# STRESS ANALYSIS ON SPUR GEAR IN MARINE APPLICATOINS BY FEM TECHNIQUE

A project review report submitted for the partial fulfillment of the
Requirement for the award of the degree

**BACHELOR OF TECHNOLOGY**
**IN**
**MECHANICAL ENGINEERING**
Submitted by

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**SANGIVALASA, VISAKHAPATNAM (District) – 531162**
**2020-2021**

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## CERTIFICATE

This is to certify that the Project Report entitled "**STRESS ANALYSIS ON SPUR GEAR IN MARINE APPLICATION BY FEM TECHNIQUES**" being submitted by VARANASI UDAY KIRAN (317126520229), BUDDHA HEMANTH KUMAR (318126520L46), S RISHIKESH RAVI SHANKAR (317126520219), AVALA SAI KALYAN (317126520182), TEKUMALLA SAMUEL PAUL (317126520225) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.M.RAJA ROY**, Associate Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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# ABSTRACT

Gear is one of the most critical components in a mechanical power transmission system, and most industrial rotating machinery. The gears are generally used to transmit power and torque. The efficiency of power transmission is very high when compared to other kind of transmission.

This project work is made an attempt to summarize about stress developed in a mating spur gear in marine applications. Marine engines are generally used for heavy duty application, so need to be taken care during the development of prototype in best way. Marine engines are operated at very high speed so large stresses and deflections in the gear as well as in other rotating component are produced. The stresses and deflections should be reduced for the safe functioning of engine. For this work, structural analysis on a high speed spur gear in marine engines, have been carried out. Theoretical methods are generally used for arrival of dimensions. The deflections of the tooth and dimensions have been analyzed for different material. Finally the results obtained by theoretical method and finite element analysis are compared to check the correctness. A conclusion has been arrived on the material which is best suited. Basically the project involves the design, modeling and manufacturing of spur gears for marine application. Main aim of this design is reduction of weight and producing high accuracy gears. Generally, this type of gear box is used in fishing boat in which marine engine is used. It requires high load carrying capacity, strength, torque and it should operate efficiently. There are various types of engines are available which ranges from 220HP to 500HP are and for this engine 12 to 13 types of gear box are available.

Face width and weight are important geometrical parameters in determining the state of stress during the design of gears. Thus, in this work the parametric study is conducted by varying the face width and reducing weight to study their effect on contact stress of spur gear. The analysis of contact stresses has become popular as an area of research on gears to minimize and reduce the failures. The present investigation is carried out to make use of spur gear, by analyzing the contact stress for different (15 mm,20mm, 25mm) face width along with introducing circular, elliptical , rectangular holes where ever material is unnecessary to reduce its weight.

A Three dimensional solid model is generated by solid works which is powerful a modern solid modeling software. The numerical solution is done by Ansys, which is a finite element analysis package. The analytical approach is based on contact stress equation, to determine the contact stress between the two matting gears. As there involves many complications in calculating contact stress analytically a simplified approach is made in visual basic for different parameters like module, face width etc.

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# SOFTWARE REQUIRED

1. SOLID WORKS for preparing model

2. ANSYS for simulation

## Chapter-1

# 1. INTRODUCTION

**DEFINITION:**

Gears are one of the oldest of humanity's inventions. Nearly all the devices we think of as machines utilize gearing of one type or another. Gear technology has been developed and expanded throughout the centuries. In many cases, gear design is considered as a specialty. Nevertheless, the design or specification of the gear is only part of the overall system design picture. From industry's standpoint, gear transmission systems are considered one of the critical aspects of vibration analysis.

There are many types of gears such as spur gears, helical gears, bevel gears, worm gears, gear rack, etc. These can be broadly classified by looking at the positions of axes such as parallel shafts, intersecting shafts and non-intersecting shafts.

It is necessary to accurately understand the differences among gear types to accomplish necessary force transmission in mechanical designs. Even after choosing the general type, it is important to consider factors such as: dimensions (module, number of teeth, helix angle, face width, etc.), standard of precision grade (ISO, AGMA, DIN), need for teeth grinding and/or heat treating, allowable torque and efficiency, etc.

Besides this page, we present more thorough gear technical information under Gear Knowledge (separate PDF page). In addition to the list below, each section such as worm gear, rack and pinion, bevel gear, etc. has its own additional explanation regarding the respective gear type. If it is difficult to view PDF, please consult these sections.

It is best to start with the general knowledge of the types of gears as shown below. But in addition to these, there are other types such as face gear, herringbone gear (double helical gear), crown gear, hypoid gear, etc.

Different gear types are used in machines as they can be designed for a range of forces from a range of materials. They can also be used to increase/decrease rotational velocity as well as change the direction of rotation.

Gears can also be used to pump liquids as in the case of gear pumps for fuel oil and lubrication oil for instance. They mesh so well (forming a positive displacement pumps) that the liquid is pushed ahead with high delivery pressures.

They are also used in chain blocks to lift heavy objects easily. Thus, gears are a core component of most equipment as they are quite versatile and able to perform a variety of tasks.

An external gear is one with the teeth formed on the outer surface of a cylinder or cone. Conversely, an internal gear is one with the teeth formed on the inner surface of a cylinder or cone. For bevel gears, an internal gear is one with the pitch angle exceeding 90 degrees. Internal gears do not cause output shaft direction reversal

## 1.1 TYPES OF GEARS:

There are many types of gears and each one offer some trade-offs. It comes down to what expectations a designer has from a gear train. The factors that may be considered are as follows:

- Torque/duty cycle needs
- Rotation speed/gear ratio
- Service environment
- Space availability/restrictions
- Budget

Based on these factors, the selection is further narrowed down to whether the gears will be operating on parallel/non-parallel and intersecting/non-intersecting axes. Let's learn a little more about what choices one has and what each one of them offers.

## 1.1.1 Spur Gear:

The most common type of gear used. It's simple and effective design creates a possibility for a wide range of applications. The teeth on spur gears are parallel and straight-cut on a cylindrical gear body.

Spur gears use the parallel axes configuration in mated pairs. They work great for moderate load and moderate speed applications and are generally used in applications where noise and vibration are not a concern.
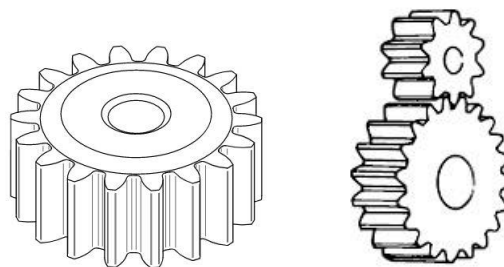


**Fig.1.1 Spur gear**

### 1.1.2 Helical Gear:

Helical gears are used with parallel shafts similar to spur gears and are cylindrical gears with winding tooth lines. They have better teeth meshing than spur gears and have superior quietness and can transmit higher loads, making them suitable for high speed applications. When using helical gears, they create thrust force in the axial direction, necessitating the use of thrust bearings. Helical gears come with right hand and left hand twist requiring opposite hand gears for a meshing pair

**Fig.1.2 Helical gear**

### 1.1.3 Gear Rack:

Same sized and shaped teeth cut at equal distances along a flat surface or a straight rod is called a gear rack. A gear rack is a cylindrical gear with the radius of the pitch cylinder being infinite. By meshing with a cylindrical gear pinion, it converts rotational motion into linear motion. Gear racks can be broadly divided into straight tooth racks and helical tooth racks, but both have straight tooth lines. By machining the ends of gear racks, it is possible to connect gear racks end to end.
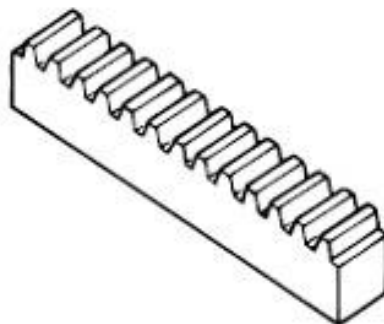
**Fig.1.3 Gear rack**

### 1.1.4 Bevel Gear:

Bevel gears have a cone shaped appearance and are used to transmit force between two shafts which intersect at one point (intersecting shafts). A bevel gear has a cone as its pitch surface and its teeth are cut along the cone. Kinds of bevel gears include straight bevel gears, helical bevel gears, spiral bevel gears, miter gears, angular bevel gears, crown gears, zero bevel gears and hypoid gears
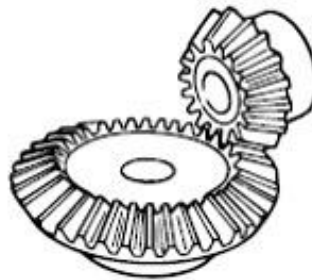


**Fig.1.4 Bevel gear**

### 1.1.5 Spiral Bevel Gear:

Spiral bevel gears are bevel gears with curved tooth lines. Due to higher tooth contact ratio, they are superior to straight bevel gears in efficiency, strength, vibration and noise. On the other hand, they are more difficult to produce. Also, because the teeth are curved, they cause thrust forces in the axial direction. Within the spiral bevel gears, the one with the zero twisting angles is called zero bevel gears.
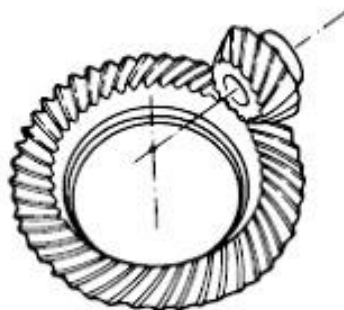


**Fig.1.5 Spiral bevel gear**

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### 1.1.6 Screw Gear:

Screw gears are a pair of same hand helical gears with the twist angle of 45° on non-parallel, non-intersecting shafts. Because the tooth contact is a point, their load carrying capacity is low and they are not suitable for large power transmission. Since power is transmitted by the sliding of the tooth surfaces, it is necessary to pay attention to lubrication when using screw gears. There are no restrictions as far as the combinations of number of teeth.



**Fig.1.6 Screw gear**

### 1.1.7 Miter Gear:

Miter gears are bevel gears with a speed ratio of 1. They are used to change the direction of power transmission without changing speed. There are straight miter and spiral miter gears. When using the spiral miter gears it becomes necessary to consider using thrust bearings since they produce thrust force in the axial direction. Besides the usual miter gears with 90° shaft angles, miter gears with any other shaft angles are called angular miter gears.
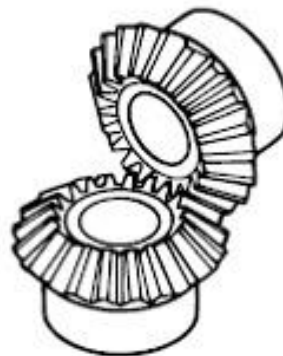


**Fig.1.7 Miter gear**

### 1.1.8 Worm Gear:

A screw shape cut on a shaft is the worm, the mating gear is the worm wheel, and together on non-intersecting shafts is called a worm gear. Worms and worm wheels are not limited to cylindrical shapes. There is the hour-glass type which can increase the contact ratio, but production becomes more difficult. Due to the sliding contact of the gear surfaces, it is necessary to reduce friction. For this reason, generally a hard material is used for the worm, and a soft material is used for worm wheel. Even though the efficiency is low due to the sliding contact, the rotation is smooth and quiet. When the lead angle of the worm is small, it creates a self-locking feature.
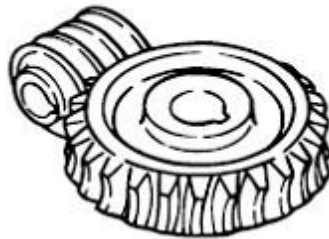


**Fig.1.8 Worm gear**

### 1.1.9 Internal gear:

Internal gears have teeth cut on the inside of cylinders or cones and are paired with external gears. The main use of internal gears is for planetary gear drives and gear type shaft couplings. There are limitations in the number of teeth differences between internal and external gears due to involute interference, trochoid interference and trimming problems. The rotational directions of the internal and external gears in mesh are the same while they are opposite when two external gears are in mesh.
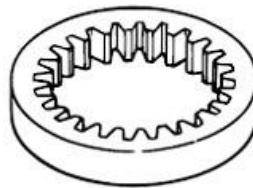


**Fig.1.9 Internal gear**

## 1.2 Spur Gear Nomenclature:
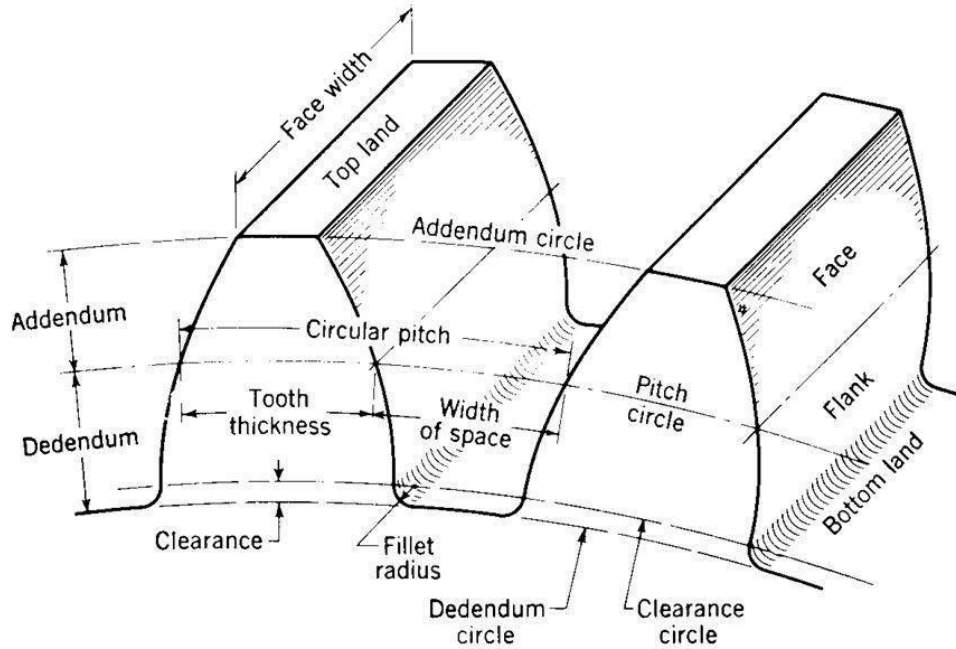


**Fig 1.10 Gear nomenclature**
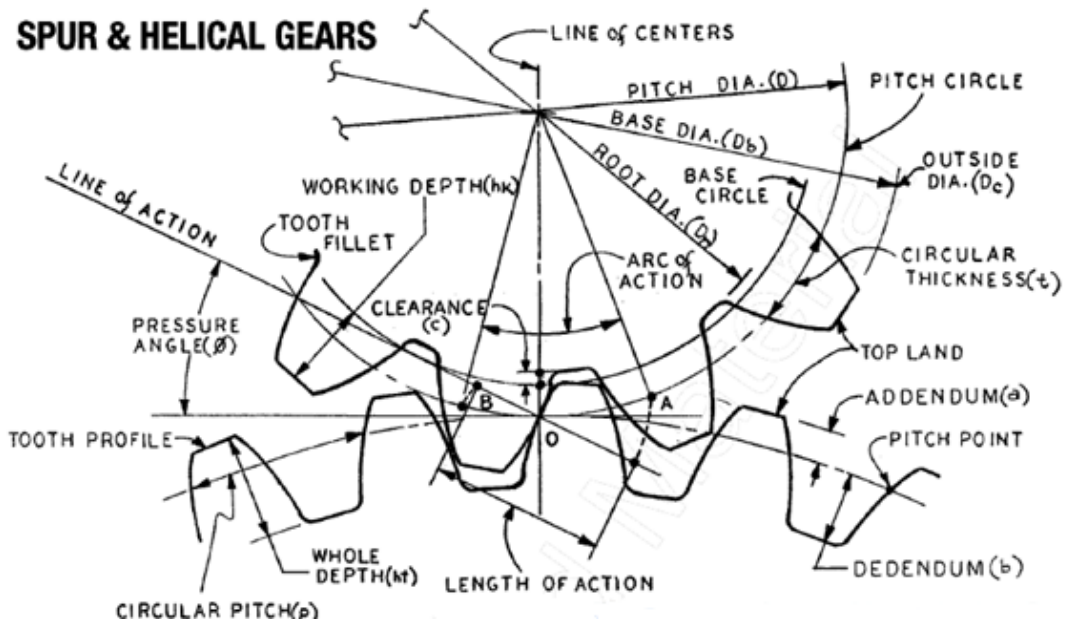
**Pinion**

- The smaller of two matting gear. The largest often called the gears or the wheel. pitch circle

- It is an imaginary circle, which is pure rolling action. For actual gear to give the same motion.

**Pitch circle diameter**: It is diameter of the Pitch Circle. When the size of the gear is specified by pitch circle diameter. It is also known as pitch diameter.

**Pitch point:** It is a common point of contact between the two pitch circles.

**Pitch surface**: It is a surface of Rolling disc which meshing gears are replaced at pitch circle.

**Pitch**: Two mating gear of pitch are same. That should be having Three Types of pitch.

**Circular pitch:** What is distance between circumferences of a pitch circle from a point of one tooth to the corresponding point of adjacent tooth?

**Diametral pitch**: It is the ratio between the pitch circle diameter to number of teeth. It is called diametral pitch.

**Module pitch:** It is ratio between pitch circle diameters to the number of teeth.

**Addendum Circle (tip circle):** The circle drawn through the top of the teeth and it is concentric with the Pitch Circle.

**Addendum**: Is radial distance between the Pitch circles to bottom of the tooth.

**Dedendum circle (root circle):** It is circle draw through bottom of the circle

**Dedendum:** The radial distance of teeth in between pitch circle to bottom of the teeth.

**Clearance:** The Clarence is a radial distance between the top of teeth to the bottom of the teeth in two meshing gear. A circle is drawn through the top of the meshing gear is called as clearance circle.

