent on whether the car is all-wheel drive, front-wheel drive, or rear-wheel drive. [1] [4]

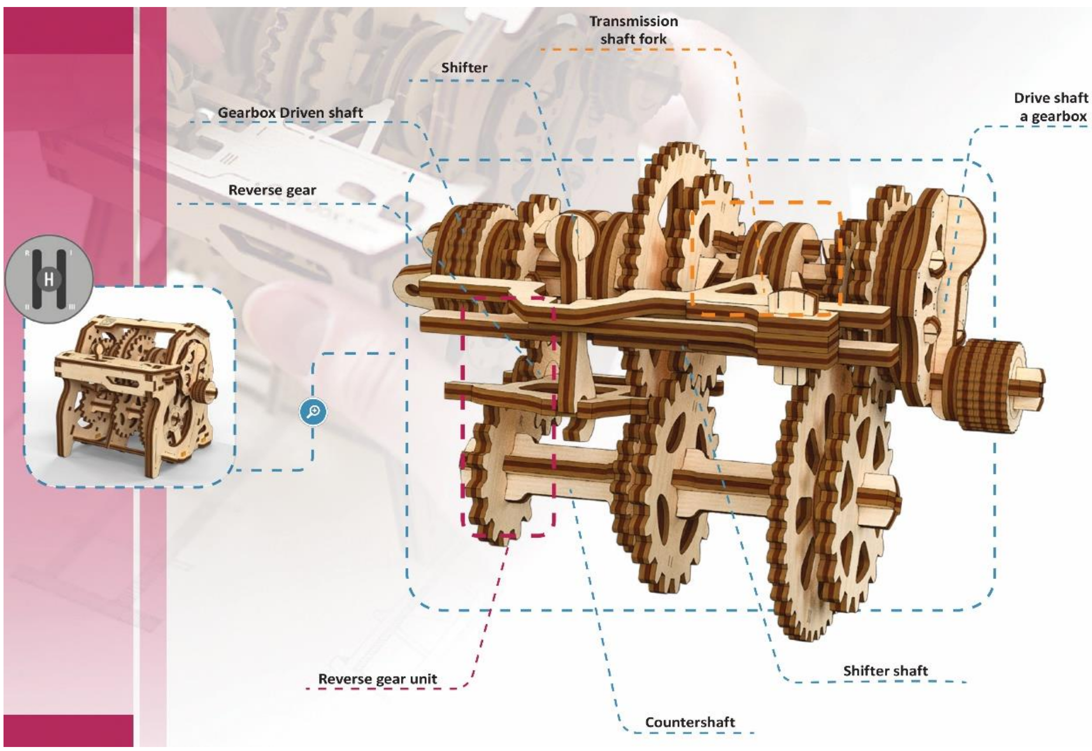

Figure IV- 1 : components of transmission

IV.1.1 from engine to wheels via Transmission

. Fuel (gasoline) is ignited in the combustion chamber of your vehicle's engine.

. When the fuel ignites, the expanding gas and heat from the miniature explosion pushes a series of pistons into your engine's cylinders.

. When the pistons are pushed, they move up and down, turning your engine's crankshaft.

. The crankshaft then turns the drive wheels of your car. This mechanism converts explosive energy into mechanical energy.

Without a transmission, the explosive power of a typical car's internal combustion engine would simply be too high for starting or stopping your car or when you need to drive relatively slowly.

A typical car transmission consists of five to six sets of gears and a series of gear trains (essentially belts or chains running around the outside of two or more gears) which allow a driver to control how much power is delivered to the car without changing how fast the engine is running.

Put another way, a car transmission helps ensure your engine is turning at the correct speed without overspeeding or under speeding for your needs. It also ensures your wheels are getting the right amount of power. Without a transmission, any car would be difficult to start and stop and totally unreliable.

A transmission changes gears depending on car speed and how far down you push the pedal of your car so that the engine's RPM or "revolutions per minute" are kept appropriately low.[2][3]

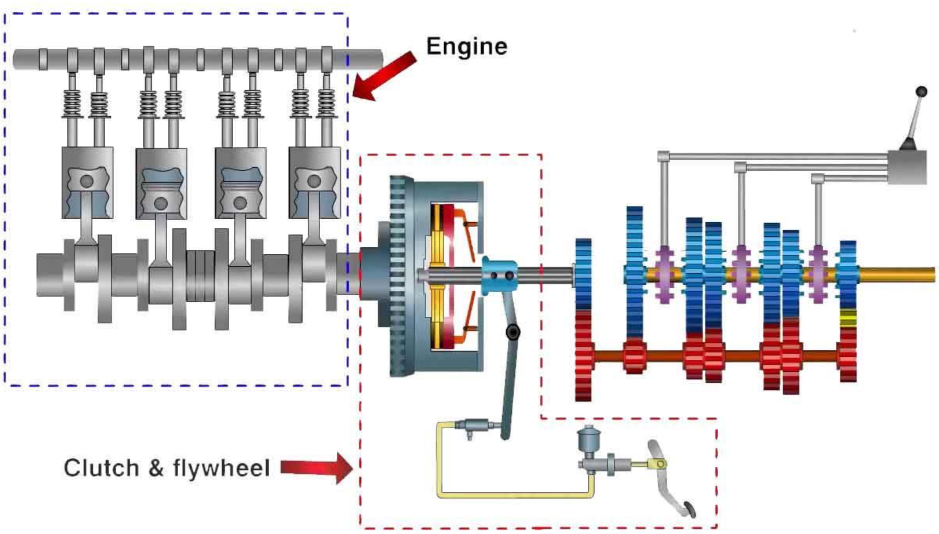

Figure IV- 2 : transmission of power 1

IV.2. Purpose

. It helps the engine to disconnect from driving wheels.

. It helps the running engine connect to the driving wheel smoothly and without shock.

. It provides the leverage between engine and driving wheels to be varied.

. This helps in reducing the engine speed in the ratio of 4 : 1 in case of passenger cars and in a greater ratio in case of heavy vehicles like trucks and lorries.

. It helps the driving wheels to drive at different speeds.

. It gives the relative movement between engine and driving wheels due to flexing of the road spring. [6]

IV.3. Features

IV.3.1 The clutch and clutch pedal

Consisting of various small parts, the clutch transfers the engine torque to the transmission. The clutch pedal is a piece of gear that is hydraulically controlled. When you depress, it disengages the clutch. [8]

IV.3.2 Flywheel

Normally circular in shape and used to send the engine torque to the clutch disc, which interacts with the smooth surface of the flywheel. [8]

IV.3.3 Collar and selector fork

An arm-like-looking piece of gear that aids in moving the collars through the output shaft. By locking the collar to a specific gear, you can always select different other gears. This results in the transmission of torque from the layshaft to the output shaft. [8]

IV.3.4 Synchronizers

Helps the collar and the gear engage with each other and importantly matches their speed if there is a difference. [8]

IV.3.5 Output shaft and Layshaft

The output shaft's gears mesh with the lay shaft's gears when one receives the engine power first. [8]

IV.3.6 Gears

Gear often comes in different sizes in a manual gearbox. Large gearwheels contain more teeth and offer more torque to reduce the car's speed, whereas small gears provide less torque to your car so that it can run at a higher speed. [8]

IV.4. Function

IV.4.1 Neutral

All the gears except those needed for reverse are constantly in mesh. The gears on the output shaft revolve freely around it, while those on the layshaft are fixed. No drive is being transmitted. [5]

Figure IV- 3 : Neutral

IV.4.2 First gear

In first gear, the smallest gear on the layshaft (with the fewest teeth) is locked to it, passing drive through the largest gear on the mainshaft, giving high torque and low speed for a standing start. [5]

Figure IV- 4 : First gear

IV.4.3 Second gear

In second gear, the difference in diameter of the gears on the two shafts is reduced, resulting in increased road speed and lower torque increase. The ratio is ideal for climbing very steep hills. [5]

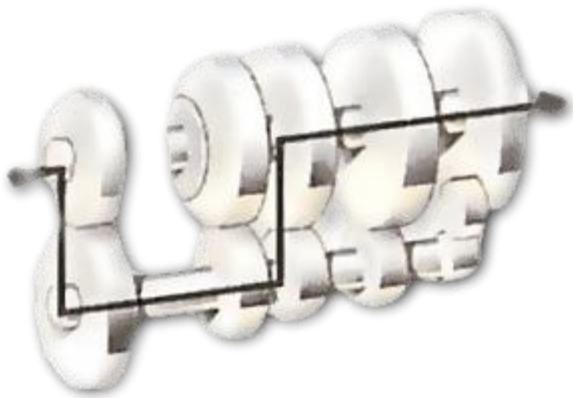

Figure IV- 5 : Second gear

IV.4.4 Fourth gear

In fourth gear, the input shaft and mainshaft are locked together, providing 'direct drive': one revolution of the propellor shaft for each revolution of the crankshaft. There is no increase in torque. [5]

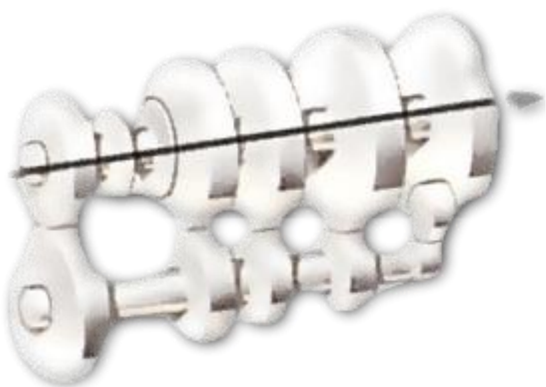

Figure IV- 6 : Fourth gear

IV.4.5 Reverse

For reversing, an idler gear is interposed between gears on the two shafts, causing the mainshaft to reverse direction. Reverse gear is usually not synchronised. [5]

Figure IV- 7 : Reverse

IV.5. Types

IV.5.1 Automatic

Automatic gearbox enables the driver to drive without pushing the clutch. This gearbox contains different ratios, allowing the engine to have more power. [7] [9]

IV.5.2 Manual

Manual gearboxes are among the common ones that need the clutch to decouple the gearbox from the engine. The driver should push the clutch when he or she wants to shift the gears.[7][9]

IV.5.3 Dual-Clutch

The dual-clutch gearbox is also known as DSG or PDK. It also goes by the name “power-shift”. This gearbox uses two clutches. One clutch is used for even-numbered gears and the other is used for odd-numbered gears. [7] [9]

IV.5.4 Automated Manual, Semi-Automatic

This gearbox type contains automatic transmission except for a torque converter. This type also uses a clutch when the driver wants to change the gears. [7] [9]

IV.5.5 Continuously Variable Transmission

This gearbox is like the automatic one, except that it doesn’t have fixed ratios. A steel drive-belt exists between the two pulleys of the engine. This unit affects the ratios by adjusting their diameters with the range of speed. [7] [9]

Table 1. Advantages and disadvantages of vehicle gearboxes.

Gearbox type	Advantages	Disadvantages
Mechanical gearbox with manual shifting	• simple design; • low price; • efficiency	• increases driver fatigue and work intensity due to gear shifting and clutch release, particularly in the urban cycle; • no continuous transmission when shifting.
Mechanical gearbox with automatic clutch	decreases driver fatigue only partially due to the elimination of the necessity for clutch release	• the price is twice as high if compared to the first type; • no continuous transmission when shifting.
Automated mechanical gearbox	decreases driver fatigue	• the price is high enough; • requires the high pressure of the power liquid and, consequently, a high-duty pump driven by the vehicle engine; it results in engine net power decrease and fuel consumption increase, particularly, in the urban cycle, which is explained by the fact that, for operation of a pump with an idle engine, overspeed of the cranked shaft is required; • no continuous transmission when shifting
Hydromechanical transmission with electronic control	• decreases driver fatigue; • upon blocking a torque converter on high gears in suburban traffic, it is compared to mechanical gearboxes in efficiency	• the price is about thrice as high if compared to mechanical gearboxes; • significant power input to torque converter stall and a hydraulic pump drive for compression of clutch friction disks; • in the urban cycle, the result is lower than the one mechanical gearboxes show; • notable loss of vehicle dynamic qualities, about 5%.
Variator (continuously variable transmission)	decreases driver fatigue due to continuously variable transmission	• their mass is bigger and efficiency coefficient is smaller, they are much more expensive than mechanical gearboxes; • increased power input to the control system operation; • the transformation coefficient is smaller than required for speed cars with high-speed engines; • maximum transmitted power is technologically limited to 100 kWt [Dolgikh (2014)].

Table IV- 1 : Advantages and disadvantages of vehicle gearboxes.

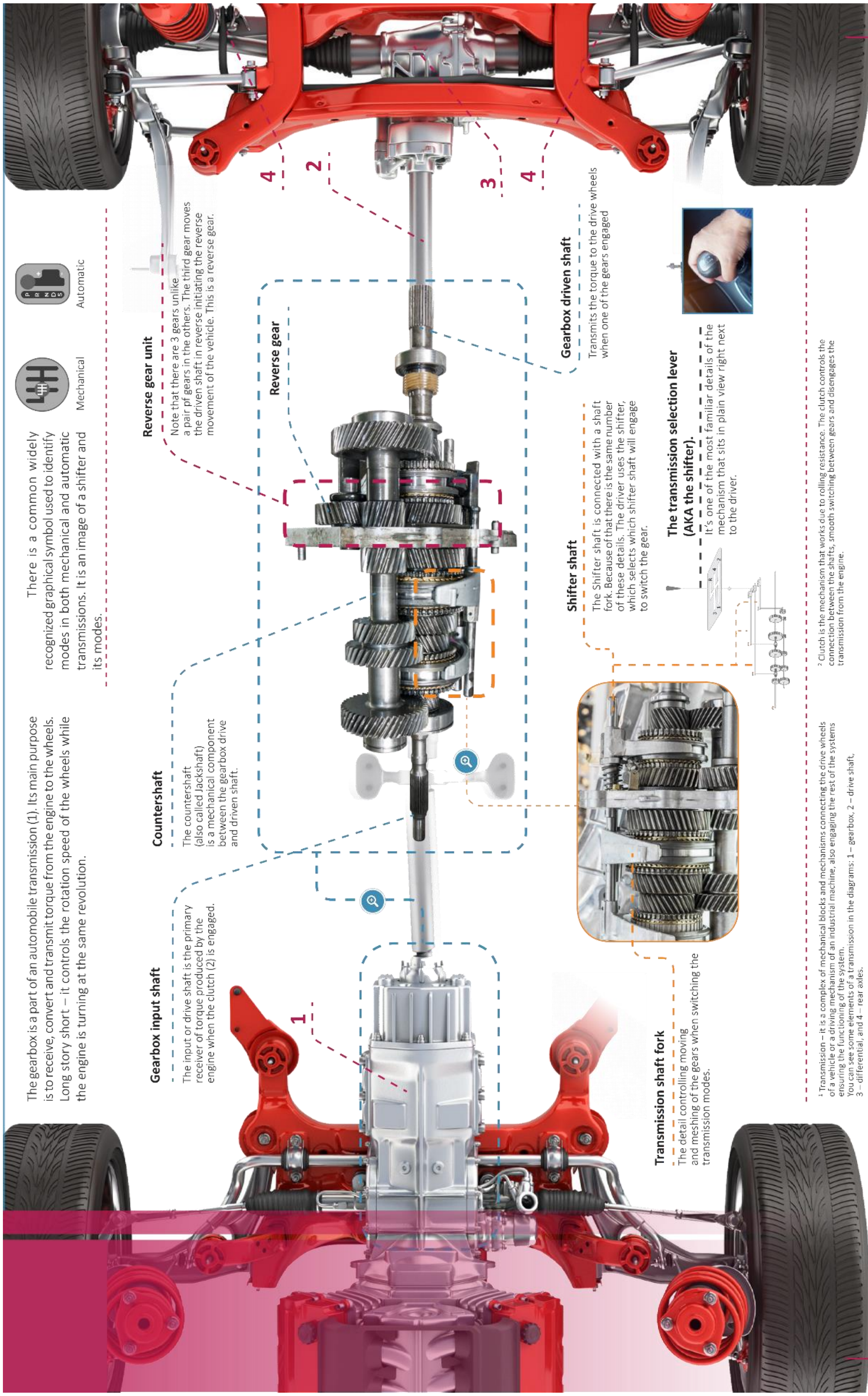

Figure IV- 8 : transmission of power 2

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CHAPTER V
MODELING AND CALCULATION