**Total depth**: It is radial distance between the addendum circle to dedendum circle of gear.

So we can calculate the total death:

Total depth = addendum + dedendum

**Working depth:** It is a Radial distance between the addendum circles to clearance circlet. It is also equal to sum of addendum of the two meshing gear.

**Tooth thickness**: The Measuring of width the tooth along the Pitch Circle.

**Tooth space:** It is measurement by space of width between two adjacent teeth measuring along the pitch circle.

**Backlash:** It is difference between space of the tooth and thickness of the tooth along the Pitch Circle.

Backlash = tooth space – tooth thickness

**Face Width:** It is measurement of gear width by parallel to its axis.

**Top land:** It is your surface of top of the teeth. It is called top land.

**Bottom Land:** It is surface of the bottom of the teeth between adjacent fillets.

**Face:** It is tooth surface between top Lands to Pitch Circle.

**Flank:** The tooth surface between bottom lands to pitch circle including fillet.

**Fillet:** It is curved shape of the toothed flank at root circle.

Pressure angle (angle of obliquity):

The angle between the common normal to two gearing of teeth at point of contact and a common tangent at a point of pitch Point. It is called pressure angle in the Gearing. The standard pressure angle of the teeth is 14 1/2 degree and 20 degree.

**Path of contact:** The point of contact of two teeth from beginning to end of engagement.

Length of path of contact (contact length):

It is measured by length of the common normal cutoff by addendum circle of the pinion and wheel.

**Arc of content:** The path is measured by a point on the circle from beginning to end of engagement in pair of teeth. The arc of contact is divided by two types. They are

(i) arc of approach

(ii) Arc of recess

Arc of approach: It is path of contact from the beginning of engagement to end of pitch point.

Arc of recess: it is path of contact from Pitch point to end of engagement of pair of teeth.

**Velocity ratio:** It is ratio between speeds of driving gear to speed of driven gears.

**Contact ratio:** The ratio between lengths of Arc of contact to circular pitch. It is called as Contact ratio.

**Law of Gearing**: To obtain a constant velocity ratio, the common normal of any instant of teeth at each point of contact should always pass through a pitch point, Situated on line joining center of rotation of the of mating gear.

Mean of Other Words :( The condition made by the tooth profile to maintain a constant angular velocity ratio in between two pair of gear. The fundamental of condition which must be satisfied designing the profile of the teeth of gear wheel.)

**General form of gear tooth profile:** The shape of two curve that fulfill the law of gearing, it can be used in teeth profile. If the profile of teeth of one matting gear is arbitrarily and profile of other gear is determined, so to satisfy the law of gearing, it type of teeth is known as conjugate teeth. The gear are having conjugate teeth can be successfully used for power transmission of motion. But there are difficult to manufacturing by using a special device which is costly. So the conjugate teeth are not used in most common method.

So the common form of the profile used in actual practical purpose;

they are (I) involute profile (ii) cycloidal tooth profile

The common difference between involute tooth profile and cycloidal tooth profile.

[wpsm_comparison_table id="1″ class=""]

Standard System of gear tooth profile:

American gear manufacture Association (AGMA) and American National standard Institute (ANSI) for standardized following for form of gear teeth profile depending upon the pressure angle.

1. 14 ½ $^0$ composite system

2. 14 ½ $^0$ full depth involute system

3. 20$^0$ full depth envelope system

4. 20$^0$ degree stub involute system

Advantages of 14 ½ $^0$ involute system

It type of profile teeth could be having smooth and noiseless operation.

Very strong teeth

Advantages of 14 degree involute system

It will be reduced the risk of undercutting

It will be stronger teeth with a load carrying capacity

It will be having greater length of contact

# Chapter-2

# LITERATURE SURVEY

The previous research works addressing gear analysis published by some author is as follows,

- **Neha Pawar, Shweta Khankal, Suraj Lakde, Rushikesh Jadhav**; In this paper their aim in this project is to design Gear train for HG 13 gearbox which should not be fail at high speed and high load. For fishing, boats need to stay longer time in the sea so our aim is to operate marine engine efficiently and smooth for different condition, and increases its working life. The required research work has been completed and the validation of project has been proved as well as design is safe is also proved. Hence it can be said that the aim of the project "Design of Gear Train of HG 13 Gearbox used in marine

- **Rushikesh A Padwe ,Prof.A.C.Gawande, Prof.Pallavi S. Sarode(2016).,**have discussed about the face gear used in spinning machine to lift the spinning mechanism. The face gear are attach with the heart cam for spinning the yarn about spindle. During the working, the tangential force is acting on face gear, which may cause to break the teeth. The tangential load which is acting on the gear is from pinion. The face gear are working similar to the bevel gear and transmitting the power. The intersection axis of both the pinion and gear at right angle to each other. The failure of the gear is due to low strength of the gear material. Analysis is done in Ansys software by developing the model of the gear and applying loads. At last they have concluded that, the failure of face gear is due to the tooth load .The another load i.e. axial load and radial load is less as compare to tooth load. Due to this tooth load, the stress develop in tooth is more than the basic stress of gear, that why gear fail. Due to gear fail, the machine is in break down stage, so the production is hamper. To avoid breakdown it is very important to chance the material of gear. Here in this project an analytical calculation and analysis in ANSYS of face gear is done. This show that by changing the material with new material is good for desirable application in spinning machine.

- **B.Sivakumar, I. Joe Michael(2018) .,** In this paper they have considered Spur gear made of cast iron is considered as the conventional model in this project. The conventional model is optimized with carbon fiber high modulus material and the analysis is carried out. Boundary constraints are defined and the total deformations for model are calculated and the results are tabulated**.**Experimental results from testing the spur gear under moment are listed in the Table. Analysis has been carried out by optimizing the material such as carbon fiber high modulus. The results such as total deformation, equivalent elastic strain and equivalent stress for each material are determined. Comparing the optimized materials and the conventional material, carbon fiber high modulus material has the low values of total deformation, stress and strain. Hence it is concluded that carbon fiber high modulus material is suitable for the spur gear manufacturing.

- **Rufus Ogbuka Chime, Samuel I(2016).,**in this paper they have concluded thatCAD combines the characteristic of designer and computer that are best applicable made CAD such as popular design tool. CAD Has allowed the designer to bypass much of the Manuel drafting and analysis. Simulation tools enable us to be creative and to quickly test new ideas that would be much more difficult, timeconsuming and expensive to test in the lab. (Jeffrey D. Wilson, NASA Glenn Research Centre) It also help us reduce cost and time-to-market by testing our designs on the computer rather than in the field. Many of the individual tasks within the overall design process can be performed using a computer. As each of these tasks is made more efficient, the efficiency of the overall process increases as well. The computer is well suited to design in four areas, which correspond to the latter four stages of the general design process; Computers function in the design process through geometric modelling capabilities, engineering analysis calculations, testing procedures, and automated drafting, From the result of the testing and the affordability in terms of cost, it can be concluded that the project is successful. Therefore software design should be encouraged in our institution of higher learning base on the following facts, long product development, countless trial and error, and accountability and limited profitability.

- **Dharshini.R ,Dr. M. Vasundara (2018) .,** in this paper they have considered The bending and contact stresses are considered as the cause of failure on spur gear. The detailed study on modes of failure is made. The load factor is calculated with various angular arrangements. The analysis is carried out with and without considering the external factors. The mathematical model is analysed with Finite Element Analysis (FEA) and compared with the analytical procedure and the percentage error is calculated.at last they concluded the causes for the respective stress and there effect due external factors.

- **Ms.Nilesha U. Patil, Mr. Sunil P. Chaphalkar ,Mr.Gajanan L. Chaudhari(2017).,**The main objective of the present work is to investigate Finite Element Analysis of the spur gear pair for different material in ANSYS software. In this paper A review has been taken for case-I purpose is to design the spur gear and study the weight reduction and stress distribution for cast steel and composite materials and results are observed. And in case-II Static analysis is performed to determine the deformation and Von-misses stresses. Analysis is done by considering different materials for gears like Structural Steel, Grey Cast Iron, Aluminium Alloy and Epoxy E Glass UD, and results are compared.

- **Ahmed Saeed Mohamed , SadokSassi , and Mohammad RoshunPaurobally (2018).,**In this study, a numerical model was developed to analyze the dynamic behaviour of a one-stage gearbox with external spur gears with an involute tooth profile. A set of MATLAB codes were used to generate the gear tooth profiles, perform the contact analysis, and evaluate the contact ratio. The variable gear mesh stiffness with respect to the angular position was obtained by using the FEM. The total mesh stiffness was then used in a simplified six-DOF nonlinear lumped parameter model to simulate the vibration response of the gears. First, various time domain statistical parameters were extracted from the original, and the residual vibration signals, where the gear was kept healthy, and a single crack was supposed to appear on the pinion. The results of this model were verified in three stages. First, the contact ratios obtained from the Shock and Vibration.

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- **DeepikaPotghan, Prof.SumanSharma(2015).,**The main aim of this paper is to relieve stress from the maximum value to as minimum as possible. So the highest point of contact of teeth is selected as pressure application point which causes highest stress. Stress relieving feature having the shapes of circular, elliptical and aero- fin were used in the path of stress flow which helped to regulate stress flow by redistributing the lines of force. Stress relieving feature having the shape of aero- fin yielded better results when compared to elliptical and circular holes. This study gives the better result when an aero-fin hole is introduced and the percentage of stress reduction in case of grey cast iron is 67.822. In case of high carbon steel is 20.162 and for medium carbon steel its 33.645.

- **Elsayed S. Aziz, C. Chassapis(2001).,**In this paper they have concluded that An accurate description of the tooth geometry and the associated mating gears model were provided by ACES for gear design, having a direct interface with a FEM processor and a CAD tool (Pro/E). The results presented in this effort show that the FEM analysis gives more accurate and realistic results and offers a complete stress distribution on the mating gear teeth that is necessary for predicting the initial fatigue crack location and the optimal depth of hardness required at the contacting surface to avoid surface failure and other forms of failure. The FEM results give fillet and contact stress values less than those obtained by the AGMA equations, and in this manner provide a basis for setting allowable stress limits that are more representative of the actual loading conditions that would be experienced in-service. The procedure is useful in that it provides designers a great functionality in getting a high degree of accuracy in the design evaluation. The problems of experience and expertise for the designers are also overcome through this intelligent gear design system, which helps to avoid unexpected design iterations that cause wastage of a great amount of engineering time and effort. The methodology can be easily extended to other types of gearing systems.

- **Getachew A. Ambaye, Hirpa G. Lemu,** "Dynamic analysis of spur gear with backlash using ADAMS", Gear tooth profile can deviate from its initial design shape and size as a result of increasing service time under time-varying load, introducing external agents like debris, overheating due to friction, wear, and in generally due to other nonlinear factors

such as backlash. As a result, the dynamics of the gear will also vary depending on the resulting gear tooth profile. In this study, the worn-out gear tooth is modelled as a backlash by assuming a uniformly distributed worn out surface and the effect on the dynamic performance is investigated. By changing the amount of backlash of the gear tooth from 0 mm to 1 mm by 0.2 mm increment, the gear is modelled and analysed for three loading cases using MSC ADAMS software. This paper discusses the effect of backlash or uniformly worn out spur gear tooth faces on the dynamics specifically the contact and angular accelerations of the gear. The simulated results using ADAMS show that the tangential and radial angular acceleration of the gear increase when the value of the backlash increases, and the optimum acceleration is found on the gear with 0.2 mm backlash. In addition, the angular acceleration (tangential and radial) of the gear decrease as the load increases except for the gear with 0.6 mm and 0.8 mm backlash. Thus, this paper demonstrated the dynamics of the selected spur gear with different amounts of backlash.

- **E. Jayakiran Reddy , V. PanduRangadu,**"Development of knowledge based parametric CAD modelling system for spur gear: An approach", This paper presents an approach as a preliminary attempt for developing CAD model of spur gear using knowledgebased parametric modelling technique. The basic idea behind the development of the approach is to reduce the CAD modelling time of the spur gear by accepting the available design data from the unskilled user. This developed system uses Visual Basic and SolidWorks redevelopment technologies. The procedure of system development is explained with a reasonable example. This system is easy-to-use, trouble-free, handy and capable of improving design quality and efficiency. Results of this system are satisfactory and are found reasonably close to AGMA calculations after due validation. Whenever there is an update in the AGMA standard, the system cannot update itself by its own, a skilled developer needs to attend for the same. This is a drawback in the system and it can be nullified by enhancing the developed knowledge base system in such a way that it should be able to update its knowledge whenever AGMA standards get updated.

- **P.B.Pawar ,Abhay A Utpat,** "Analysis of Composite Material Spur Gear under Static Loading Condition", In the present work Al-SiC composite have been prepared by stir casting and various mechanical tests are conducted for evaluating properties of composite. Following conclusions are drawn from the experimental work and numerical analysis done on gears, ¾ Al-SiC composite prepared by stir casting provides improved hardness, Tensile strength over base metal. Better results have been obtained at 18% SiC is added. ¾ Gears manufactured from composite provides almost 60% less weight compared to steel gear, while power rating of both gears remains almost same. ¾ FE Analysis also shows less chances of failure in Al-SiC gear. Almost 3-4% difference has been observed between theoretical and FEA values of bending stress. ¾ These gears can be used for transmitting almost 24kW power.

- **Edward M. Vavrek,et all** "Computer Aided Spur Gear Design and Analysis", This program allows the student to design and analyze a spur gear system. The program allows the student to select a gear material based on the allowable bending stress and allowable contact stress. The program is fairly long with about twenty forms to go through to select a material. Even though the program is long, it is straight foreword to use. Many factors are not only based on the input data but are sometimes selected based on experience. The user should have some background in gear design.

- **B.Sivakumar, I. Joe Michael,** "Design and stress analysis of spur gear", A gear or "gear wheel" is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit power. Two or more gears working in tandem are called a transmission and produce a mechanical advantages through a gear ratio and thus may be considered a simple machine. gears are mostly used in the mechanical field for power transmission, this project report on stress analysis of spur gears. Spur gear made of cast iron is considered as the conventional model in this project. The conventional model is optimized with carbon fibre high modulus material and the analysis is carried out. Boundary constraints are defined and the total deformations for model are calculated and the results are tabulated.

- **K Senthilnathan , S Bharani Kumar , G Suresh , Rajesh Ravi, T Srinivasan , G Sai Krishnan,** "Design and analysis of gear testing kit and static structural analysis of spur gear using ANSYS software", The main objective of this work is to design the components in a gear testing kit and the components involved in the gear testing domain, are modelled using CATIA software. The main components in our paper are 1/2hp motor, coupling; shaft and bearing, mating gears are made of same dimensions and of different materials. Further the work is to analyse the mating gears which are made of same material and analysis are carried through ANSYS software. Static Structural Analysis is carried through ANSYS analytical Software. Two types of plots are performed and their corresponding Von – Misses stress and Total Deformation at three different torque levels are evaluated.

- **PinaknathDewanji, et all** "Design and stress analysis of spur gear", In this project an attempt is made to co-relate the bending stresses and displacement of a spur gear tooth which are obtained analytically as well as by FEM. Recent developments in the field of mechanical engineering are demanding refined gear teeth in terms of loading capacities and speed with which they can operate. The static and dynamic analysis of spur gear tooth helps to determine maximum displacement, maximum induced stress and effect of stress variation with respect to time. The loading capacity and operating speed of geared system can be increased by reducing the maximum induced stresses. The following conclusions can be drawn from the results obtained: The maximum stresses for gear teeth occur in the root region of gear tooth. Static analysis of spur gear tooth with element type as Beam give more accurate results for maximum displacement and maximum induced stress. The accuracy of stress calculated using FEA model and analytical calculations is 99.45% and that of displacement is almost 100%. Thus we can conclude that beam element is more suitable for static analysis of spur gear. This is in accordance with Lewis bending stress calculation formula who has considered the gear tooth as cantilever beam. With the help of dynamic analysis the stress and displacement variation at any node with respect to time and stress and displacement variation at any time instant for all nodes can be known and corresponding results can be represented graphically. Nature of graph can be used to predict force variation along tooth. Maximum value of stresses and

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displacement of dynamic analysis are obtained from the graph are comparable with static analysis results. Hence FEM model is good enough for dynamic stress consideration.

- **S Rajeshkumar and R Manoharan,** "Design and analysis of composite spur gears using finite element method", In this paper, the gear tooth contact analyses in spur gears through finite element analysis are carried out. A general finite element model was developed for evaluating the contact stress in spur gears of equal geometry in both gears. FEA was used to simulate the gear tooth contact behavior through the mesh, contact elements and adaptive method with the aid of an augmented Lagrange contact algorithm. The detailed procedures to create a 3D model in finite element software were described. The displacements, stress distributions and strain for three different materials with two different speeds were obtained. From the result it could be concluded that the deformation of composite material gear is very less compared to steel and plastic materials. Also the rotational speeds of the spur gear influences the behavior of the materials like stress, strain and deformation etc. Therefore the composite material has better alternative for steel and plastic material.

- **Pradeep Kumar Singh, ManwendraGautam, Gangasagar, ShyamBihariLal,** "Stress Analysis Spur Gear Design By Using Ansys Workbench", The finite element method is most widely for find a real model of the geared set using the stress analysis in the pair of gears. The development off finite element analysis model of the spur gear assembly to simulate the contact stress calculation and bending stress calculation is play more significant role in the design of gears. The study is show that Hertz theory is the basis of contact stress calculation and Lewis formula is use for calculating bending stress is a pair of gear. Theoretically result obtained by Lewis formula and hertz equation and result found by comparable with finite element analysis of spur gear. As a result, based on this finding if the contact stress minimization in the primary concern and if the large power is to be transmitted then spur gears with higher model is preferred. Hence we conclude that analysis software can be used for other analysing purpose

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# Chapter-3

# PROBLEM STATEMENT

Marine engines are generally used for heavy duty application, so need to be taken care during the development of prototype in best way. Marine engines are operated at very high speed so large stresses and deflections in the gear as well as in other rotating component are produced. The stresses and deflections should be reduced for the safe functioning of engine.

Main aim of this design is reduction of weight and producing high accuracy gears. Generally, this type of gear box is used in fishing boat in which marine engine is used. It requires high load carrying capacity, strength, torque and it should operate efficiently. There are various types of engines are available which ranges from 220HP to 500HP are and for this engine 12 to 13 types of gear box are available.

For this work, structural analysis on a high speed spur gear in marine engines, have been carried out. Theoretical methods are generally used for arrival of dimensions. The deflections of the tooth and dimensions have been analyzed for different material. Finally the results obtained by theoretical method and finite element analysis are compared to check the correctness. A conclusion has been arrived on the material which is best suited. Basically the project involves the design, modeling and manufacturing of spur gears for marine application.

# CHAPTER-4

# CONTACT STRESS

## 4.1 Introduction:

Contact stress is generally the deciding factor for the determination of the requisite dimensions of gears. Research on gear action has confirmed fact that beside contact pressure, sliding velocity, viscosity of lubricant as well as other factors such as frictional forces, contact stresses also influence the formation of pits on the tooth surface. So thorough study of contact stress developed between the different mating gears are mostly important for the gear design. Gearing is one of the most critical components in mechanical power transmission system.
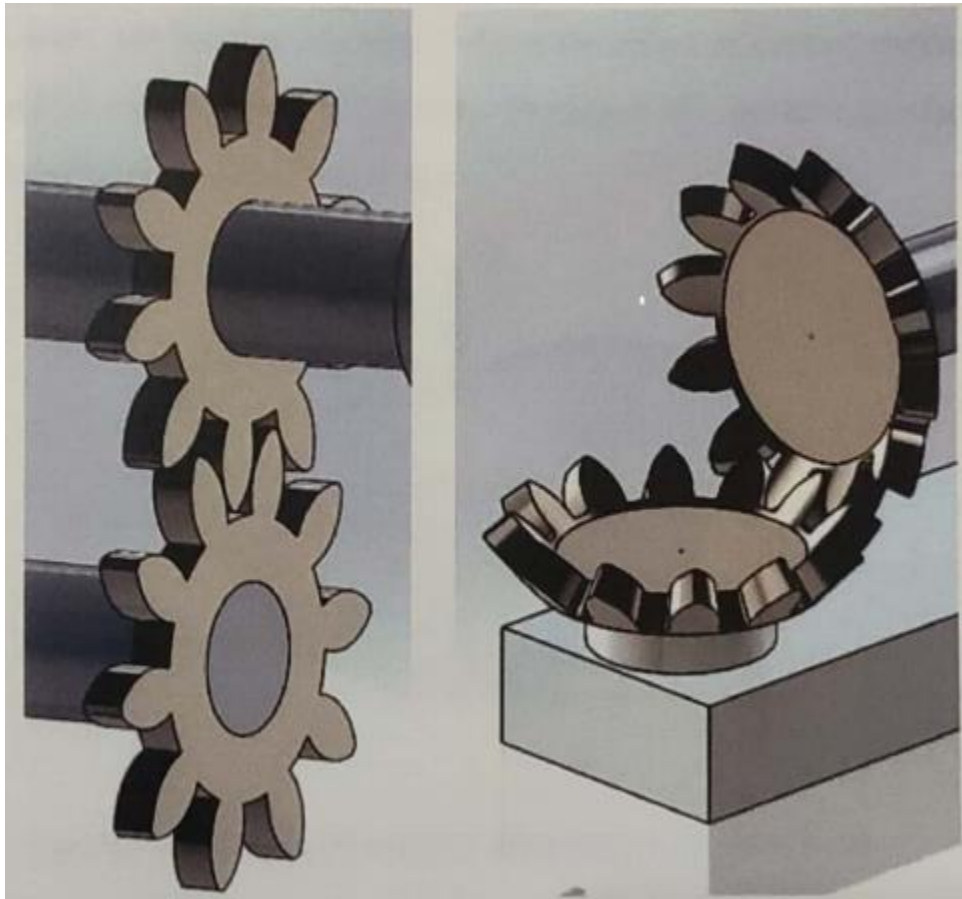


**Fig:4.1 Gear mating**

Current Analytical methods of calculating gear contact stresses use Hertz's equations, which were originally derived for contact between two cylinders. So for CONTACT STRESSES it is necessary to develop and to determine appropriate models of contact elements and to calculate contact stresses using ANSYS and compare the results with Hertzian theory.

## 4.2 Contact Mechanics:

Study of deformation of solids under contact is called contact mechanics, comprising of mechanics of material and continuum mechanics. Contact mechanics provides the information for safe and energy efficient design of mechanical elements in contact, while continuum mechanics provides for analysis of the kinematics and the mechanical behaviour of materials modelled as a continuous mass rather than as described particles.

Contact between two continuous, non-confirming solids is initially a point or line. Under the action of a load the solids deform and a contact area is formed as shown in Figure3.2. Hertz contact stress theory allows for the prediction of the resulting contact area, contact pressure, compression of the bodies and the induced stress in the bodies. In 1880 Henrich Hertz developed his theory for contact stresses after studying Newton's rings with two glass lenses. He became concerned about the effect of contact pressure between two lenses and set out to analyse theeffects. The result was the first satisfactory theory for contact mechanics and is still in use today.
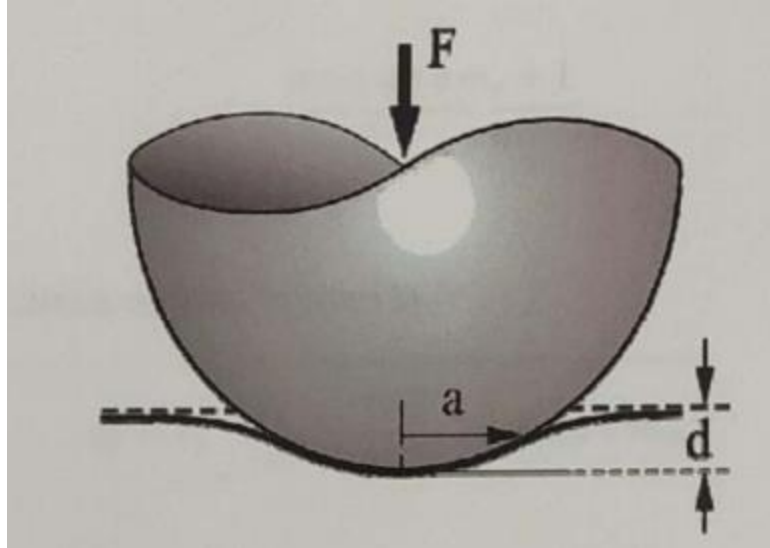
**Fig:4.2: Depiction of contact area under applied load**

In the course of developing his theory Hertz made some simplifying assumptions which are summarized as follows:

➢ Surfaces are continuous and non-confirming (i.e., initial contact is a point or a line)

➢ Strains are small

➢ Solids are elastic

➢ Surfaces are frictionless

## 4.3 Hertz contact stress(Involute Gear Tooth Contact Stress Analysis)

One of the main gear tooth failure is pitting which is a surface fatigue failure due to many repetition of high contact stresses occurring in the gear tooth surface while a pair of teeth is transmitting power.

Contact failure in gears is currently predicted by comparing the calculated Hertz contact stress to experimentally determined allowable values for the given material.

The method of calculating gear contact stress by Hertz's equation originally derived for contact between 2 cylinders.

$$\sigma_c = C_p [\frac{F_t}{dLI}]^{\frac{1}{2}}$$

$$C_p = \left[ \frac{1}{\pi \left( \frac{1 - v_1^2}{E_1} + \frac{1 - v_2^2}{E_2} \right)} \right]^{1/2}$$

$$F_t = F_n * cos\emptyset$$

$$I = \frac{cos\alpha \; sin\alpha \; m_g + 1}{2 \; m_g}$$

The AGMA contact stress equation is given by:

$$\sigma_H = C_p \sqrt{\frac{F_t}{bDI} \left( \frac{cos\beta}{0.95 \; CR} \right) K_v K_o (0.93 \; K_m)}$$

# CHAPTER-5

## ANALYTICAL CONTACT STRESS OF SPUR GEAR

### 5.1 Hertz Contact Stress

Contact pressure for two mating spur gears is calculated using hertz equation. Those two mating gears are taken from lathe box as shown in figure. The details of these gears are shown below.

### Table 5.1 Specifications of Gear

| S.No | Pinion | Gear |
|------|--------|------|
| Module(mm) | 5 | 5 |
| No. Of teeth | 144 | 144 |
| Pitch circle dia.(mm) | 720 | 720 |

### 5.2 Nomenclature of parameters in hertz theory

- A is the transverse pressure angle, deg
- as is the addendum, mm
- b is the length of contact, mm
- $\beta$ is the helical angle, deg
- $C_p$ is the elastic coefficient factor
- D is the pitch diameter of pinion and gear, mm
- E is the Young's modulus ,Gpa
- $F_t$ is tangential force on gear tooth, Nn
- $F_n$ is normal force on gear tooth, N
- i is the speed ratio
- I is geometry factor
- $K_v$ is dynamic factor
- $K_o$ is overload factor
- $K_m$ is load distribution factor

- ➢ $K_s$ is size factor
- ➢ n1 and n2 number of teeth, suffix 1 for the pinion and 2 for the gear
- ➢ C is contact stresses, Mpa
- ➢ R is the radial distance from centre to pitch circle, mm
- ➢ r1 and r2 are the pitch radii of pinion and gear, mm
- ➢ $\mu$ is the coefficient of friction
- ➢ $\vartheta$ is the Poisson's ratio
- ➢ V is velocity of rotation, m/s
- ➢ $Z_R$ is surface condition factor

The AGMA contact stress equation is given by

$$\sigma_H = C_p \sqrt{\frac{F_t}{bDI}\left(\frac{cos\beta}{0.95 \, CR}\right)K_v K_o (0.93 \, K_m)}$$

Hertz Contact Equation is given by

$$\sigma_c = C_p \sqrt{W^t K_0 K_v K_s \frac{K_m C_f}{dPFI}}$$

Hertz contact stresses for different parameters like module, power, are easily calculated by making an interface in VISUAL BASIC (VB)

VB makes an easy way to make calculate much iteration for calculating contact pressure and stress.

## Chapter-6

# SELECTING GEAR MATERIAL

When load to flank of gear is excessive, wearing off (pitting) of flank may occur easily. It is necessary to select material with greater strength of surface durability therefore the case hardening steel is recommended due to higher hardness.

The impact to flank of gear during operations causes damage to the gear tooth; therefore it is necessary to select steel with higher bending strength. Selected material should be able to apply induction hardening after quenching and annealing treatment. Such selection emphasizes on core hardness instead of surface strength.

Take note of the following while selecting material with manufacturing expense and productivity in mind.

1) For necessary strength for gear, select the material character by emphasizing on either Surface durability or Bending strength. Generally, ideal material selected for gear tooth should be tough and hard to withstand damaged by the load.

2) Suitable material for machining. Pitting occur easily in free cutting steel even after surface treatment is applied to gear. This material is unsuitable for gear even though it has good machinability.

3) Material which is easy to apply heat treatment and little deformation. Even if deformed after applying heat treatment, amount should be stable.

4) Material should be economical and easily obtained.

The below table shows the common materials adopted for designing of gear.

| S.NO | GEAR MATERIAL |
|------|---------------|
| 1 | Cast iron |
| 2 | Bronze |
| 3 | Aluminum |
| 4 | Copper |
| 5 | Structural steel |
| 6 | Stainless steel |

**Table 6.1 Gear materials**

6.1 CAST IRON :

Cast iron is made from pig iron, which is the product of melting iron ore in a blast furnace. Cast iron can be made directly from the molten pig iron or by re-melting pig iron, often along with substantial quantities of iron, steel, limestone, carbon (coke) and taking various steps to remove undesirable contaminants. Phosphorus and sulfur may be burnt out of the molten iron, but this also burns out the carbon, which must be replaced. Depending on the application, carbon and silicon content are adjusted to the desired levels, which may be anywhere from 2–3.5% and 1–3%, respectively. If desired, other elements are then added to the melt before the final form is produced by casting.

Cast iron is sometimes melted in a special type of blast furnace known as a cupola, but in modern applications, it is more often melted in electric induction furnaces or electric arc furnaces. After melting is complete, the molten cast iron is poured into a holding furnace or ladle.

**Chemical composition** :

| ELEMENT | PERCENTAGE |
|---|---|
| Carbon (C) | >4.50 |
| Sulfur(S) | >0.150 |
| Magnesium(Mg) | 0.0016 |
| Silicon(Si) | 2.63 |
| Manganese(Mn) | 0.269 |
| Phosphorus(P) | 0.158 |

**Table 6.2 chemical composition of cast iron**

**Mechanical properties** :

| PROPERTIES | CAST IRON |
|---|---|
| Young's Modulus | 89.4 Gpa |
| Poisson's Ratio | 0.26 |
| Density | 6.999e-6 kg/mm^3 |
| Thermal Expansion | 9.8*10^-6/k |
| Tensile Yield Strength | 79.81 Mpa |
| Compressive Yield Strength | 79.81Mpa |
| Ultimate Tensile Strength | 141.1 Mpa |

**Table 6.3 mechanical properties of cast iron**

## 6.2 BRONZE :

**Bronze** is an alloy consisting primarily of copper, commonly with about 12–12.5% tin and often with the addition of other metals (such as aluminum, manganese, nickel or zinc) and sometimes non-metals or metalloids such as arsenic, phosphorus or silicon. These additions produce a range of alloys that may be harder than copper alone, or have other useful properties, such as strength, ductility, or machinability.

**Chemical composition**:

| ELEMENT | PERCENTAGE |
|---|---|
| Cu | 89.0764 |
| Al | 10.8230 |
| Si | 0.0495 |
| Fe | 0.0242 |
| Mg | 0.0150 |
| Zn | 0.0019 |

**Table 6.4 chemical composition of bronze**

**Mechanical properties:**

| PROPERTIES | BRONZE |
|---|---|
| Young's Modulus | 70 Gpa |
| Poisson's Ratio | 0.34 |
| Density | 8.89e-6 kg/mm^3 |
| Thermal Expansion | 18*10^-6/k |
| Tensile Yield Strength | 125 Mpa |
| Compressive Yield Strength | 125 Mpa |
| Ultimate Tensile Strength | 240 Mpa |

**Table 6.5 mechanical properties of bronze**

### 6.3 Aluminum:

**Aluminum** (**aluminum** in American and Canadian   English)   is   a chemical   element with the symbol **Al** and atomic  number 13. Aluminum  has  a  density  lower  than  those  of  other common metals, at approximately one third that of steel. It has a great affinity towards oxygen, and forms  a  protective  layer of oxide on  the  surface  when  exposed  to  air. Aluminum  visually resembles  silver,  both  in  its  color  and  in  its  great  ability  to  reflect  light.  It  is  soft, non-magnetic and ductile.  It  has  one  stable  isotope, Al;  this  isotope  is  very  common,  making aluminum  the  twelfth  most  common  element  in  the  Universe.  The  radioactivity  of  Al is  used in radio dating.

**Chemical composition**:

| ELEMENT | PERCENTAGE |
|---------|-----------|
| Si | 0.4430 |
| Fe | 0.1638 |
| Cu | 0.0041 |
| Mg | 0.5832 |
| Mn | 0.0132 |
| Al | 98.751 |
| Zn | 0.0001 |
| Ti | 0.0078 |
| Cr | 0.0024 |
| Ca | 0.0003 |

**Table 6.6 chemical composition of aluminum**

**Mechanical properties:**

| PROPERTIES | ALUMINIUM |
|-----------|-----------|
| Young's  Modulus | 68 Gpa |
| Poisson's  Ratio | 0.32 |
| Density | 2.689e-6kg/mm^3 |
| Thermal Expansion | 23*10^-6/k |
| Tensile Yield Strength | 75 Mpa |
| Compressive Yield Strength | 75Mpa |
| Ultimate Tensile Strength | 290 Mpa |

**Table 6.7 mechanical properties of aluminum**

**6.4 Copper:**

**Copper** is a chemical element with the symbol **Cu** (from Latin: *cuprum*) and atomic number. It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a pinkish-orange color. Copper is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys, such as sterling silver used in jewelry, cupronickel used to make marine hardware and coins, and constantan used in strain gauges and thermocouples for temperature measurement.

**Chemical composition**:

| ELEMENT | PERCENTAGE |
|---------|------------|
| Oxygen | 49.72 |
| Silicon | 21.50 |
| Magnesium | 13.10 |
| Aluminum | 1049 |
| Iron | 8.09 |
| Potassium | 1.68 |
| Calcium | 0.57 |
| Copper | 0.92 |
| Titanium | 0.90 |

**Table 6.8 chemical composition of copper**

**Mechanical properties:**

| PROPERTIES | COPPER |
|------------|--------|
| Young's Modulus | 130 Gpa |
| Poisson's Ratio | 0.34 |
| Density | 8.933e-6kg/mm^3 |
| Thermal Expansion | 16.7*10^-6/k |
| Tensile Yield Strength | 117 Mpa |
| Compressive Yield Strength | 117Mpa |
| Ultimate Tensile Strength | 210 Mpa |

**Table 6.9 mechanical properties of copper**

## 6.5 STRUCTURAL STEEL:

Structural steel is used to construct residential and commercial buildings, warehouses, aircraft hangers, hospital and school buildings, metro stations, stadiums, bridges etc. construction of these structures is done with the structural steel design components such as channels, beams, angles, and plates. Ductile and malleable properties of structural steel make it possible to mould and shape them in several ways and forms. It possesses high heat dissipation capacity due its high thermal conductivity and is suitable for high strength and high temperature applications as well.