V.1. Parts and their Projections

V.1.1. Projections of Input Shaft

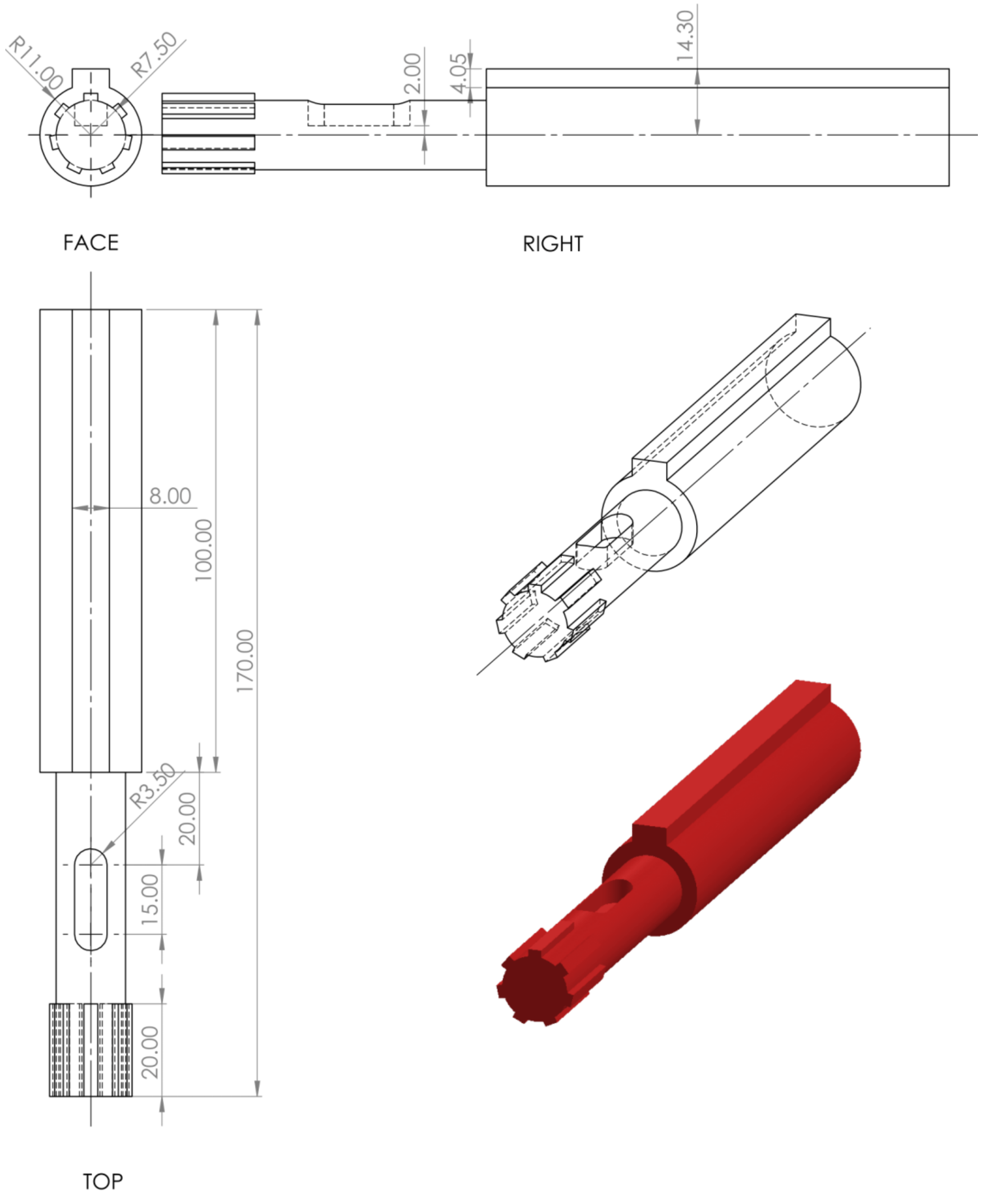

Figure V- 1 : Projections of Input Shaft

V.1.2. Projections of Output Shaft

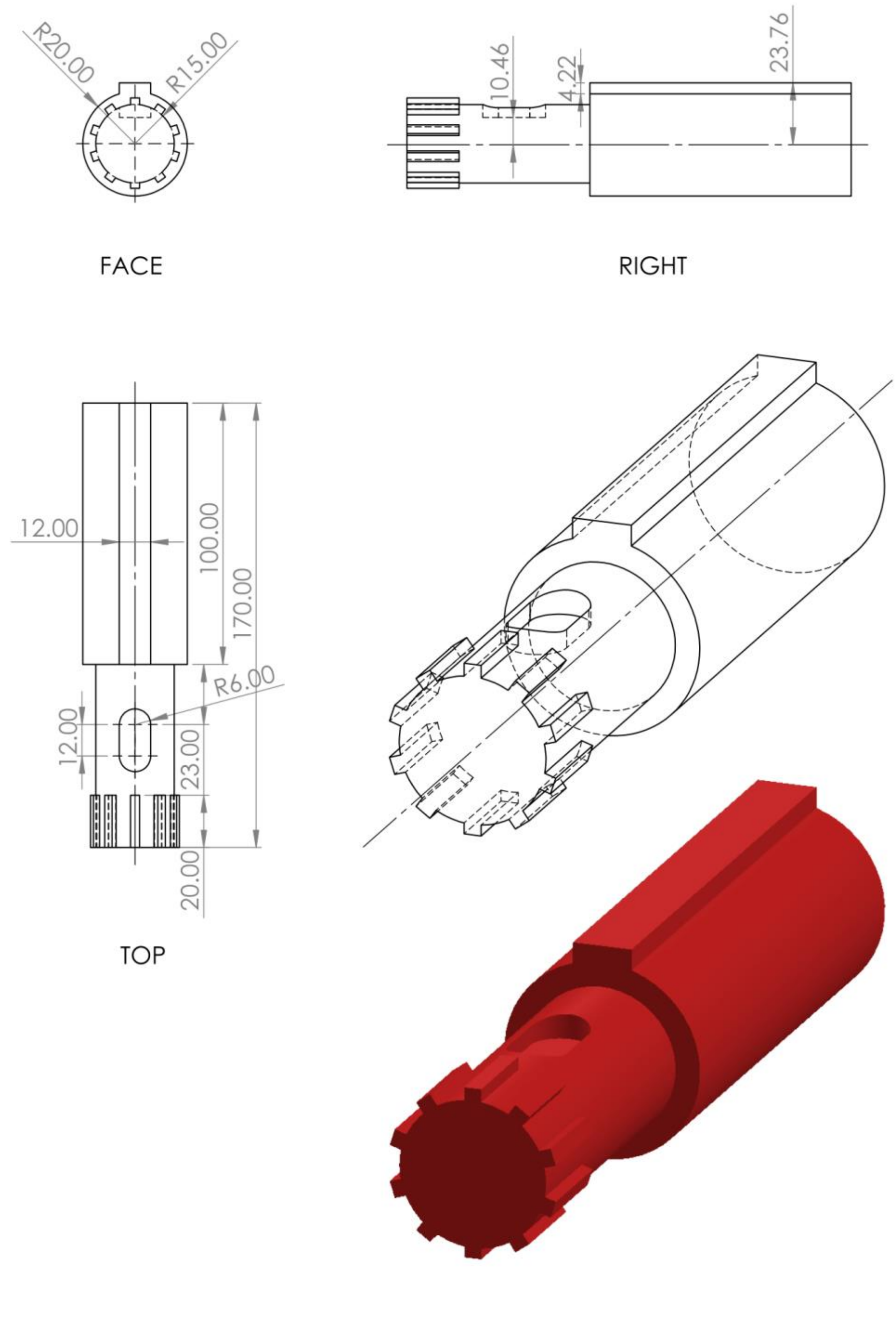

Figure V- 2 : Projections of Output Shaft

V.1.3. Projections of Middle Shaft

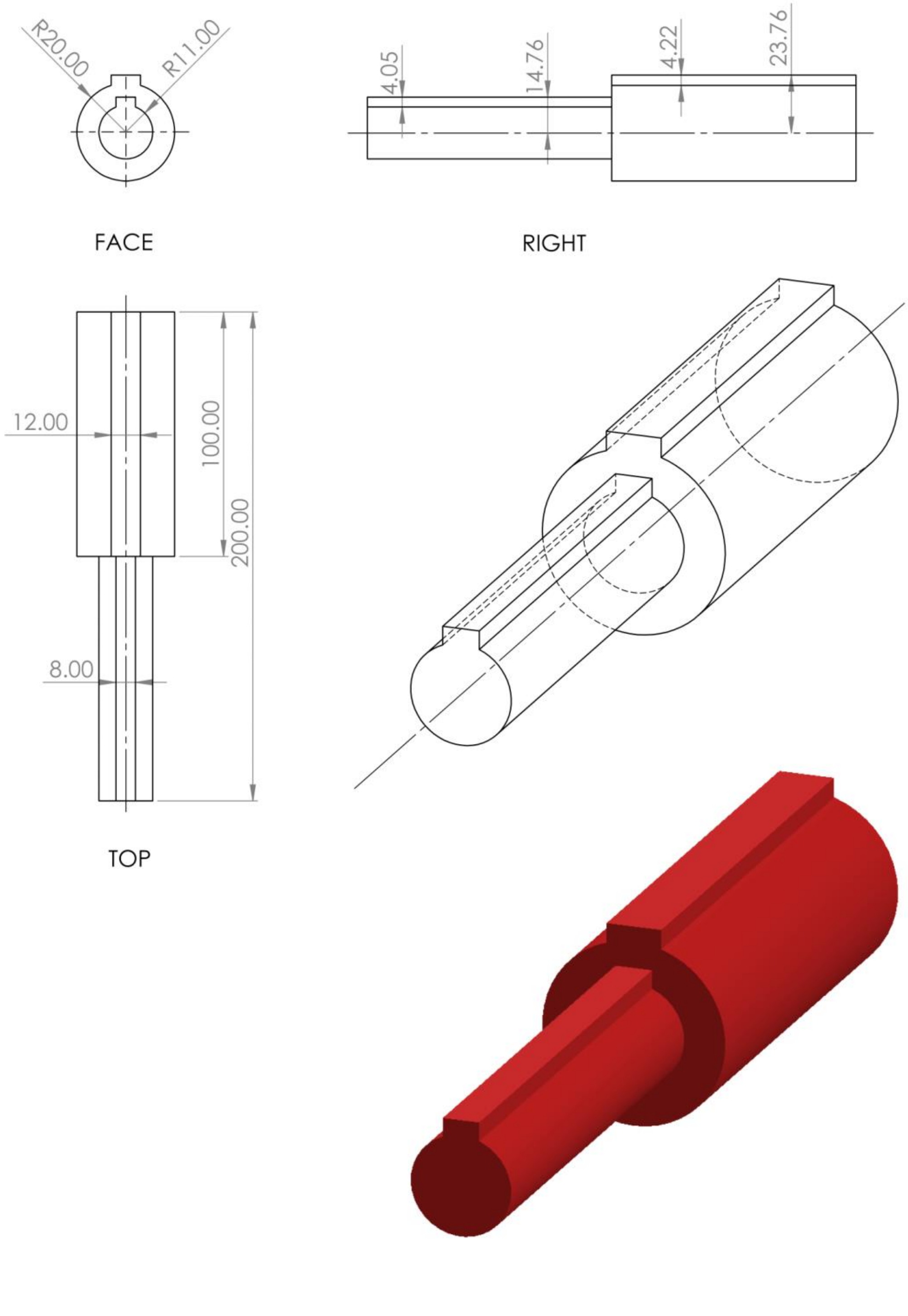

Figure V- 3 : Projections of Middle Shaft

V.1.4. Projections and Proprieties of Bevel Gear

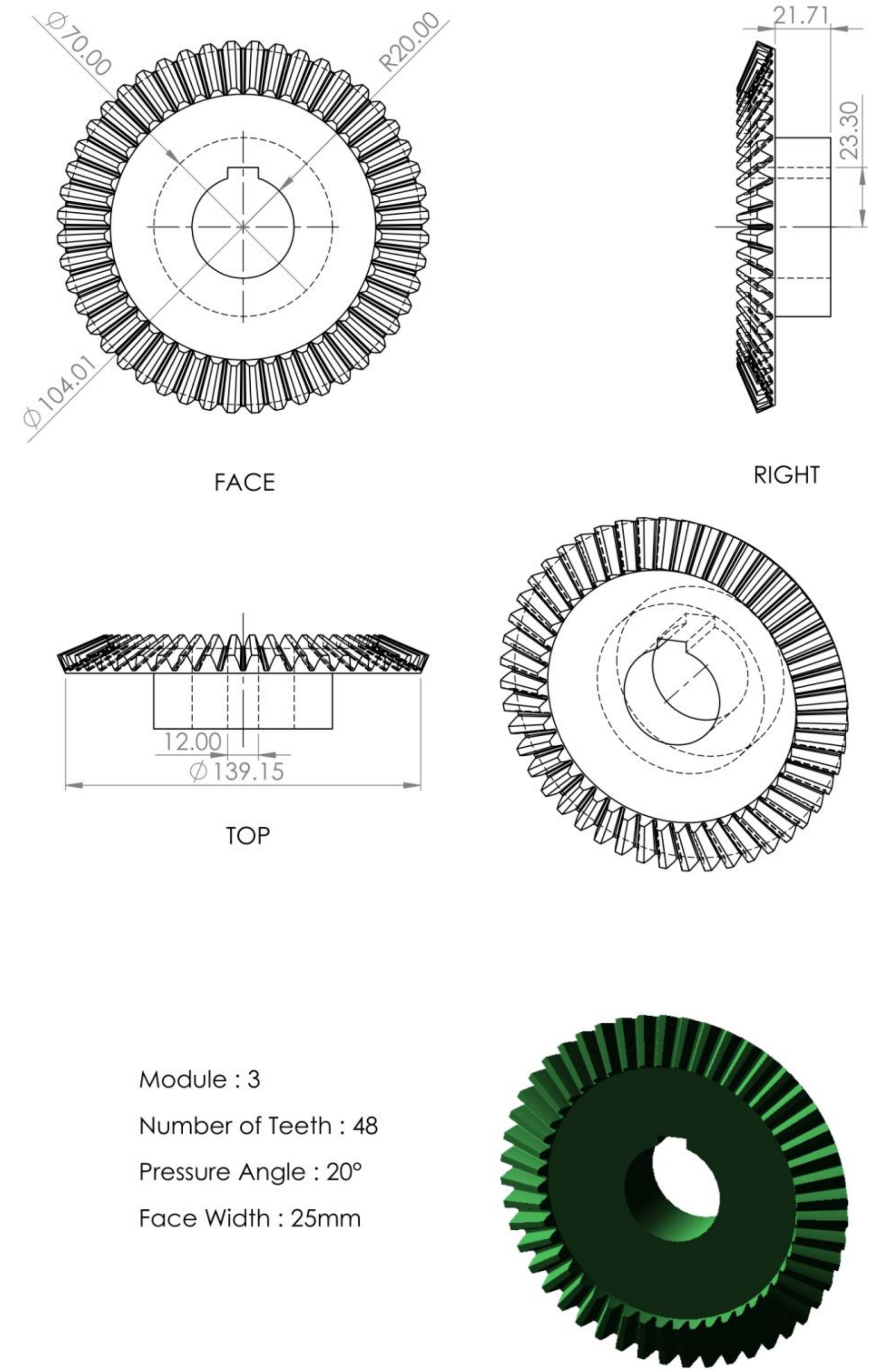

Figure V- 4 : Projections and Proprieties of Bevel Gear

V.1.5. Projections and Proprieties of Pinion

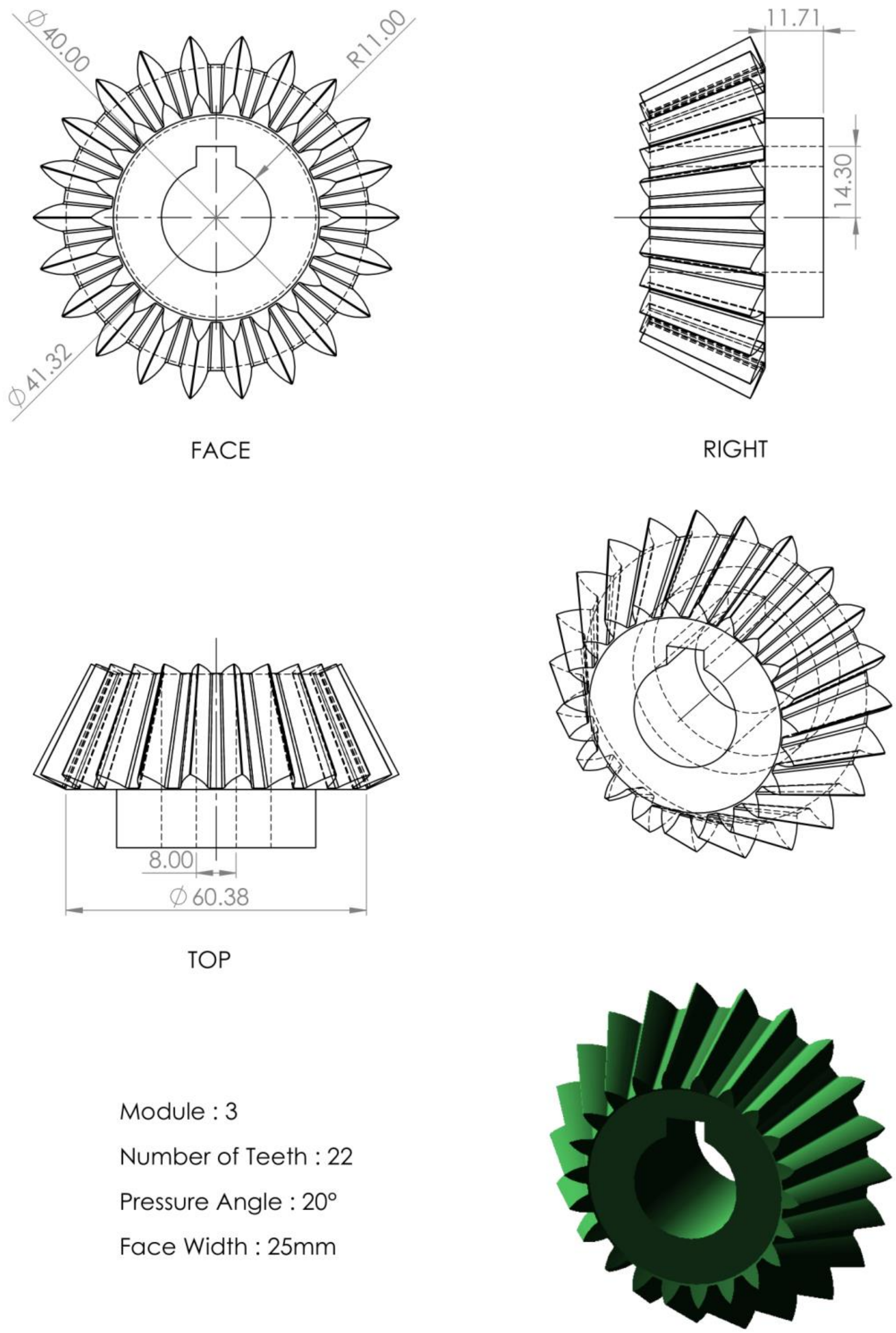

Figure V- 5 : Projections and Proprieties of Pinion

V.1.6. Projections and Proprieties of Large Spur Gear

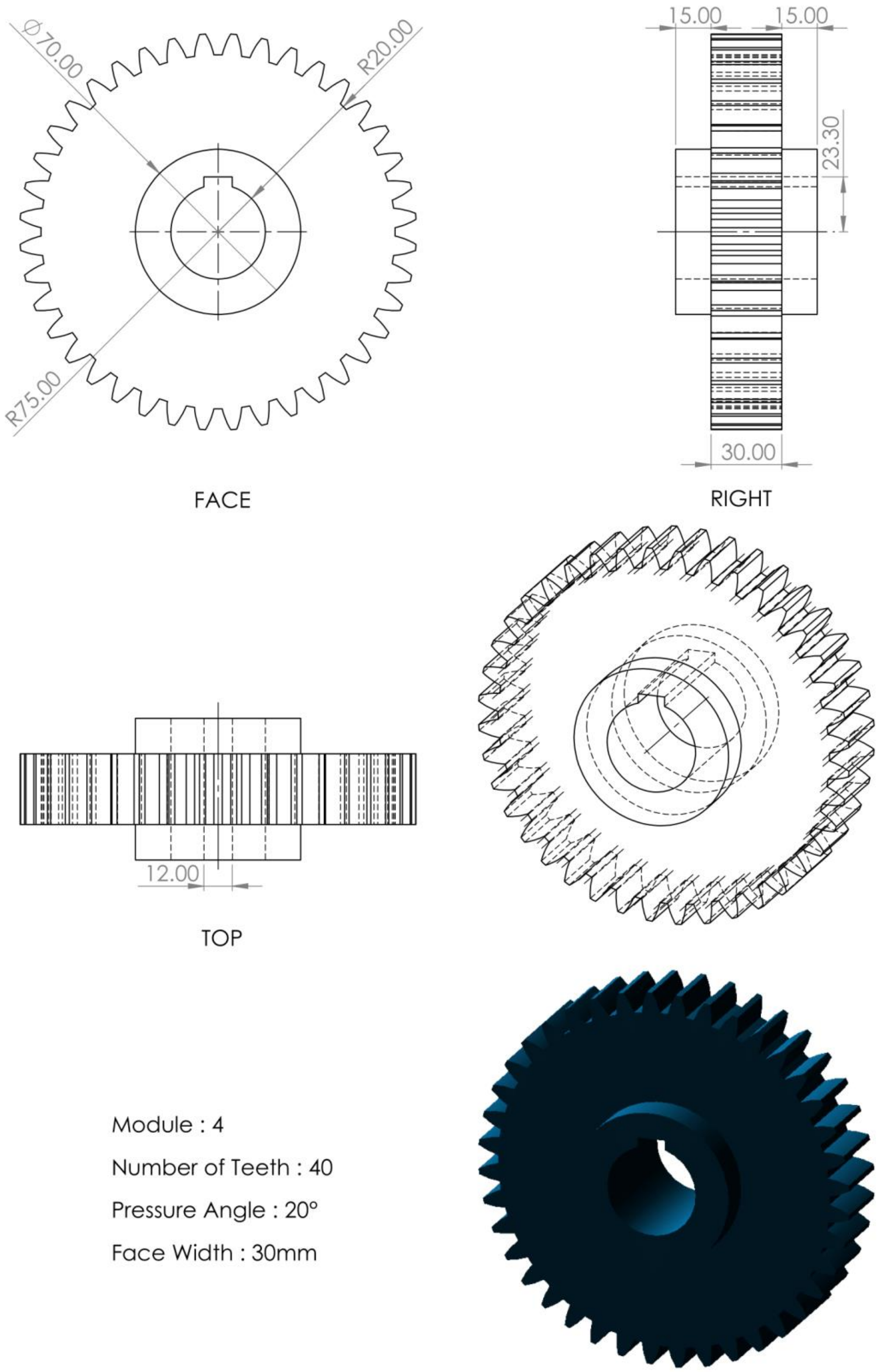

Figure V- 6 : Projections and Proprieties of Large Spur Gear

V.1.7. Projections and Proprieties of Small Spur Gear

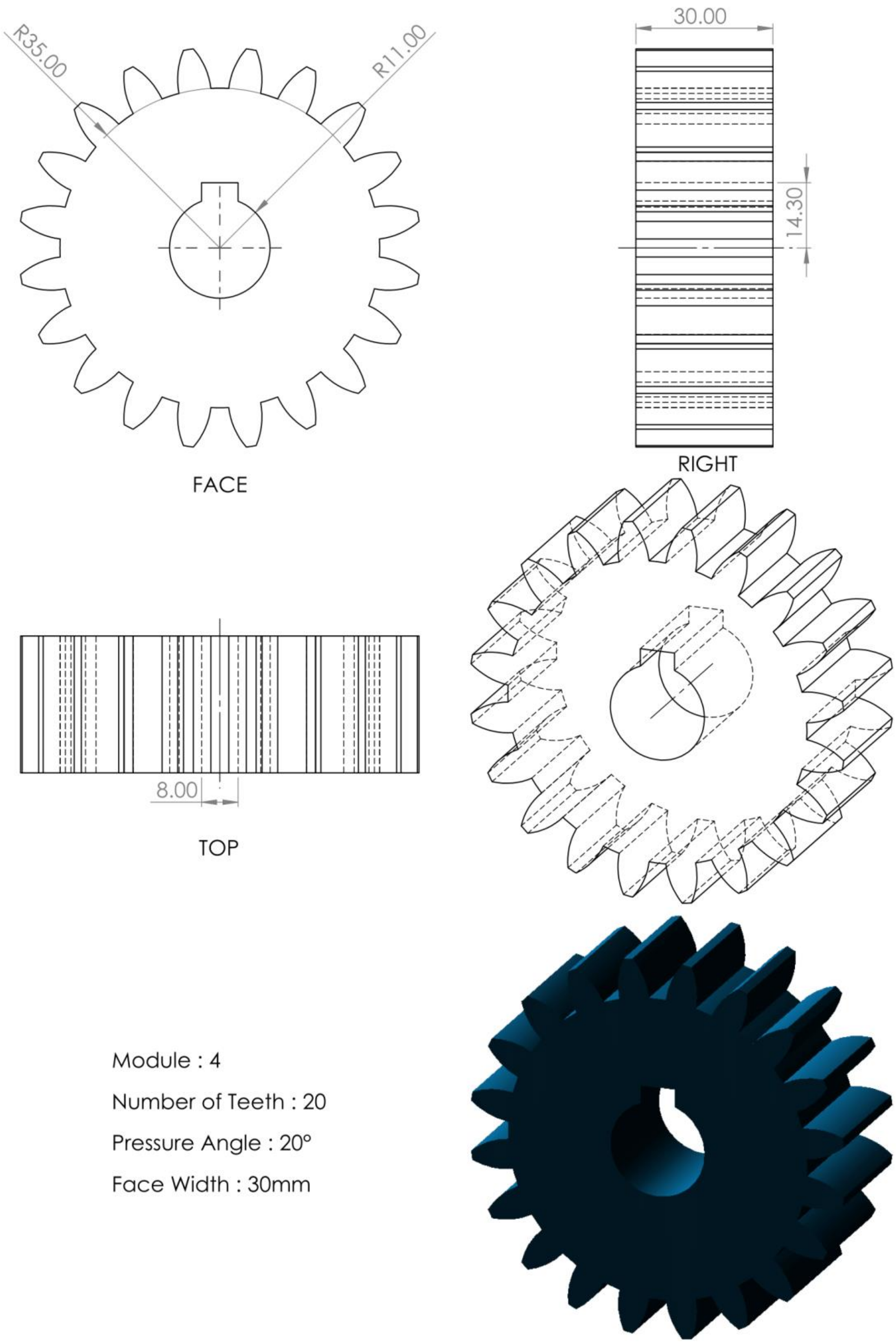

Figure V- 7 : Projections and Proprieties of Small Spur Gear

V.1.8. Assembly