**Chemical composition**:

| ELEMENT | PERCENTAGE |
|---------|------------|
| C | 0.20 |
| Si | 0.80 |
| Mn | 1.70 |
| P | 0.025 |
| S | 0.015 |

**Table 6.10 chemical composition of structural steel**

**Mechanical properties:**

| PROPERTIES | STRUCTURAL STEEL |
|-----------|------------------|
| Young's Modulus | 200 Gpa |
| Poisson's Ratio | 0.30 |
| Density | 7.85e-6 kg/mm^3 |
| Thermal Expansion | 1.2*10^-6/k |
| Tensile Yield Strength | 250 Mpa |
| Compressive Yield Strength | 250 Mpa |
| Ultimate Tensile Strength | 460 Mpa |

**Table 6.11 mechanical properties of structural steel**

### 6.6 STAINLESS STEEL:

**Stainless steel** is a group of ferrous alloys that contain a minimum of approximately 11% chromium, a composition that prevents the iron from rusting and also provides heat-resistant properties. Different types of stainless steel include the elements carbon (from 0.03% to greater than 1.00%), nitrogen, aluminium, silicon, sulfur, titanium, nickel, copper, selenium, niobium, and molybdenum. Specific types of stainless steel are often designated by their AISI three-digit number, e.g., *304 stainless*. The ISO 15510 standard lists the chemical compositions of stainless steels of the specifications in existing ISO, ASTM, EN, JIS, and GB (Chinese) standards in a useful interchange table.

**Chemical composition**:

| ELEMENT | PERCENTAGE |
|---------|------------|
| C | 0.03 |
| Cr | 16-17.2 |
| Mn | 0.5 |
| P | 0.04 |
| Si | 0.5 |
| S | 0.03 |
| Ni | 10-11 |
| Cu | 0.1 |
| Mo | 2-2.4 |

**Table 6.12 chemical composition of stainless steel**

**Mechanical properties:**

| PROPERTIES | STAINLESS STEEL |
|------------|-----------------|
| Young's Modulus | 200 Gpa |
| Poisson's Ratio | 0.265 |
| Density | 7.969e-6 kg/mm^3 |
| Thermal Expansion | $1.2*10^{-6}/k$ |
| Tensile Yield Strength | 252 Mpa |
| Compressive Yield Strength | 252 Mpa |
| Ultimate Tensile Strength | 594 Mpa |

## Table 6.13 mechanical properties of stainless steel

# Chapter -7
# Visual basics

## INTRODUCTION

## What is Visual Basic?

- ➢ **Visual Basic** is a tool that allows you develop Windows(Graphic User Interface) applications. The applications have a familiar appearance to the user.
- ➢ Visual Basic is **event-driven**, meaning code remains idle until called upon to respond to some event(button pressing, menu selection...). Visual Basic is governed by an event processor. Nothing happens until an event detected. Once an event is detected, the code corresponding to that event (event procedure) is executed. Program control is then returned to event processor.



**Event processor**
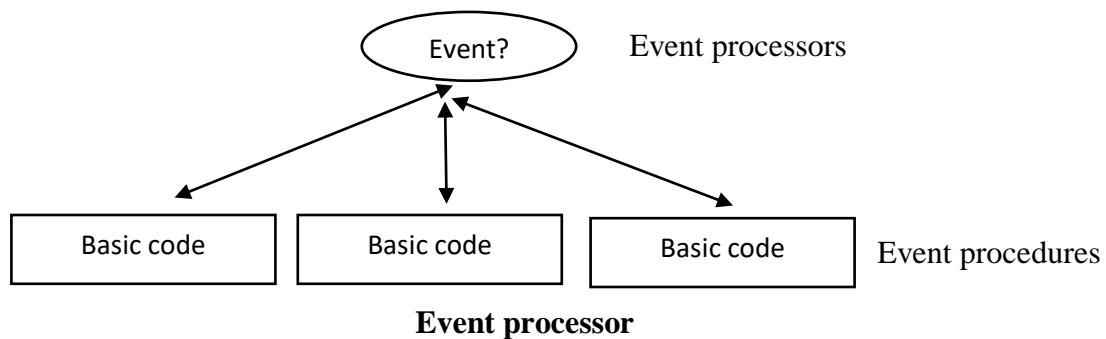
- ➢ **Some features of Visual Basic**
- – Full set of objects - you 'draw' application
- – Lots of icons and pictures for your use
- – Response to mouse and keyboard actions
- – Clipboard and printer access
- – Full array of mathematical, string handling and graphics functions
- – Can handle fixed and dynamic variable and control arrays
- – Sequential and random access file support
- – Useful debugger and error-handling facilities
- – Powerful database access tools
- – ActiveX support

### 7.1 Design calculators:

With the help of spur gear design calculators the required dimensions of the spur gear and induced stress are also obtained.

Spur gear design calculator interface:

## SPUR GEAR CALCULATOR - MODULE
Enter your values as required for module, number of teeth, pressure angle and ratio.

NORMAL MODULE:

NUMBER OF TEETH - FIRST GEAR:

PRESSURE ANGLE:

GEAR RATIO:

CENTRE DISTANCE (A):                                    mm

## BOTH GEARS

ADDENDUM:                                              mm

DEDENDUM:                                              mm

TOOTH DEPTH:                                           mm

NORMAL PITCH (PN):                                     mm

NORMAL TOOTH THICKNESS AT PITCH CIRCLE                 mm
(SN):

## FIRST GEAR

PITCH CIRCLE DIAMETER (D):                             mm

TIP DIAMETER (DA):                                     mm

ROOT DIAMETER (DR):                                    mm

## SECOND GEAR

NUMBER OF TEETH - SECOND GEAR:

PITCH CIRCLE DIAMETER (D):                             mm

TIP DIAMETER (DA):                                     mm
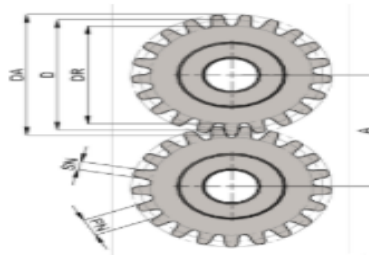
ROOT DIAMETER (DR):                                    mm
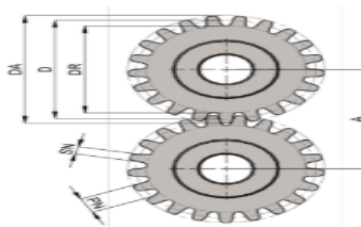


# Fig.7.1 Interface of spur gear design calculator

Trail data obtained for design of a spur gear using spur gear calculator.

# SPUR GEAR CALCULATOR - MODULE and DP VERSIONS

These calculators will give you results for a simple two gear train.

The first calculator is for a metric gear train and the second for an imperial gear train.

## SPUR GEAR CALCULATOR - MODULE

Enter your values as required for module, number of teeth, pressure angle and ratio.

| NORMAL MODULE: | 5 | |
| NUMBER OF TEETH - FIRST GEAR: | 144 | |
| PRESSURE ANGLE: | 14.5 | |
| GEAR RATIO: | 1 | 1 |
| CENTRE DISTANCE (A): | 720.0000 | mm |

## BOTH GEARS

| ADDENDUM: | 5.0000 | mm |
| DEDENDUM: | 6.2500 | mm |
| TOOTH DEPTH: | 11.2500 | mm |
| NORMAL PITCH (PN): | 15.7080 | mm |
| NORMAL TOOTH THICKNESS AT PITCH CIRCLE (SN): | 12.0312 | mm |

## FIRST GEAR

| PITCH CIRCLE DIAMETER (D): | 720.0000 | mm |
| TIP DIAMETER (DA): | 740.0000 | mm |
| ROOT DIAMETER (DR): | 717.5000 | mm |

## SECOND GEAR

| NUMBER OF TEETH - SECOND GEAR: | 144 | |
| PITCH CIRCLE DIAMETER (D): | 720 | mm |
| TIP DIAMETER (DA): | 740 | mm |
| ROOT DIAMETER (DR): | 717.5 | mm |



**Fig.7.2 Trail data of spur gear for design.**

## 7.2 horse power calculator

# Spur and Helical Gear Horsepower Calculator

| Type of Load: | # of Teeth: | | | Input values cannot be empty or contain strings. | |
|---|---|---|---|---|---|
| uniform | | | | Safe static stress per sq. inch of material (lbs/sq. inch) | |
| Duration: | Face Width: | | | *Velocity (feet per minute) | |
| Intermittent-3 hours/day | | | | Horsepower | |
| Gear Type: | Face Width Units: | | | Torque (inch lbs) | |
| Spur | inches | | | Gear OD | |
| Pitch Type: | RPM: | | | Gear PD | |
| DP | | | | Service Factor (from load & duration) | |
| Normal Diametral Pitch: | Helix Angle: | | | *Special Considerations need to be taken if the Pitch Line VELOCITY exceeds: 1200 FPM for Metallic Spur Gears Or 2400 FPM for Helical Gears or Nonmetallic Spur gears | |
| Transverse Diametral Pitch: | Material: | | | | |
| | 1141 HR STEEL | | | | |
| Pressure Angle: | Ultitmate Tensile Strength(psi): | | | | |
| 14.5° | | | | | |

**Fig.7.3 Interface of spur gear load calculator**

Trail data obtained from spur gear horse power calculator:

# Spur and Helical Gear Horsepower Calculator

| Type of Load: | # of Teeth: | | Results: | |
|---|---|---|---|---|
| uniform | 144 | | Load in lbs @ pitch line | 103.38 |
| Duration: | Face Width: | | Safe static stress per sq. inch of material (lbs/sq. inch) | 6814.512 |
| 8-10 hours/day | 25 | | *Velocity (feet per minute) | 2258.78 |
| Gear Type: | Face Width Units: | | Horsepower | 7.0763 |
| Spur | millimeters | | Torque (inch lbs) | 1486.61 |
| Pitch Type: | RPM: | | Gear OD | 740.0747 |
| MOD | 300 | | Gear PD | 729.9350 |
| Normal Diametral Pitch: | Helix Angle: | | Service Factor (from load & duration) | 1 |
| 5.069 | 0 | | | |
| Transverse Diametral Pitch: | Material: | | *Special Considerations need to be taken if the Pitch Line VELOCITY exceeds: 1200 FPM for Metallic Spur Gears Or 2400 FPM for Helical Gears or Nonmetallic Spur gears | |
| 5.069 | CAST IRON | | | |
| Pressure Angle: | Ultitmate Tensile Strength(psi): | | | |
| 14.5° | 20464 | | | |

**Fig.7.4 Trail data of load of spur gear**

## 7.3 contact stress calculator

# Hertzian Contact Stress Calculator:

| INPUT PARAMETERS | | | |
|---|---|---|---|
| **Parameter** | **Object-1** | **Object-2** | **Unit** |
| Object shape | Sphere ⌄ | Sphere ⌄ | |
| Poisson's ratio [$v_1$,$v_2$] | | | |
| Elastic modulus [$E_1$,$E_2$] | | | GPa ⌄ |
| Diameter of object [$d_1$,$d_2$] | | | mm ⌄ |
| Force [F] | | | N ⌄ |
| | | | |
| Calculate | | | |

| RESULTS | | | |
|---|---|---|---|
| **Parameter** | **Obj-1** | **Obj-2** | **Unit** |
| Maximum Hertzian contact pressure [$p_{max}$] | --- | | MPa ⌄ |
| Max shear stress [$\tau_{max}$] | --- | --- | |
| Depth of max shear stress [z] | --- | --- | mm ⌄ |
| Circular contact area diameter [2a ] | --- | | |

**Fig.7.5 Interface of contact stress calculator**

Trai data obtained:

# Hertzian Contact Stress Calculator:

| INPUT PARAMETERS | | | |
|---|---|---|---|
| Parameter | Object-1 | Object-2 | Unit |
| Object shape | Sphere ∨ | Sphere ∨ | |
| Poisson's ratio [$v_1, v_2$] | 0.26 | 0.26 | |
| Elastic modulus [$E_1, E_2$] | 89.4 | 89.4 | GPa ∨ |
| Diameter of object [$d_1, d_2$] | 740 | 740 | mm ∨ |
| Force [F] | 621.86 | | N ∨ |
| | | | |

Calculate

| RESULTS | | | |
|---|---|---|---|
| Parameter | Obj-1 | Obj-2 | Unit |
| Maximum Hertzian contact pressure [$p_{max}$] | 200.7 | | MPa ∨ |
| Max shear stress [$\tau_{max}$] | 64.1 | 64.1 | |
| Depth of max shear stress [z] | 0.569 | 0.569 | mm ∨ |
| Circular contact area diameter [2a ] | 2.433 | | |

**Fig.7.6 Trail data of contact stress of spur gear**

7.4 Data used for gear construction:

| PARAMETER | SPUR GEAR | |
|---|---|---|
| | GEAR 1 | GEAR 2 |
| No.of teeth | 144 | 144 |
| Normal module | 5 | 5 |
| Normal pressure(deg) | 14.5 | 14.5 |
| Pitch diameter(mm) | 720 | 720 |
| Face width(mm) | 25 | 25 |
| Contact ratio | 1 | 1 |
| Torque(N-m) | 228 | 228 |
| Power(k-w) | 4.77 | 4.77 |
| Speed(rpm) | 200 | 200 |
| Contact force(N) | 621.86 | 623.86 |
| Safety static stress(mpa) | 47 | 47 |

**Table 7.1 Design data of spur gear**

| MATERIAL | Cast iron | bronze | Aluminum | Copper | Structural steel | Stainless steel |
|---|---|---|---|---|---|---|
| Load(N) | 621.86 | 621.86 | 621.86 | 621.86 | 621.86 | 621.86 |
| Velocity(m/s) | 7.54 | 7.54 | 7.54 | 7.54 | 7.54 | 7.54 |
| Torque(N-m) | 224.04 | 224.04 | 224.04 | 224.04 | 224.04 | 224.04 |
| Tertian contact stress(mpa) | 204.4 | 179.8 | 174.7 | 271.7 | 355.3 | 350.2 |
| Shear stress(mpa) | 65.3 | 54.1 | 53.4 | 81.8 | 125.1 | 125.4 |

# Chapter -8

## Solid works

In this Project, we are using Solid works version 2021 as a modeling tool.

### 8.1 About Solid works:

Solid Works is a solid modeling computer-aided design (CAD) and computer aided engineering (CAE) computer program runs primarily on Microsoft Windows. Solid Works is published by Dassault Systems.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using Solid Works as of 2013. Also, according to the company, fiscal year 2011–12 revenue for Solid Works totaled $483 million.

Solid Works released its first product Solid Works 95, in November 1995, In 1997 Dassault, best known for its CATIA CAD software, acquired Solid Works for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, Solid Works grew to a $100 million revenue company.

Solid Works is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.



**Fig 8.1: Solid Works interface**

**Parameters** refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

**Design** intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. Solid Works allows the user to specify that the hole is a feature on the top surface, and will then honour their design intent no matter what height they later assign to the can.

**Building** a model in Solid Works usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of Solid Works means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch.

In an **assembly**, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. Solid Works also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, **drawings** can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).
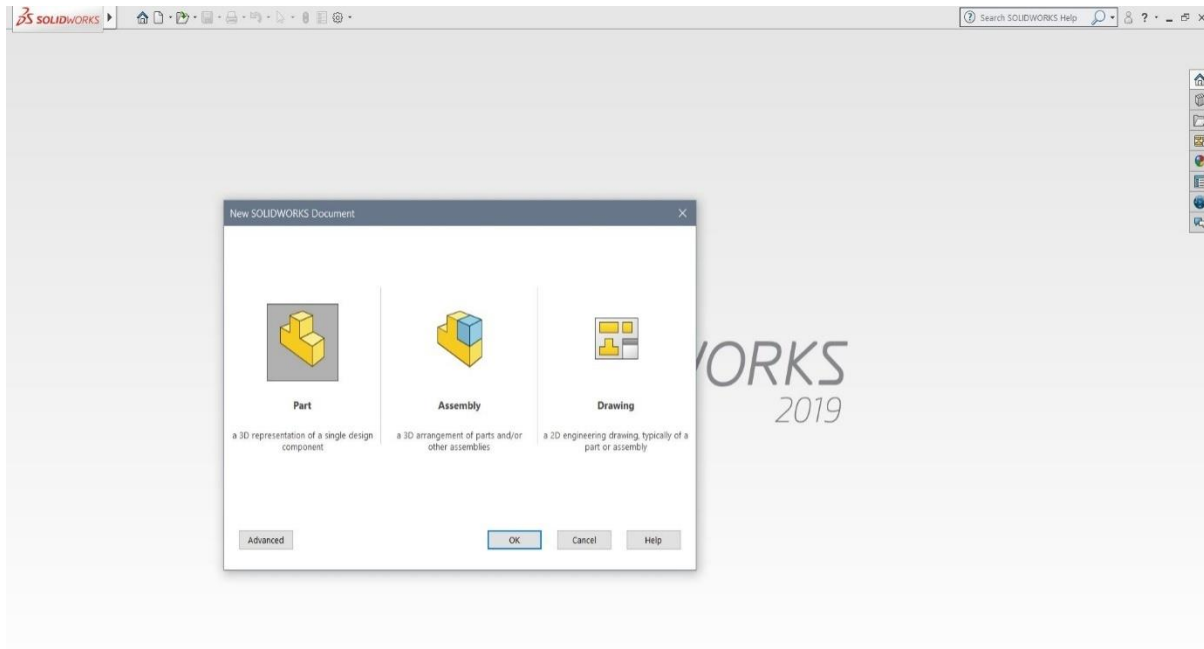
**Fig 8.2: Solid Works Drawing Interface**

## 8.2 FEATURES:

### 3D Interconnect

Open proprietary 3D CAD data directly in SOLIDWORKS, allowing you to work seamlessly with anyone, and incorporate design changes dramatically faster.

### Wrap Feature

Create geometry on any face. You are no longer limited to cylindrical surfaces when wrapping a sketch.

### Advanced Hole Wizard

Allows for the creation of holes with multiple elements, allowing for definition on either side. You now no longer need to use multiple hole wizard features to create holes with different elements.

### Sweep Profile

Previously you had to create a new sketch convert entities to create the same profile. Now you can select faces, edges, and curves to create the same profile.

**Magnetic Mates**

Whether you're working in large layouts or common parts, just grab the part or assembly until the magnet snaps it into place. It's as easy as click and drag.

**Latest Version Overwrite**

Allows you to check in your current version over your previous version, helping you save space on your server by not saving every incremental version.

**Offset On Surface**

Make your life easier when working with complex geometry with the Offset On Surface feature. It simplifies the creation of thickens, cut outs, and junctions.

**Animation Import**

Create life-like animations without additional effort or time. Save time by importing existing motion studies and animations to create amazing videos.

**FASTER 2D DRAWING CREATION**

Reference and link to BOM table cell elements in annotations. Parametrically mirror drawing views without the model. Pre-defined layers

**ELECTRIFYING ELECTRICAL/ELECTRONIC DESIGN**

Electrical: Automatic creation of schematic from a spreadsheet. Electrical: Compound parts – accessories .PCB: Unified design environment between schematic editing, board layout and 3D layout.

Shaded Sketch Contours: A handy new option in SOLIDWORKS 2017 called Shaded Sketch Contours. It is common for SOLIDWORKS users to sometimes unintentionally leave small gaps between endpoints when creating sketched profiles. If a gap is small enough, it can easily go undetected. This a new time-saving setting call Shaded Sketch Contours has been introduced which makes any closed contour, shaded. This is great feedback for users as they can immediately know the status of a sketch.

**Extrude from Any Size Planar Face**

SOLIDWORKS 2019 lets you create boss, cut, and surface extrudes from any size surface, face, or plane. This same functionality is also available for Extruded Cut and Extruded Surface. No more Unable to create this extruded feature due to geometric condition messages for you. Of course, the surface or face must be planar. But it is not limited to just parts.

**Simulation Results Processing**

This feature in SOLIDWORKS 2019 makes for easier communication and results visualization, but there are an other features that can help communicate your simulation results as well. By setting a maximum value for our stress plot, we can specify the color that we want values above that to be. This is done by clicking the top of the color gradient on our plot key.

**Convert Static Study to Non-Linear or Dynamic**

When copy study is selected you may copy your previous study into a new static study or you may choose to change the type of study to either a non-linear or dynamic study. As before when using duplicate study, you may choose new configurations and/or choose a new name. Once non-linear is selected you may choose either sub-type; static non-linear or dynamic non-linear. The same is true for the dynamic study, except dynamic has 4 sub-types; modal type history, harmonic, random vibration, and response spectrum analysis.

**Sweep Profile selection of Faces, Edges and Curves**

Previously to complete a sweep from existing geometry, a sketch was required for the sweep profile. This would require starting a sketch and converting edges or faces to complete the profile. Well now no more! Now a Face, Edge or Curve can be selected for a terrific timesaver.

**Dimensions**

With the arc extension line or opposite side selected you can attach the leader to

An extended radius. If it is not possible, the leader will attach to the opposite side of the arc. Mirrored holes are included in the total instance count when using hole callout.

**DimXpert**

The DimXpert tools within SOLIDWORKS are used add details to the model for fabrication by adding tolerance features and associated 3D annotations. These 3D annotations (datums, dimensions, and geometric tolerances) are used to partially or fully document the geometry. As the annotations are created, they are automatically oriented in 3D space to match the source feature orientation and the standard views (Front, Top, Right, etc.) of a drawing.

(a)Select edges rather than planes

Now in SOLIDWORKS 2017 basic location dimensions can be created by selecting edges (like Smart Dimension) rather than rotating the model to select planes.

(b) Basic size dimension – radii

Adding a basic size location for radii in SOLIDWORKS 2017 is as easy as using the Smart dimension in sketching.

(c) Dimension to reference features

Location dimensions may now be created from reference features like Planes, Axis, Center of Mass and Coordinate system.

## 8.3 Modeling
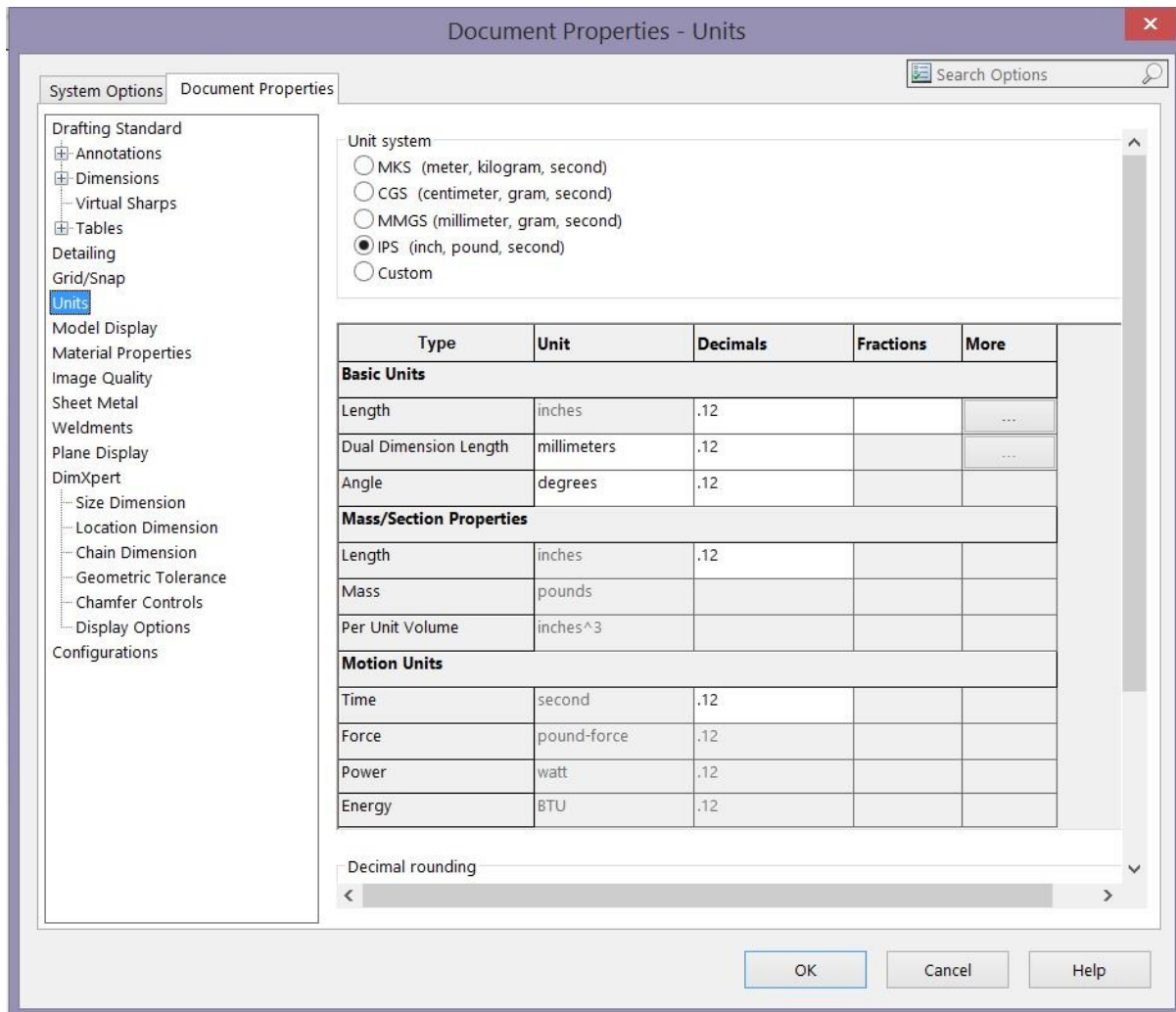


With the option for units in Solid Works, this sample shows a design set in the U.S. unit system (IPS) with two decimal places

### Equations, Global Variables, and Dimensions

| Name | Value / Equation | Evaluates to | Comments |
|---|---|---|---|
| **Global Variables** | | | |
| "p" | = 8 | 8 | Diametral pitch |
| "N" | = 16 | 16 | Number of teeth |
| "Phi" | = 20deg | 20deg | Pressure angle |
| "a" | = 1 / "p" | 0.125 | Addendum |
| "b" | = 1.25 / "p" | 0.15625 | Dedendum |
| "dp" | = "N" / "p" | 2 | Pitch circle diameter |
| "db" | = "dp" * cos ( "Phi" ) | 1.87939in | base circle diameter |
| "c" | = "b" - "a" | 0.03125in | Clearence |
| "alpha" | = sqr ( "dp" ^ 2 - "db" ^ 2 ) / "db" * 180 / pi - | 0.853958in | |
| *Add global variable* | | | |

Automatically rebuild  Angular equation units: Degrees  ☑ Automatic solve order
Link to external file:

### Equations, Global Variables, and Dimensions

| Name | Value / Equation | Evaluates to | Comments |
|---|---|---|---|
| **Global Variables** | | | |
| "p" | = 8 | 8 | Diametral pitch |
| "N" | = 16 | 16 | Number of teeth |
| "Phi" | = 20deg | 20deg | Pressure angle |
| "a" | = 1 / "p" | 0.125 | |
| "b" | = 1.25 / "p" | 0.15625 | |
| "dp" | = "N" / "p" | 2 | |
| "db" | = "dp" * cos ( "Phi" ) | 1.87939in | |
| "c" | = "b" - "a" | 0.03125in | |
| "alpha" | = sqr ( "dp" ^ 2 - "db" ^ 2 ) / "db" * 180 / pi - | 0.853958in | |
| *Add global variable* | | | |
| **Features** | | | |
| *Add feature suppression* | | | |
| **Equations** | | | |
| "D1@Sketch1" | = "dp" + 2 * "a" | 2.25in | |
| "D1@Sketch2" | = "dp" | 2in | |
| "D2@Sketch2" | = "db" | 1.88in | |
| "D3@Sketch2" | = "dp" - 2 * "b" | 1.69in | |
| "D4@Sketch2" | = 360 / ( 4 * "N" ) - "alpha" | 4.77deg | |
| "D6@Sketch2" | = "c" / 2 | 0.02in | |
| "D5@Sketch2" | = 360 / ( 4 * "N" ) - "alpha" | 4.77deg | |
| "D1@CirPattern1" | = "N" | 16 | |
| *Add equation* | | | |

Automatically rebuild  Angular equation units: Degrees  ☑ Automatic s
Link to external file:

Ø 2.25

Table with equations, global variables, and dimensions used in the initial draw

Next, to write the equation, include the circles as addendum, dedendum, and pitch, and relate the equation with every sketch in the initial draw. Begin with the addendum circle, and make the extrusion to get the initial 3D body. Give the width of the gear a value of 1 inch to get an arbitrary and standard value

Then, proceed to make the extrusion of the addendum circle at mid plane, considering 1 inch as a reference for the thickness of the gear Managing the extrude in mid plane helps to solve problems during motion, assembly, and finite elements studies, among others.
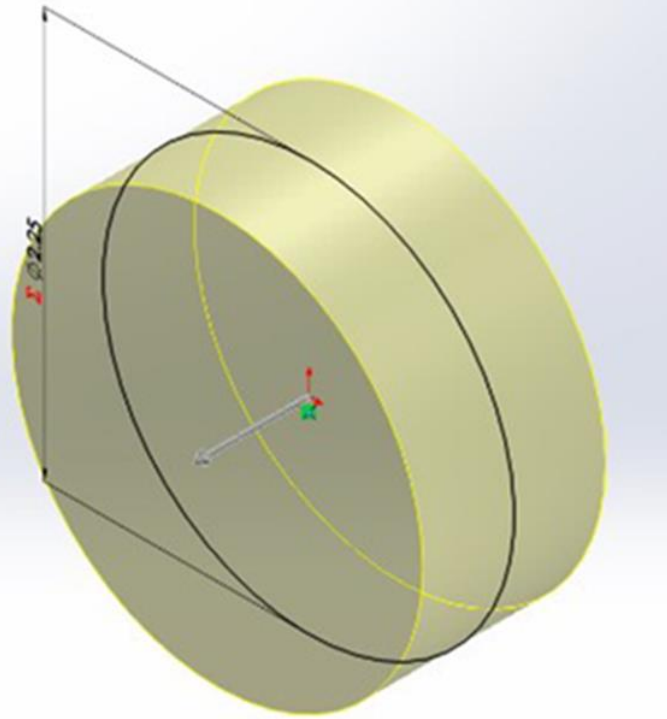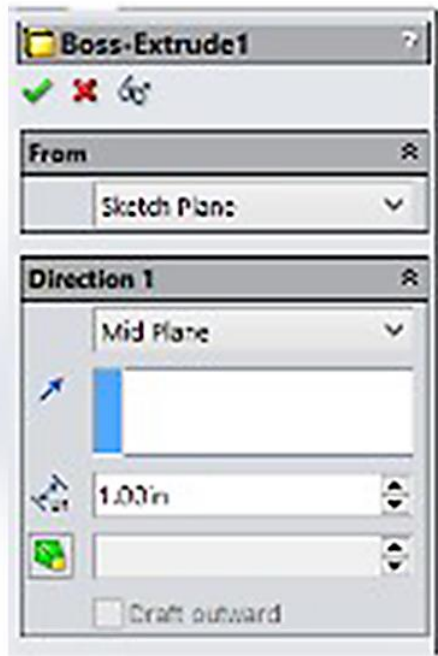
Extrusion of addendum circle at mid plane with spur gear thickness as a reference
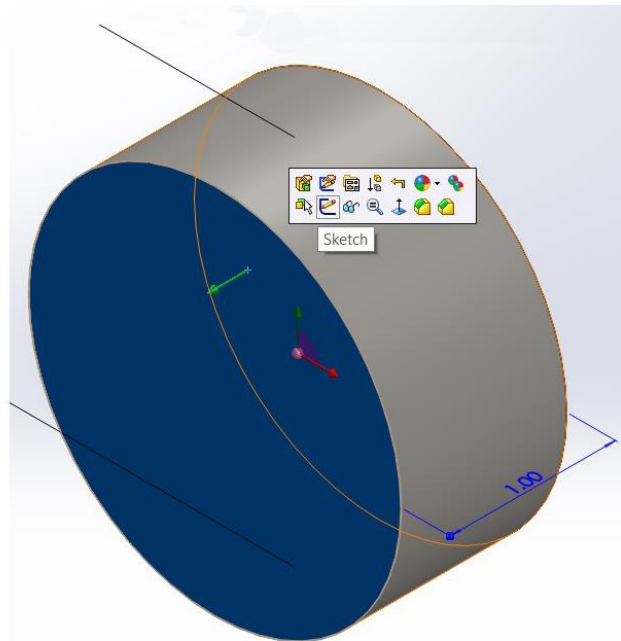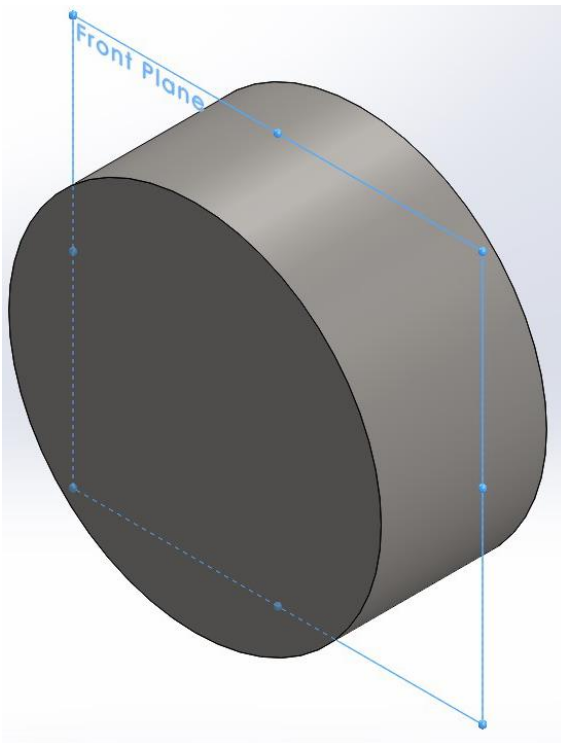


Isometric view with selection of the front face as the base to create a sketch

With the Ctrl 7 key, show the isometric view. Select the front face referent to the front plane of the new body as normal, and create a sketch

The next complete sketch includes almost all of the key parametric design. Carefully take each equation in relation to each sketch. Sketch the base circle, dedendum circle, and pitch circle related to its corresponding equation. To make the construction of the base and pitch circle, draw a construction line coincident at the center of the gear and the last point of the addendum circle.
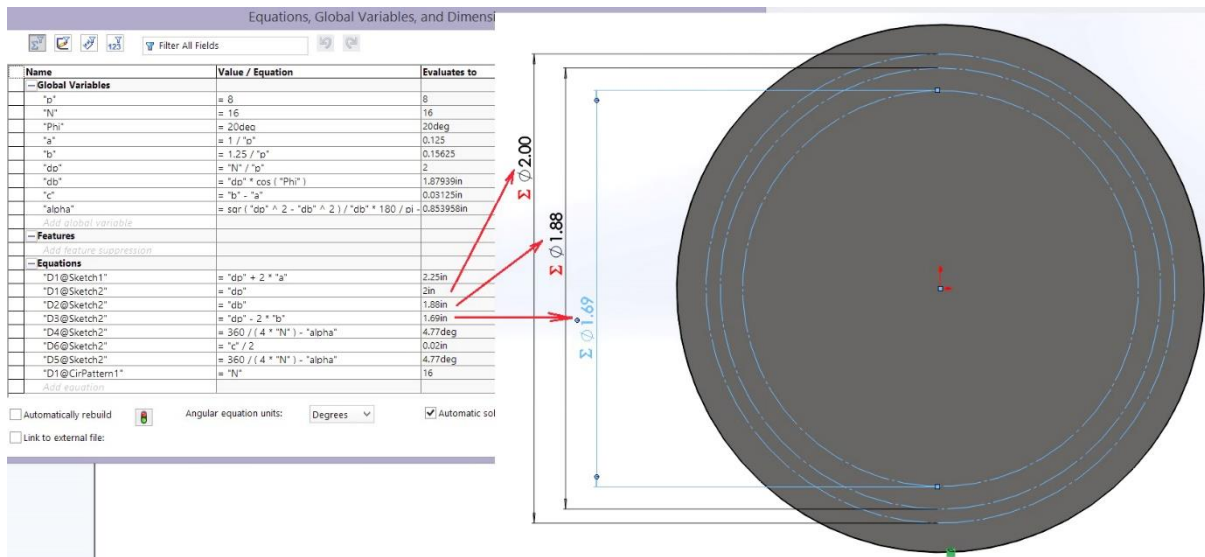