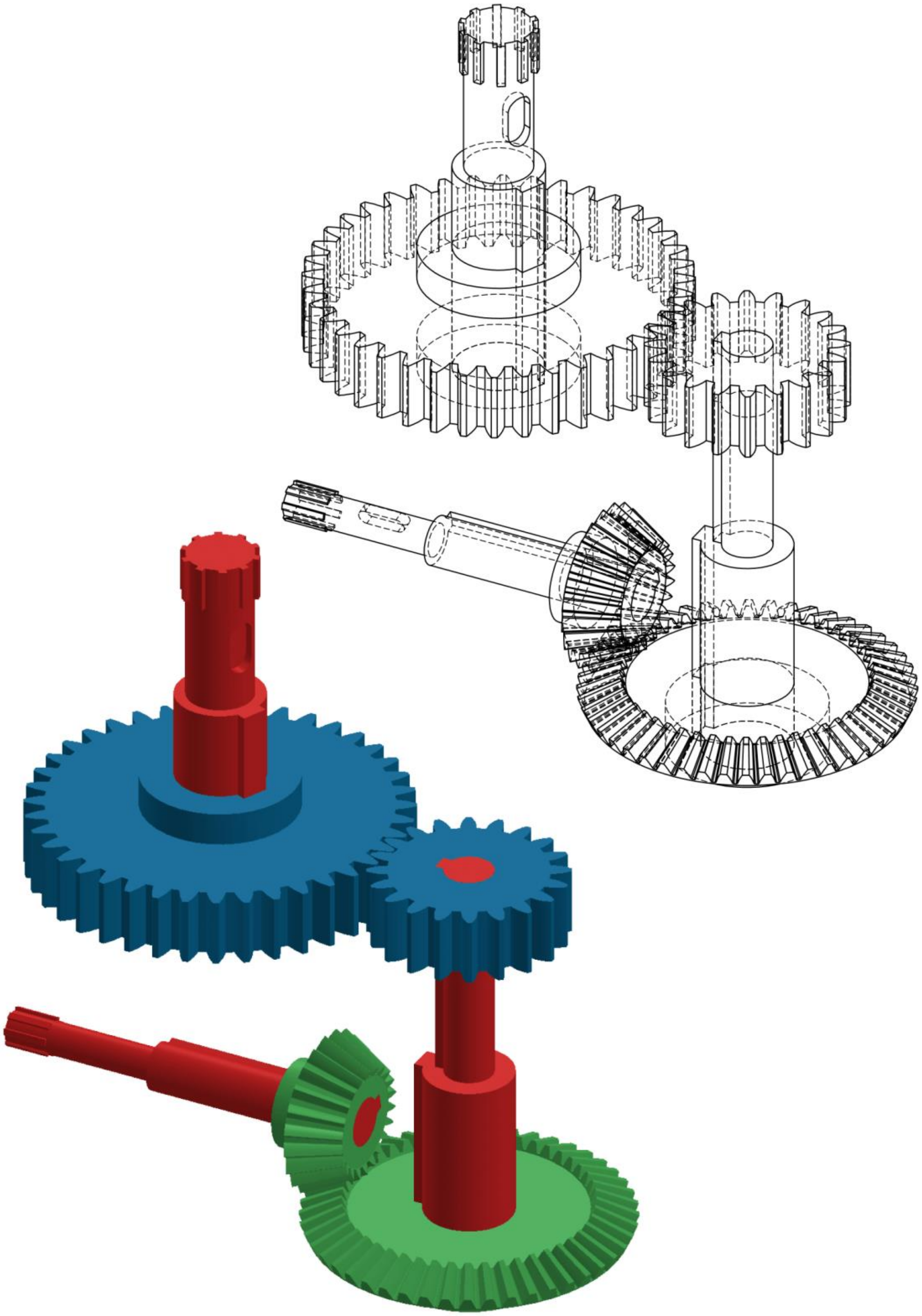

Figure V- 8 : Assembly

V.2. Force Application

V.2.1 Vertical Force on Input Shaft

Material : AISI 4130 Steel , normalized at 870C

Force = 100 N

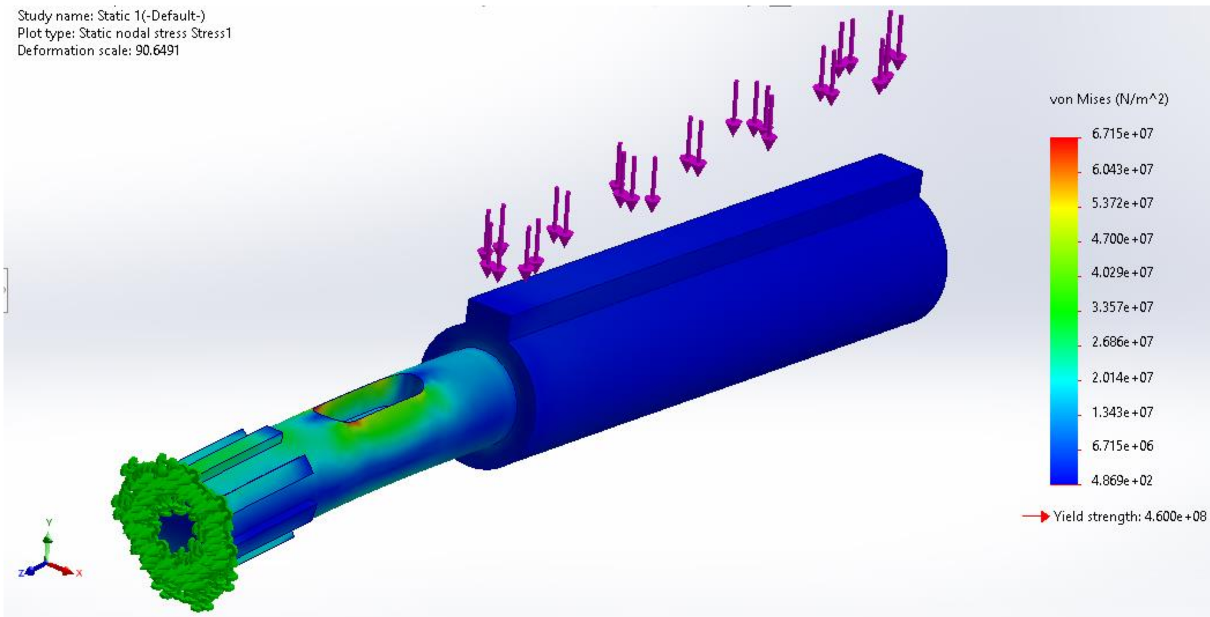

Figure V- 9 : Input Shaft Stress diagram

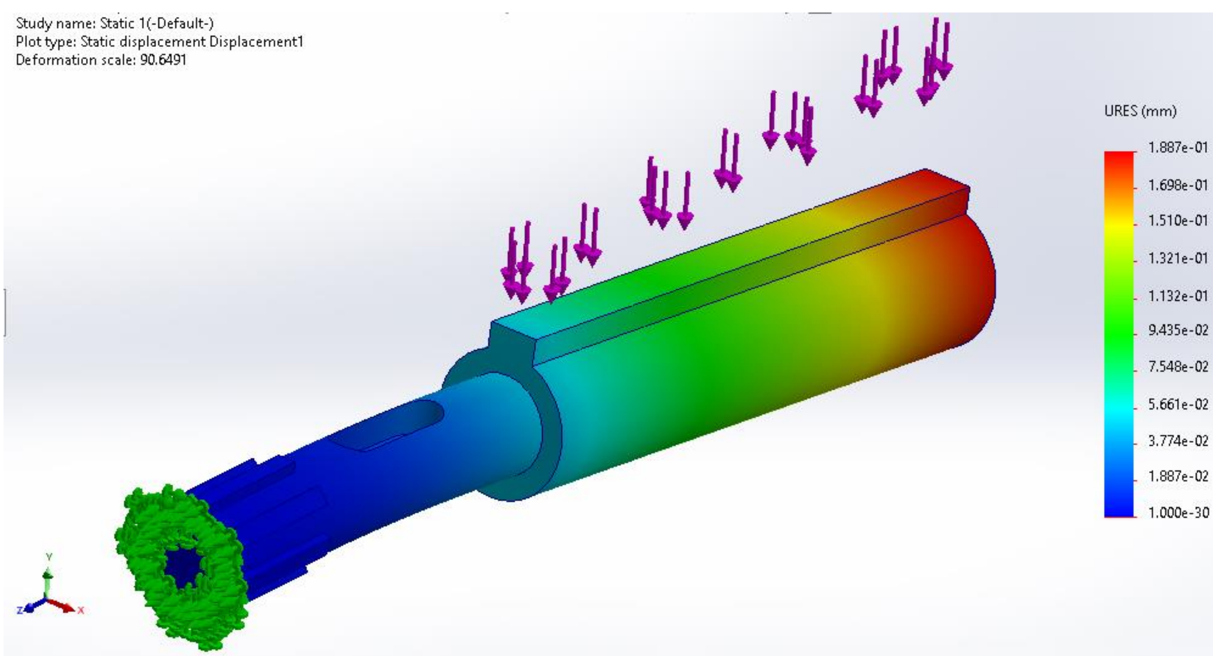

Figure V- 10 : Input Shaft Displacment Diagram

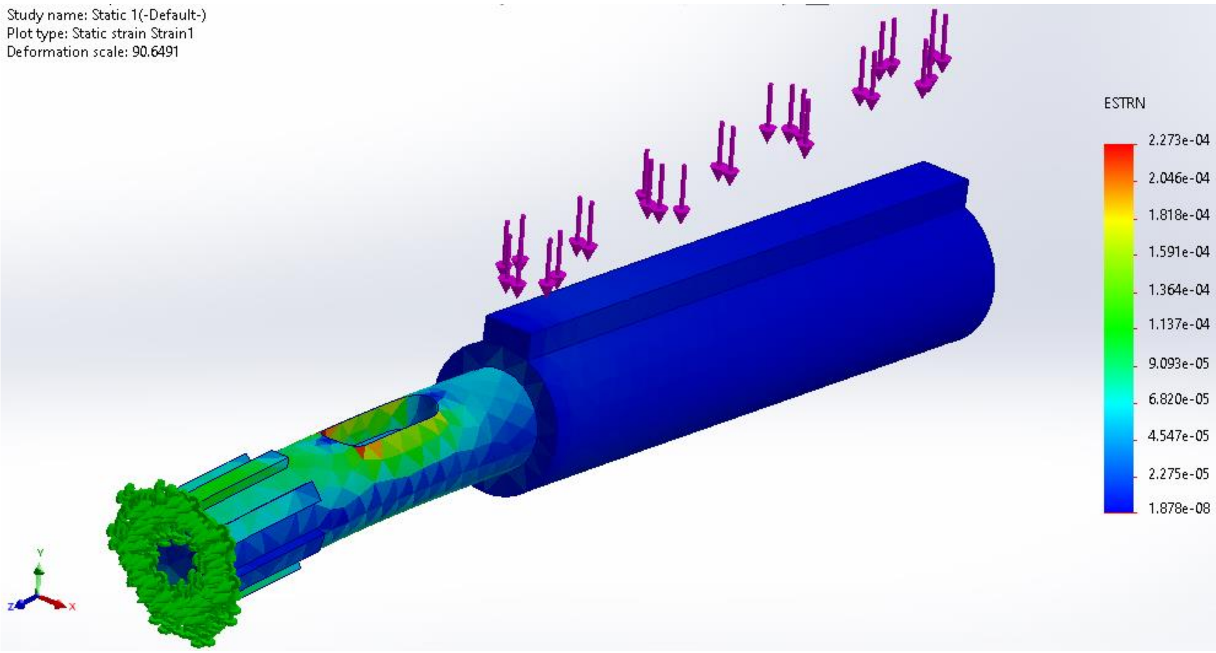

Figure V- 11 : Input Shaft Strain Diagram

V.2.2 Torque on Output Shaft

Material : AISI 4130 Steel , normalized at 870C

Torque = 100 N.m

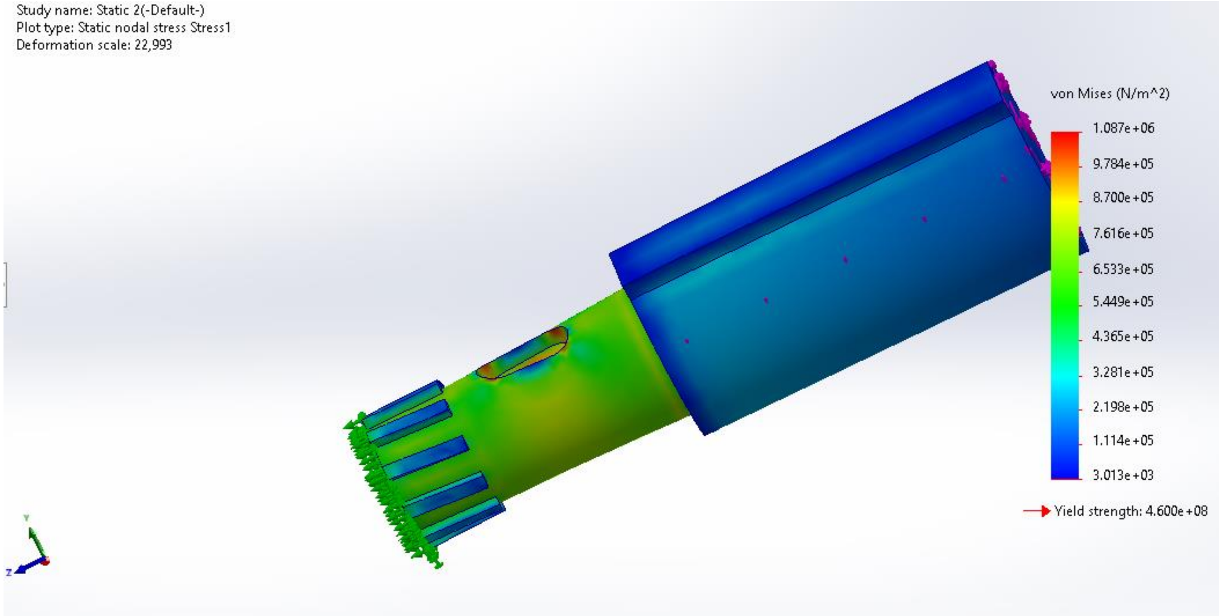

Figure V- 12 : Output Shaft Stress diagram

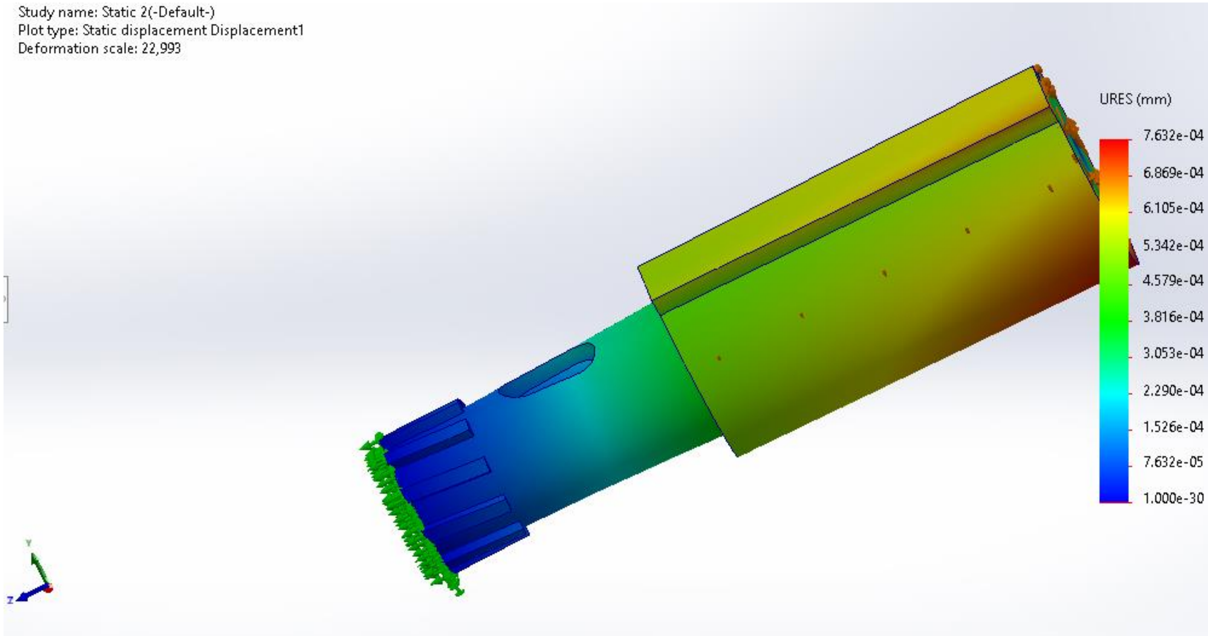

Figure V- 13 : Output Shaft Displacment Diagram

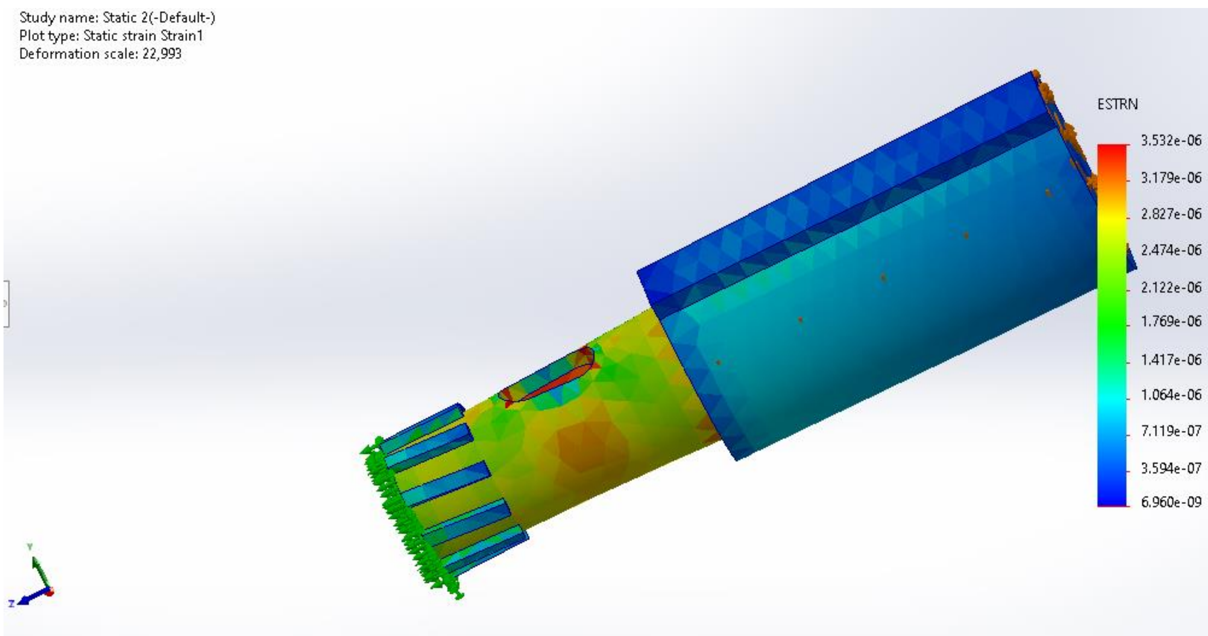

Figure V- 14 : Output Shaft Strain Diagram

V.3. calculation

number of teeth of bevel gear = 48

number of teeth of pinion = 22

number of teeth of large spur gear = 40

number of teeth of small spur gear = 20

$Z1 = 48 / 22$

$Z2 = 40 / 20$

$R2 = R1 / Z1$

$R3 = R2 / Z2$

So