Sketch of the base circle, dedendum circle, and pitch circle in relation to equations of reference

### *Involute Properties*

An involute curve can be generated as shown in Figure 6. A partial flange "B" is attached to the cylinder "A," which is wrapped with a cord "def" and held tight. Point "b" on the cord represents the tracing point, and as the cord is wrapped and unwrapped around the cylinder, point "b" will trace out the involute curve "ac." The radius of the curvature of the involute varies continuously — zero at point "a" and a maximum at point "c." At point "b," the radius is equal to the distance "be" since point "b" is instantaneously rotating around point "e." Thus, the generating line "de" is normal to the involute at all points of intersection and, at the same time, is always tangent to the cylinder "A." The circle on which the involute is generated is called the base circle [5].
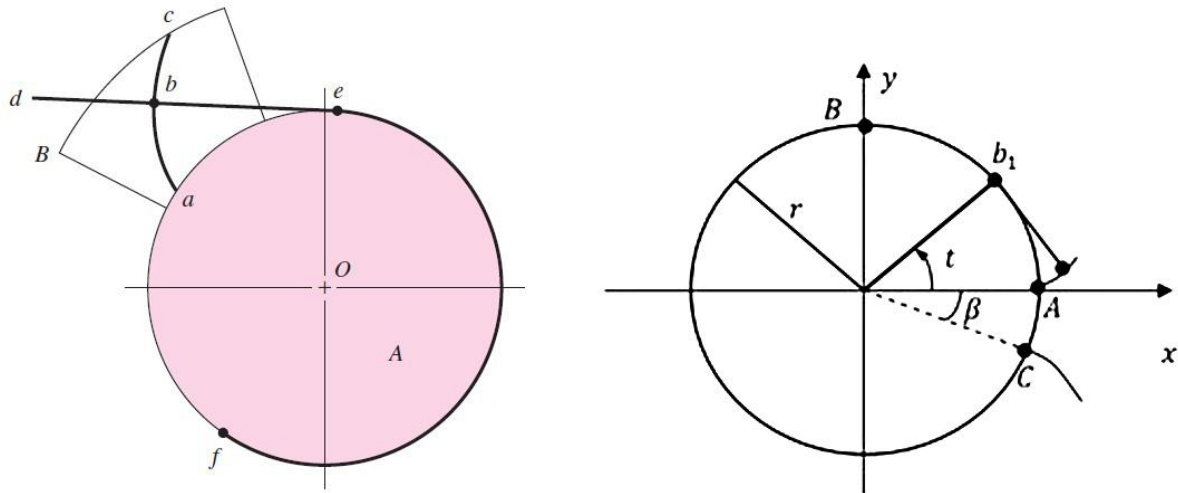
Generation of involute curve

For the parametric driven equations for t angle of the involute curve from point A of the base circle for a 2D sketch, x and y are the following:

$$x = r \cdot \cos(t) + r \cdot t \cdot \sin(t) = r \cdot (\cos(t) + t \cdot \sin(t))$$

$$y = r \cdot \sin(t) - r \cdot t \cdot \cos(t) = r(\sin(t) - t \cdot \cos(t))$$

where: r in the model represents the radius of the base circle, and the value in the model corresponds to the global equations and the corresponding sketch.

For the model

**xt = "D2@Sketch2"\*0.5\*(cos(t)+t\*sin(t))"**

**yt = "D2@Sketch2"\*0.5\*(sin(t)-t\*cos(t))"**

where: D2@Sketch2*0.5 is the base circle radius.
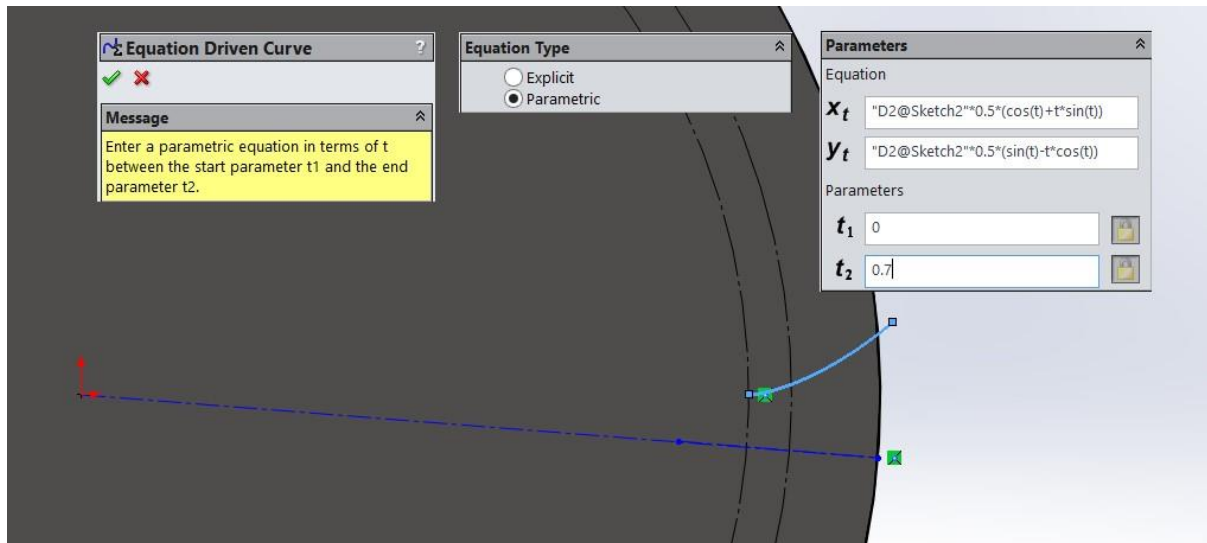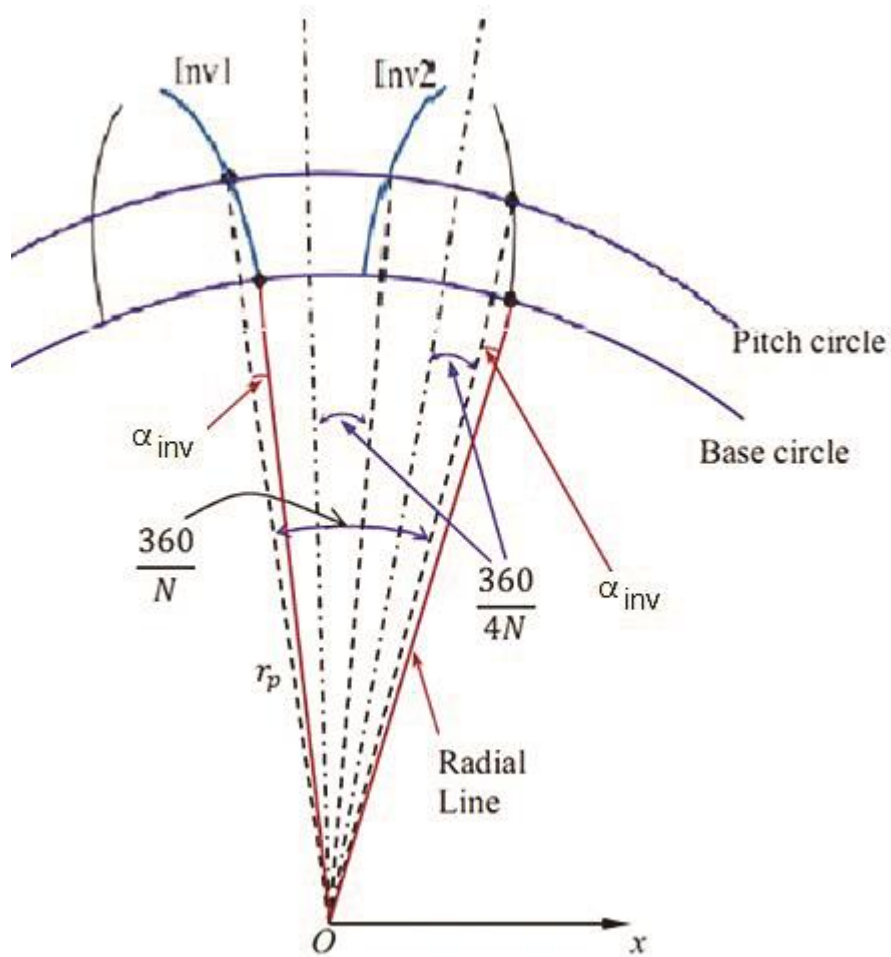
Introducing equations and parameters for generating the involute curve

The parameters $t_1 = 0$ at the beginning of the base circle and $t_2 = 0.7$ are sufficient to pass the addendum circle.

Parametric    driven    equation    for    involute    curve    of    spur    gear
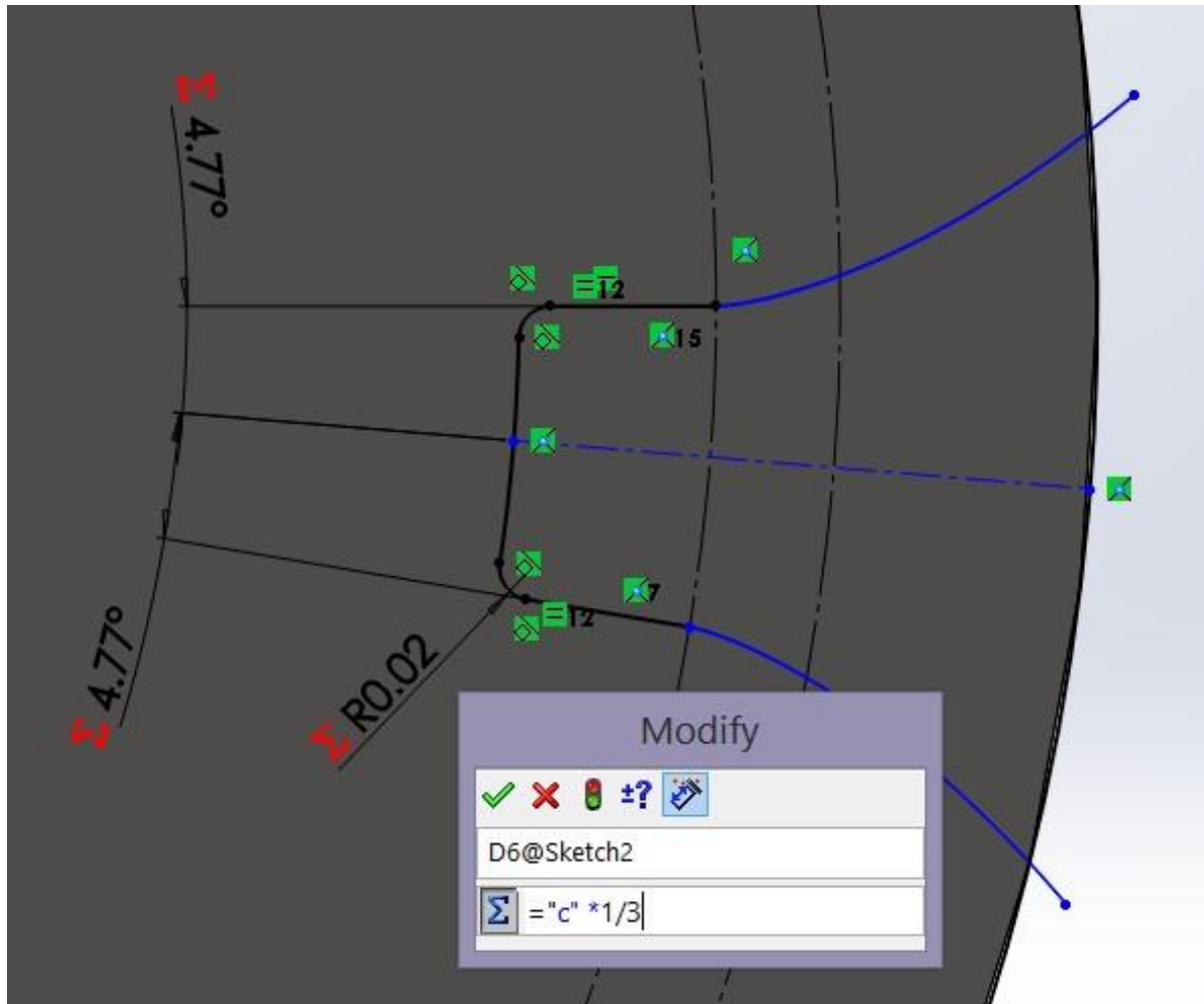


Sketch the bottom radius, which must be 1/3 or 2/3 of the clearance value

Draw two lines from the centerpoint of the circles and end at the beginning at each involute curve. Make the dimension relation as the measure of half beta angle to ensure uniform changes.

Trim the rest of the dedendum circle and centerlines to define the bottom of the teeth. Finally, sketch the bottom radius, which must be 1/3 or 2/3 of the clearance value.

Make sure all possible geometric relations are defined to ensure a solid parametric sketch when changes are made.

Extrude cut with the last sketch reference from the sketch plane direction all the way through.
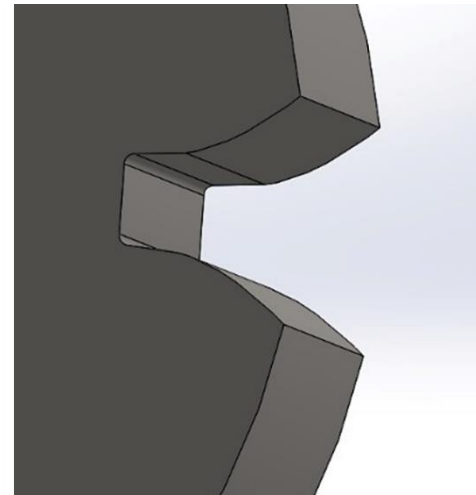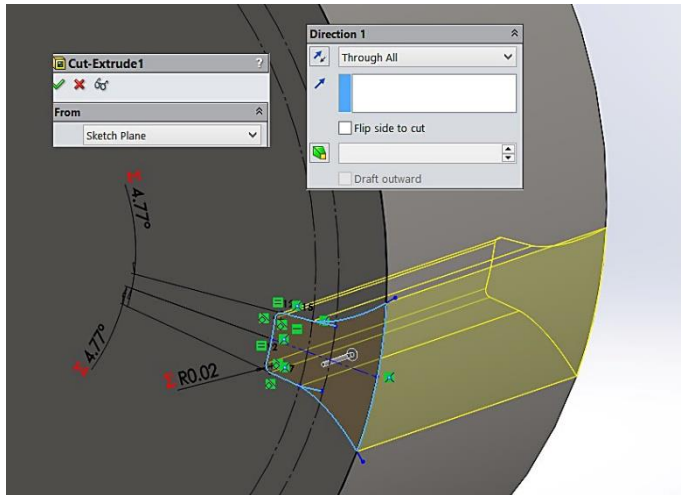
Extrusion        of        the        root        tooth        and        two        flanks        of        spur        gear
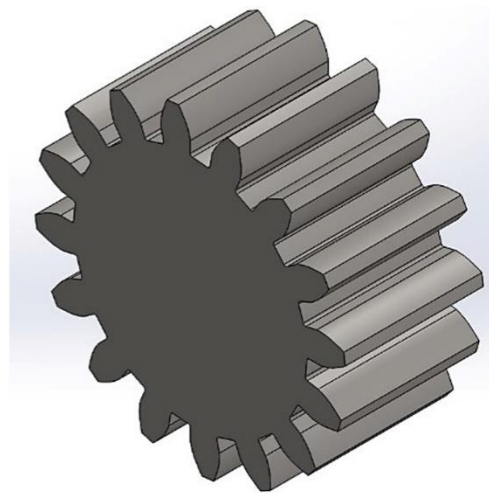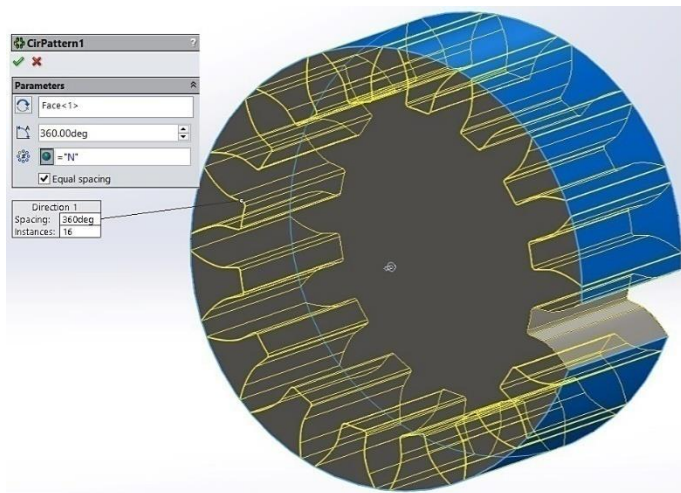


Geometric modeling of spur gear with number of teeth as global variable

Make a circular pattern, and be sure the number of instances are related with the global variable N (number of teeth).

## 8.4 modeling results

As a result of the parametric design, models can be obtained with number of teeth (N) with the same geometric characteristics and mathematical adaptation according to the global equations. In addition, the regression is included in the design tree to generate a chamfer at 45 degrees, and a bore and keyway to represent the shaft mounting can also be parameterized by shaft standards.
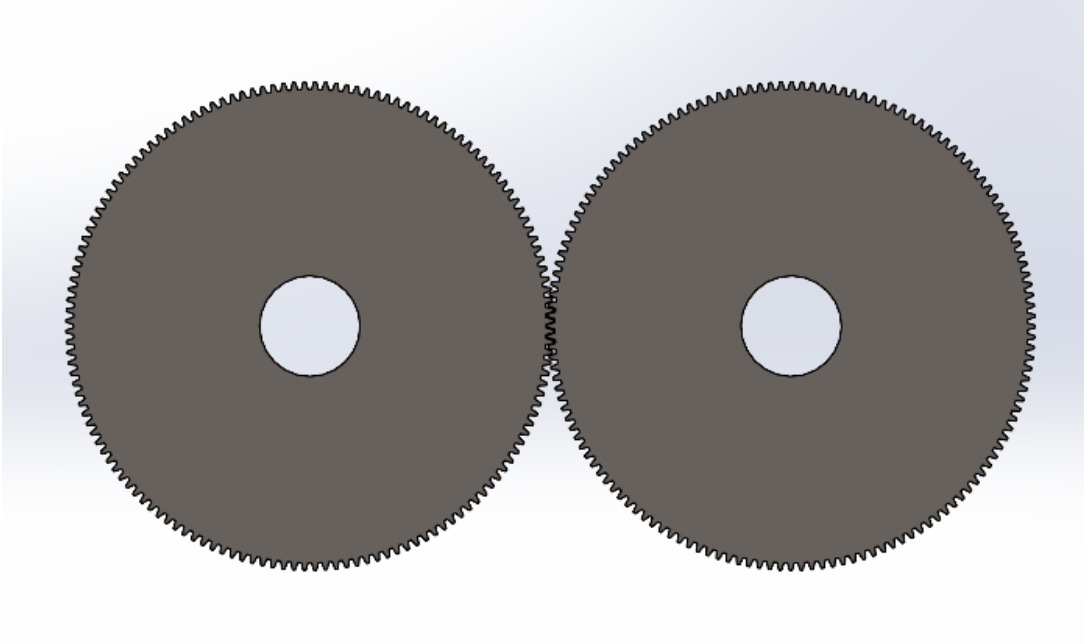
**Fig 8.3 initial gear model**
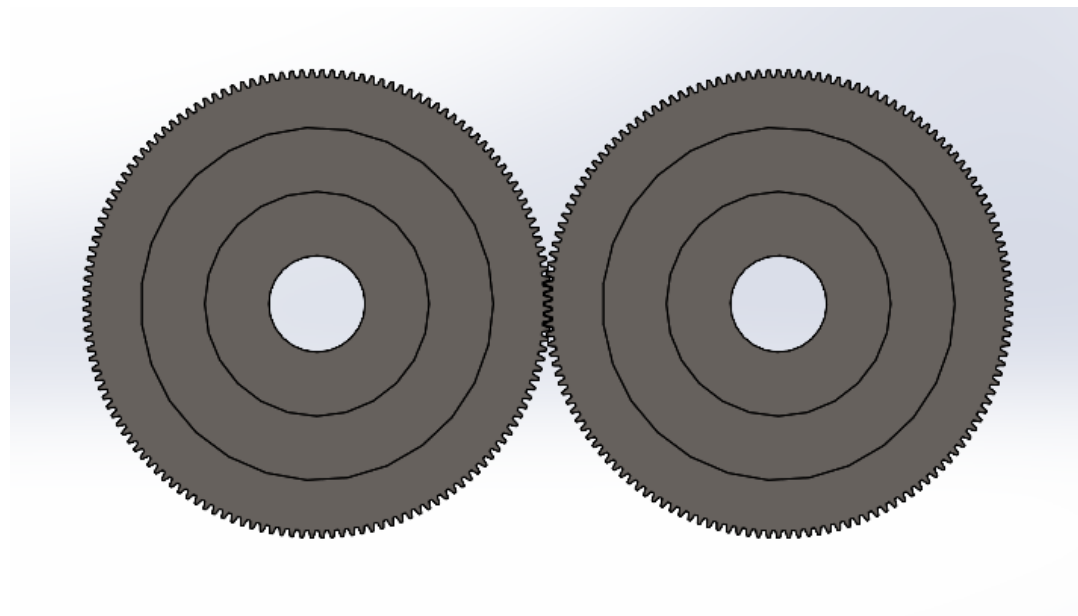


**Fig 8.4 modified gear model 1**

In initial gear model the surface of the gear is completely plain and filled with material.

In the mofied gear model 1 extrued cut is provided over the gear surface to reduce the weight of the gear according to our reqirement.
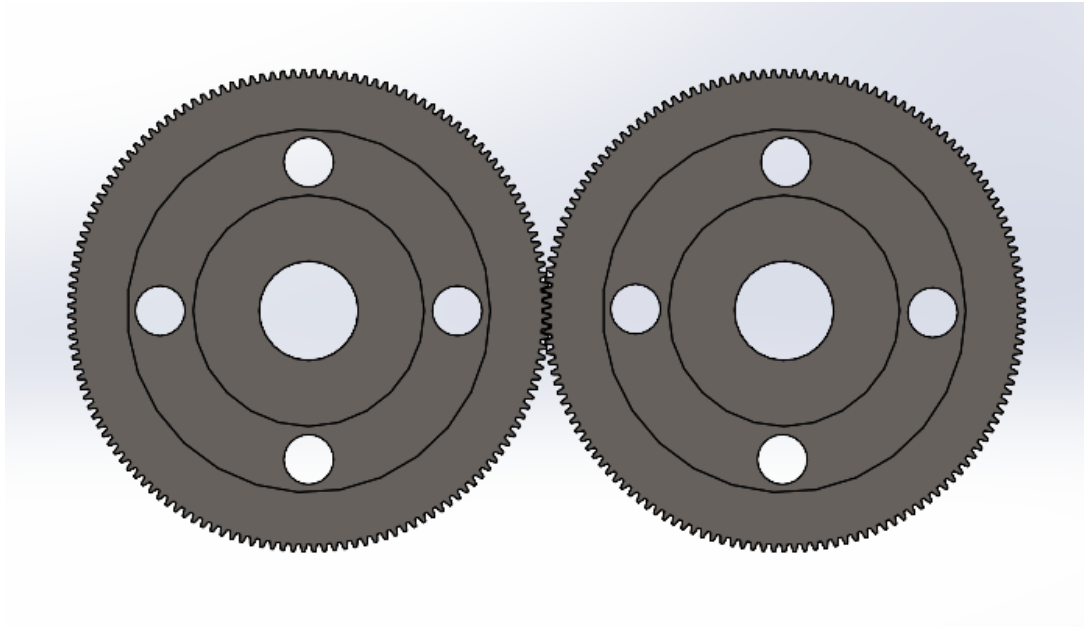
**Fig 8.5 modified gear model 2**
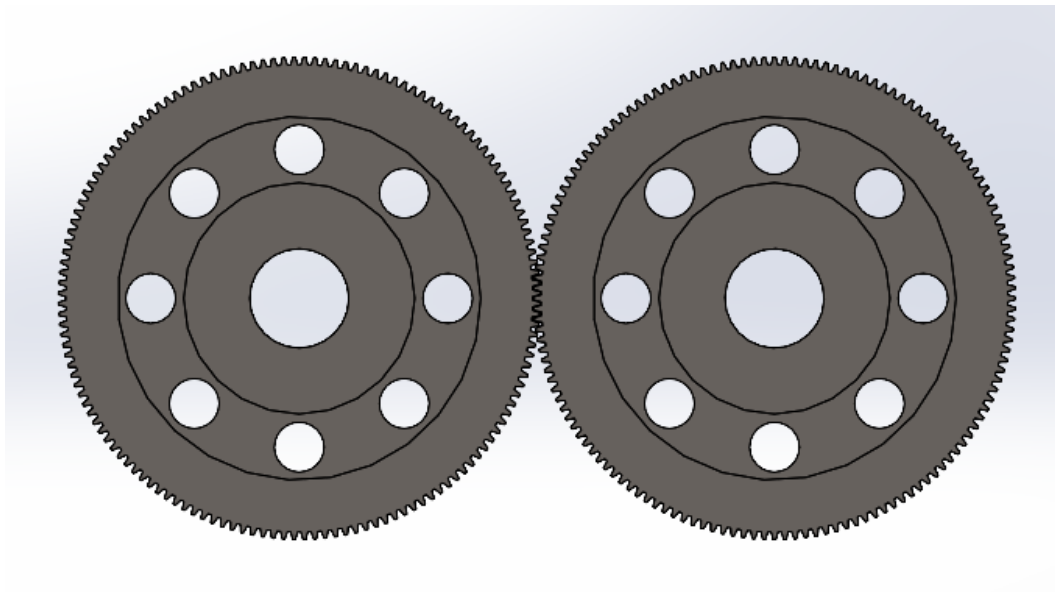


**Fig 8.6 modified gear model -3**

In modified gear model 2 in addition with the changes in modified model 1 few holes are introduced to reduce more weight.

In modified gear model 3 the number holes in modified model is doubled and more weight is reduced in order to do analysis on all the models and obtain the best model with less weight to withstand the applied loads.

# Chapter -9
# ANALYSIS

**9.1 Introduction to finite element analysis:**

Approximate solutions to a wide variety of engineering problems although originally developed to study stresses in complex airframe structures, it has since been extended and applied to the broad field of continuum mechanics. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and industry. The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. Advances in computer technology and CAD systems, has led to increased use of FEM in research as well as industry as complex problems can be modeled and released with relative ease.

**9.2 Basic Steps in the Finite Element Analysis:**

The basic steps involved in finite element analysis consist of the following

    a) **Pre-Processing Phase:**

Create and discretize the solution domain into finite elements i.e. subdivide the problem into nodes and elements.
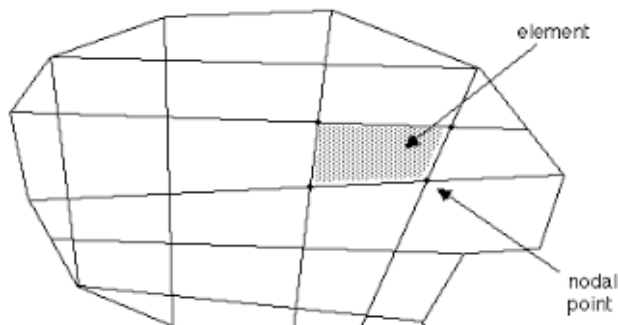


**Fig 9.1:Discretization of Real Continuum with Node and Element**

- Assume a shape function to represent the physical behavior of an element; that is an approximate continuous function is assumed to represent the solution of an element.
- Develop equations for all the elements in the mesh.
- These generally take form

- $[K]\{U\} = \{F\}$
- Where '$[K]$' is a square matrix, known as stiffness matrix
- '$\{U\}$' is the vector of (unknown) nodal displacements or temperature
- '$\{F\}$' is the vector of applied nodal forces
- Assemble the elemental equations to obtain the equations of the whole problem. Construct the global stiffness matrix.
- Apply boundary conditions, initial conditions, and loading.

   b) **Solution Phase:**

   Solve a set of linear or nonlinear algebraic equations simultaneously to obtain nodal results of primary degrees of freedom or unknowns, such as displacement values at different nodes in structural problem or temperature values at different nodes in heat transfer problem.

   c) **Post processing phase:**
- Computation of any secondary unknowns or variables e.g. the gradient of the solution.
- Interpretation of the results to check whether the solution makes sense.
- Tabular and/or graphical presentation of the results.
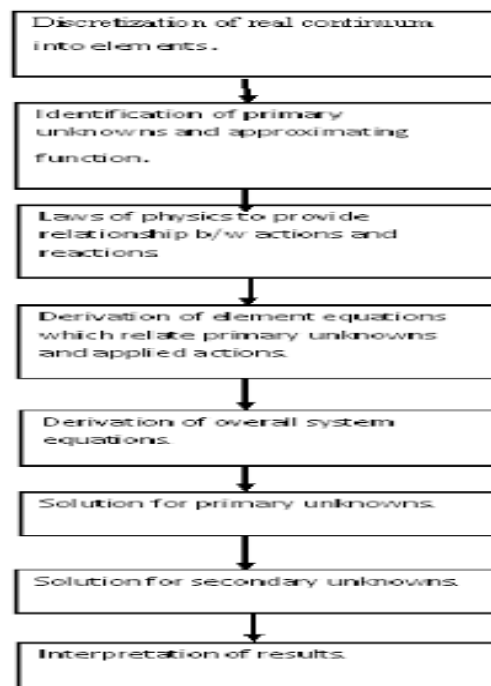
**Fig 9.2:Tabular presentation of results**

**9.3 Introduction to ANSYS Workbench:**

ANSYS Workbench is the framework upon which the industry's broadest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user every step of the way. Even complex multi physics analysis can be performed with drag-and-drop simplicity.
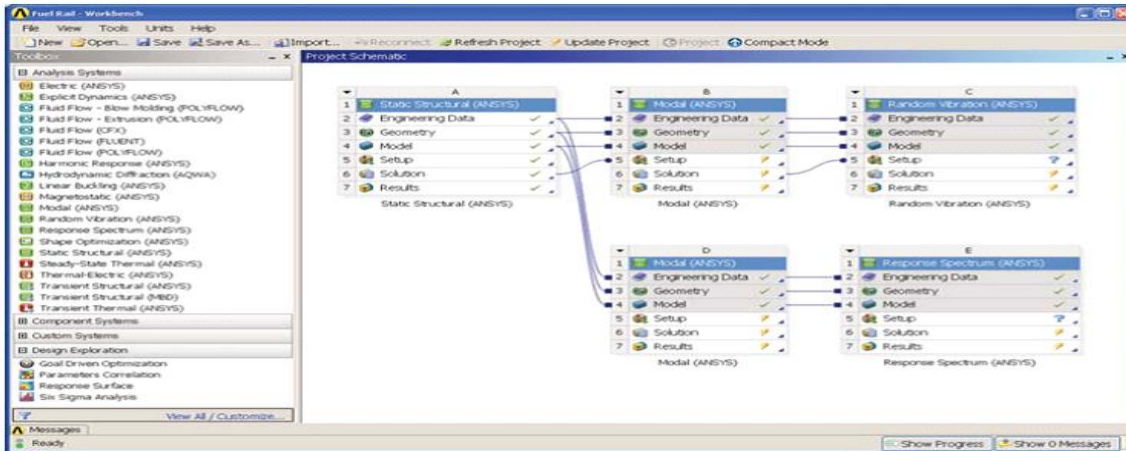


**Fig 9.3:Workbench 20 R1 Interface**

The ANSYS Workbench platform automatically forms a connection to share the geometry for both the fluid and structural analysis, minimizing data storage and making it easy to study the effects of geometry changes on both analyses. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

The ANSYS Workbench interface is arranged into two primary areas: The toolbox and the project Schematic. The toolbox contains the system templates that you can use to build a project. The project Schematic is the area if the interface where you will manage your project. The new project schematic view shows an overall view of the entire simulation project. Engineering intent, data relationships and the state of the entire project are visible at a glance, even for complex analyses involving multiple physics. In addition to this, you will see a menu bar and a toolbar with frequently used functions. You can also use context menus, accessible via a right- mouse click, on schematic items, and cells. Context menus provide capabilities to add to and modify projects. The entire process is persistent. Changes can be made to any portion of the analysis and the ANSYS Workbench platform will manage the execution of the required applications to update the project automatically, dramatically reducing the cost of performing design iterations.

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**9.3(a) ANSYS Workbench Features:**

- Bidirectional, parametric links with all major CAD systems.
- Integrated, analysis-focused geometry modeling, repair, and simplification via ANSYS Design Modeler.
- Highly-automated, physics-aware meshing.
- Automatic contact detection.
- Unequalled depth of capabilities within individual physics disciplines.
- Unparalleled breadth of simulation technologies.
- Complete analysis systems that guide the user start-to-finish through an analysis.
- Comprehensive multi physics simulation with drag-and-drop ease of use.
- Flexible components enable tools to be deployed to best suit engineering intent.
- Innovative project schematic view allows engineering intent, data relationships, and the state of the project to be comprehended at a glance.
- Complex project schematics can be saved for re-use.
- Pervasive, project-level parameter management across all physics.
- Automated what-if analyses with integrated design point capability.
- Adaptive architecture with scripting and journaling capabilities and API's enabling rapid integration of new and third-party solutions.

**9.4 Structural Analysis:**

Structural analysis is probably the most common application of the finite element method. The term *structural* (or *structure)* implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

**9.4(a) Types of structural analyses:**

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Structural, and ANSYS/Linear Plus programs only.

One can perform the following types of structural analyses

1) **Static Analysis:**

Used to determine displacements, stresses, etc., under static loading conditions. It comprises of both linear and non-linear static analysis. Non-linearity can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

2) **Model Analysis:**

Used to calculate the natural frequencies and mode shapes of a structure.

Different mode extraction methods are available.

3) **Harmonic Analysis:**

Used to determine the response of a structure to harmonically time-varying loads.

4) **Transient Dynamic Analysis:**

Used to determine the response of a structure to arbitrarily time-varying loads. All non-linearity mentioned under Static Analysis above are allowed.

5) **Spectrum Analysis:**

An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

6) **Buckling Analysis:**

Used to calculate the buckling loads and determine the buckling mode shape.

Bothlinear(Eigen value) buckling and nonlinear buckling analyses are

possible.

**9.5 Explicit Dynamics Analysis:**

ANSYS provides an interface to the LS-DYNA explicit finite element program and is used to calculate fast solutions for large deformation dynamics and complex contact problems.

- In addition to the above analysis types, several special-purpose features are available
- Fracture mechanics

- Composites
- Fatigue
- p-Method

## 9.6 Thermal Analysis:

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are

- The temperature distributions
- The amount of heat lost or gained
- Thermal gradients
- Thermal fluxes

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions).

Only the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Thermal, and ANSYS/FLOTRAN programs support thermal analysis.

The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution one performs via ANSYS calculates nodal temperatures and then uses the nodal temperatures to obtain other thermal quantities.

The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation.