$R3 = R1 / (Z1 \times Z2)$

Exemple

R1 = 100 RPM

Solution

$R3 = 100 / (2.18 \times 2) = 100 / 4.36 \approx 23$

So R3 = 23 RPM

General conclusion

A gear reducer is a mechanical system of gears in an arrangement such that input speed can be lowered to a slower output speed but have the same or more output torque.

The use of a gear reducer occurs when the drive gear is smaller and has fewer teeth than the driven gear. This is unlike the condition where the drive gear is larger with more teeth than the driven gear, which is referred to as overdrive.

A gear reducer is a speed reducer that changes the rotational speed using gears, shaft positioning, and the arrangement of gears. They are widely used with reduction transmission equipment where the transmission structure integrates the drive motor and the gearbox or gear reducer.

There are certain factors that have to be evaluated before deciding to choose a gear reducer. The main purpose of a gear reducer is to adapt the characteristics of torque and speed of the input and output axis of a mechanism.

Regular maintenance and upkeep of gear reducers are a necessity and highly recommended. With routine assessment, failures, errors, and poor performance can be minimized or avoided.

Bearings play a crucial role in our daily lives, but it is precisely because of their importance that we must constantly strive to make them more precise and durable.

Additionally, it is vital to the development of machine technology that we continue going forward to develop bearings that can work under ever harsher and more specialized conditions.

Bearings will no doubt continue to evolve and change, and to improve our livelihoods by "making the world go round".

Shaft is a critical and standard component which is used normally in all kind of industries for power/motion transmission. In real industrial field different kind of shafts are used as per functional requirements.

Different kind of loads can be carried out by the shaft like axial, bending, and torsional or any combination out of them.

Design of shaft should be carried out with consideration of fatigue and fracture for various combination of loading conditions with multiple discontinuities present on the shaft.

Gears, are the most important mechanical piece, let alone speed reducers, There are different types of gears with specific requirements and specifications, ranging from simple forms to more complex ones.

Gears are mechanical devices that permit a change in the torque and speed of machines, they provide a gear reduction in motorized equipment. This is key because often a small motor spinning very fast can provide enough power for a device, but not enough torque, the force that causes an object to rotate on an axis or twist, they also change the direction of rotation.

A car transmission, is the mechanism by which power created by the engine is transferred to the driving wheels. This part of the vehicle is the most important in determining the power and functionality of your engine systems.

There are a variety of car transmissions. Some are automatic, while manual transmissions in stick-shift cars require the driver to complete extra steps for the vehicle to operate effectively.

Abstract :

gearboxes is a tool of transmitting power from a motor to a receiving part.

we can find reducers widly in the mechanical industry, espacialy in the automotive world.

The objective of our project is the design study of a speed reducer. a two-stage speed reducers with bevel gears.

The design of the reducer was made, after a brief talking about the parts of the reducer, by the CAD software "Solidworks".

Keywords: Solidworks, simulation,reducer, gearbox, gear, transmission.

علب التروس هي أداة لنقل الطاقة من المحرك إلى جزء الاستقبال.

يمكننا أن نجد مخفضات على نطاق واسع في الصناعة الميكانيكية ، خاصة في عالم السيارات.

الهدف من مشروعنا هو دراسة تصميم مخفض السرعة. مخفض سرعة ذو مرحلتين مع تروس مخروطية.

تم تصميم المخفض، بعد حديث موجز عن أجزاء المخفض، بواسطة برنامج الرسم التقني "سوليدووركس".

الكلمات المفتاحية :سوليدووركس، المحاكاة، المخفض، علبة التروس، التروس، ناقل الحركة.