## 9.6(a) Types of thermal analysis:

ANSYS supports two types of thermal analysis

I.  A **steady-state thermal analysis** determines the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a situation where heat storage effects varying over a period of time can be ignored.

**II.** A **transient thermal analysis** determines the temperature distribution and other thermal quantities under conditions that vary over a period of time.

## 9.7 PROCEDURE FOR PERFORMING STATIC STRUCTURAL ANALYSIS:

### STEP 1: Selection of Analysis feature

Open Ansys workbench and then select static structural analysis from left side tool bar



**Fig 9.4:Structural Analysis Interface**

### STEP 2: Engineering Data

The data to be calculated is to be submitted in this module. Properties such as yield strength, young's modulus, Poisson's ratio, F.O.S are to be provided.
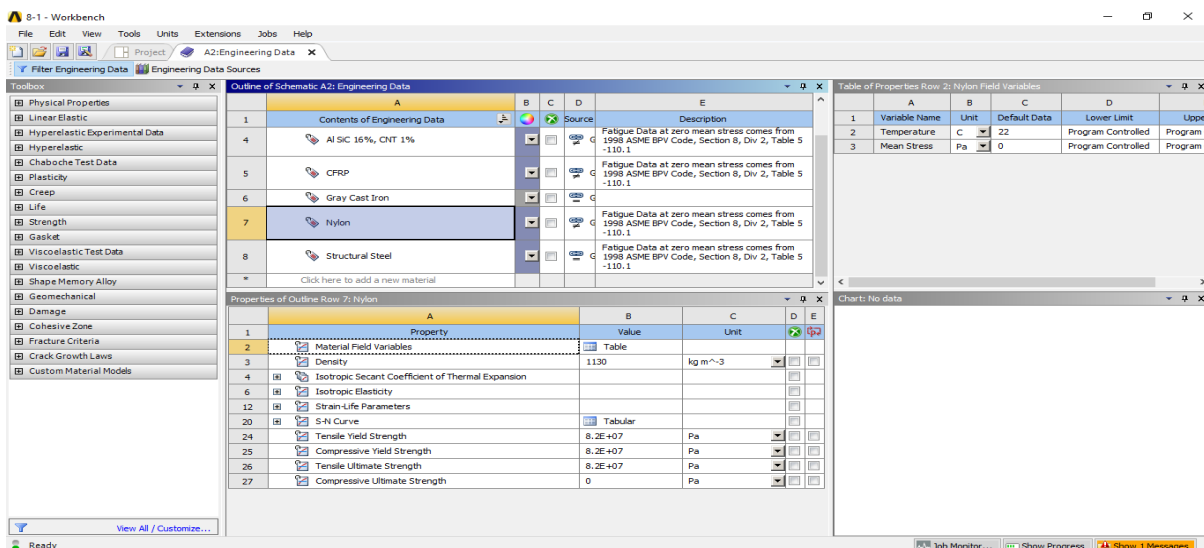


**Fig 9.5: Engineering Data interface**
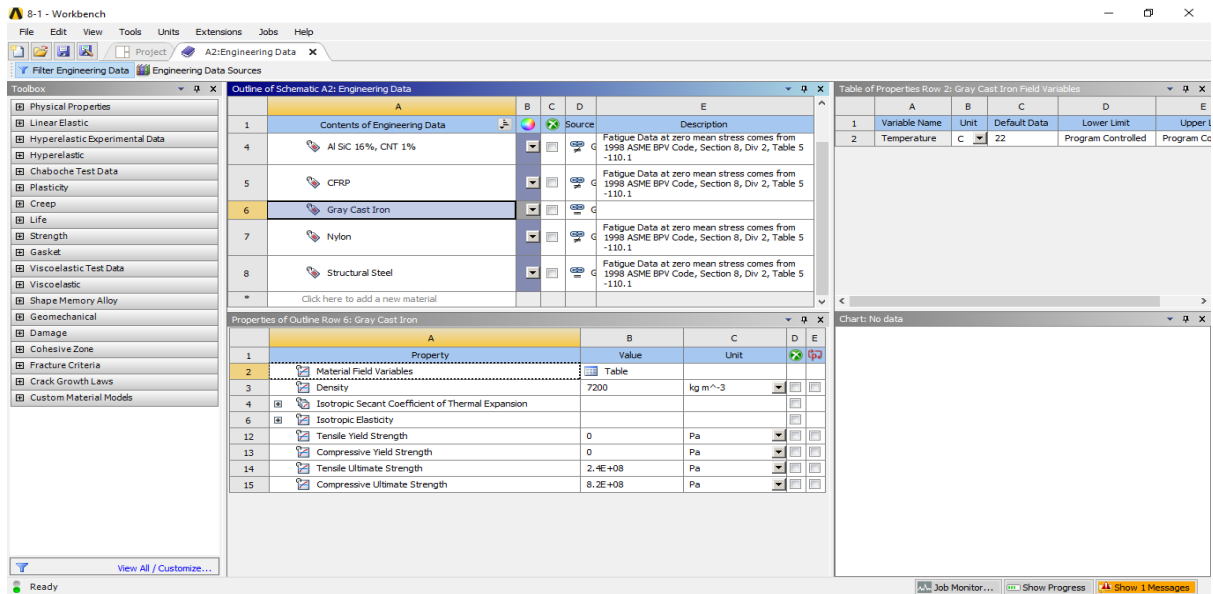
**Fig 9.6: Insertion of data in ANSYS**

## STEP 3: INSERTION OF GEOMETRY

Right click on the geometry and then click on **Import Geometry**. Then close the present tab and again right click on the geometry then click on the **Modify Designer Tool**.
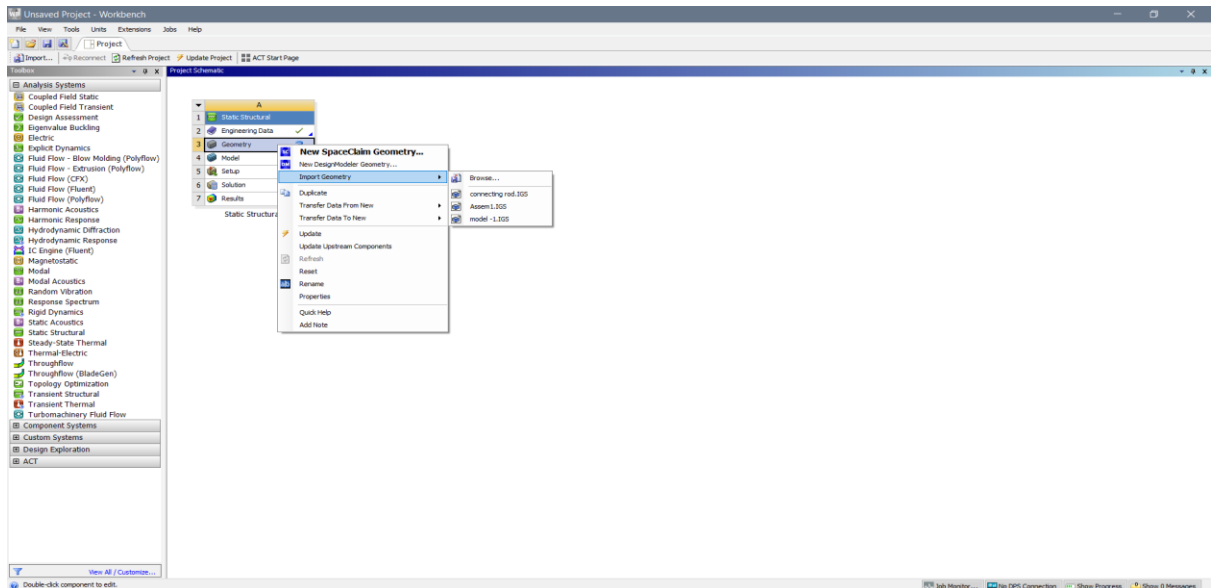


**Fig 9.7: Import of Geometry**

**STEP 4: MODEL**

        Right click on the model. To load the model in to work bench.

**STEP 5: MESHING**           Click on mesh option and insert patch conforming method and select meshing method as Tetrahedrons.
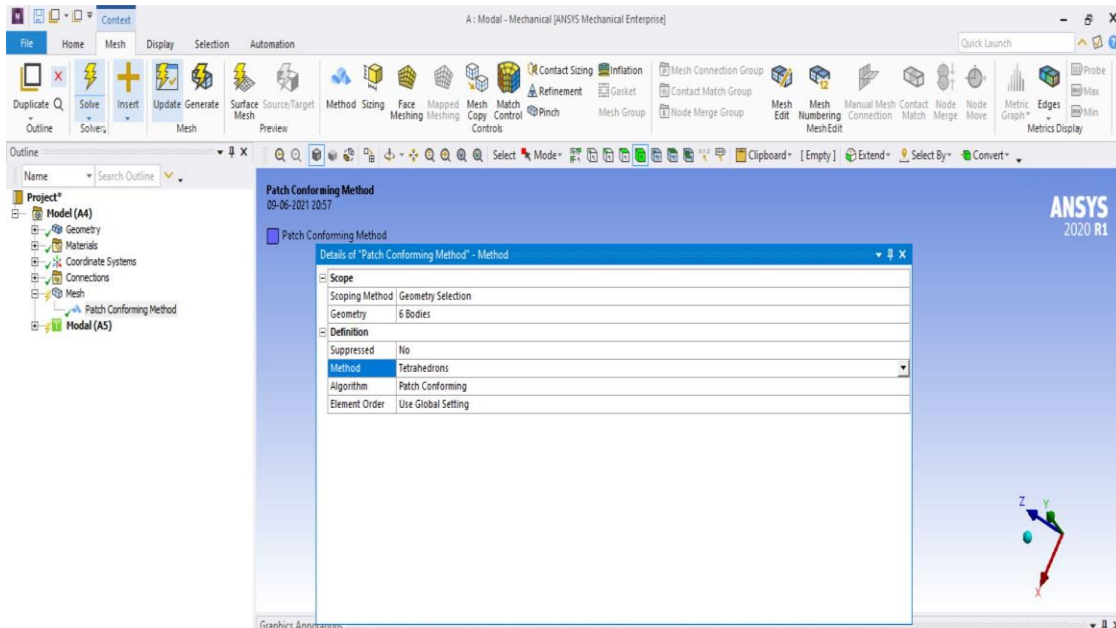


**Fig 9.9: Meshing Interface**

Select sizing and set span angle center of mesh as fine.
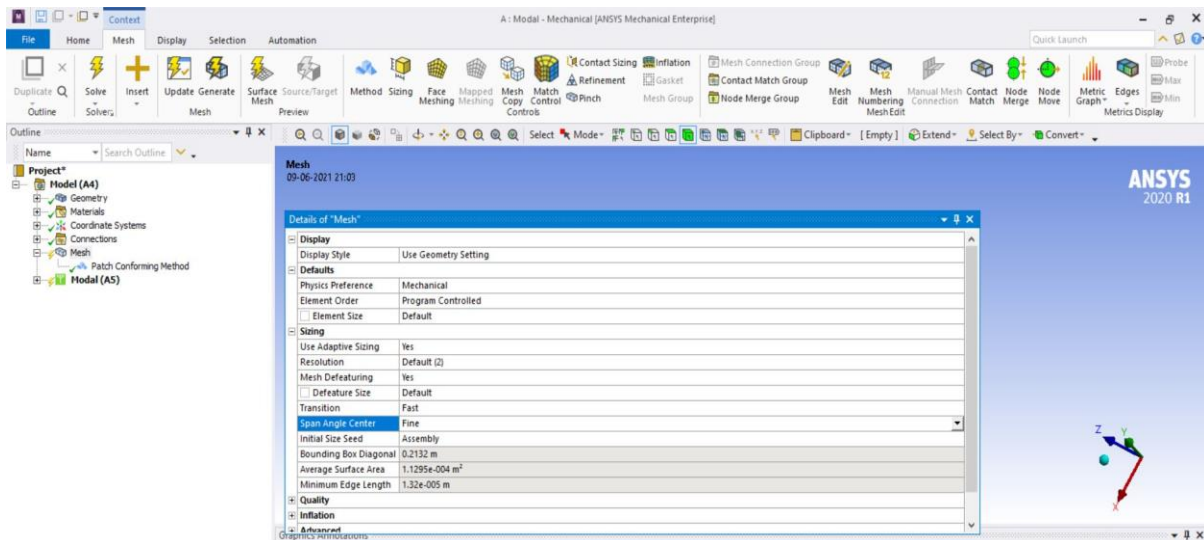


**Fig 9.10: Mesh Details**

Now right click on mesh and click on generate mesh. Then Tetrahedrons mesh is generated over the model.

**Statistics of Mesh:**

No. of nodes = 239905

No. of elements = 140238
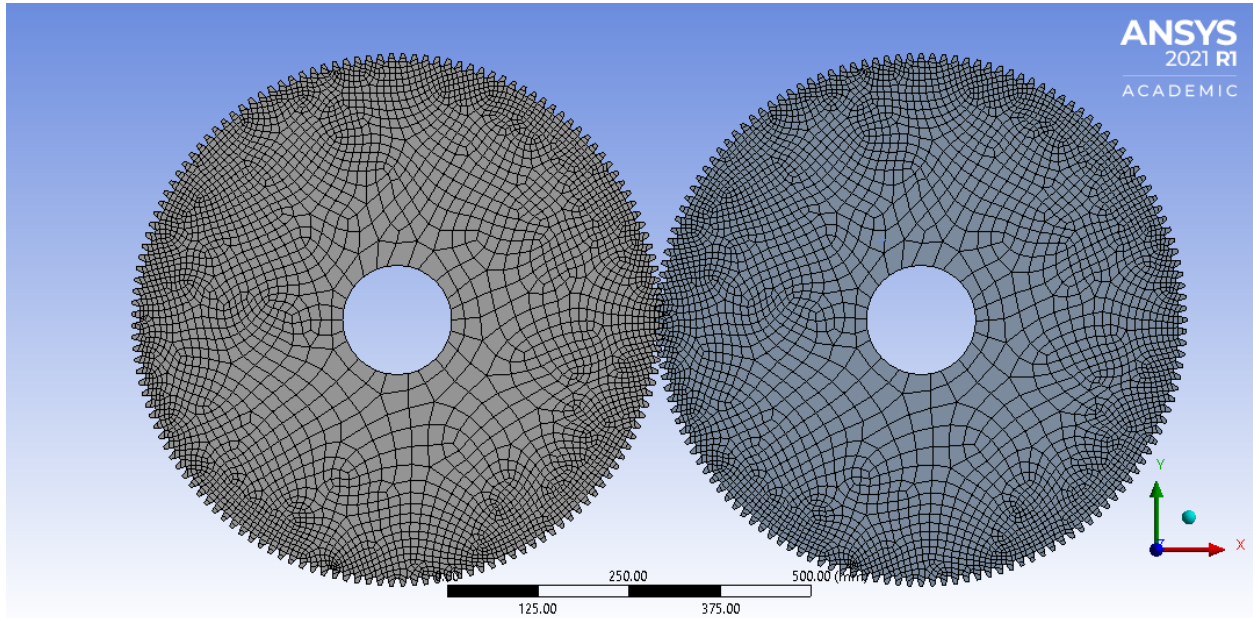


**Fig 9.11 Meshing of gear**

## STEP 6: INSERTION OF SUPPORTS AND FORCES

Right click on **Static structural** icon. Click on **INSERT**. Then select fixed support and click on apply.

Again, right click on **Static structural** icon. Click on **INSERT.** Then select force and click on apply. Then the force is defined by the component i.e., in which direction the force is to be applied.

## STEP 7: ANALYSIS

Right click on **Solution** icon. Click on **INSERT**. Then select Equivalent stress, Max. Shear stress, Safety factor, Fatigue life and click on apply. Now right click on **Solution** icon and click on **Solve**.

# Chapter-10

# ANALYSIS RESULTS

## 10.1 CASTIRON:

### 10.1.1 INITIAL GEAR MODEL:
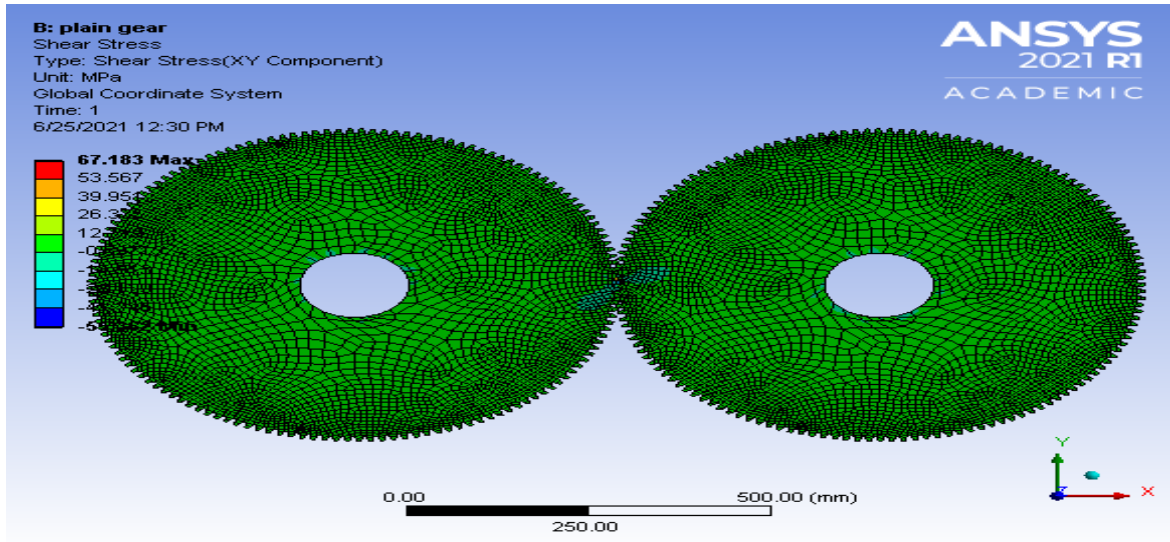


Fig 10.1 shear stress of initial cast iron gear model
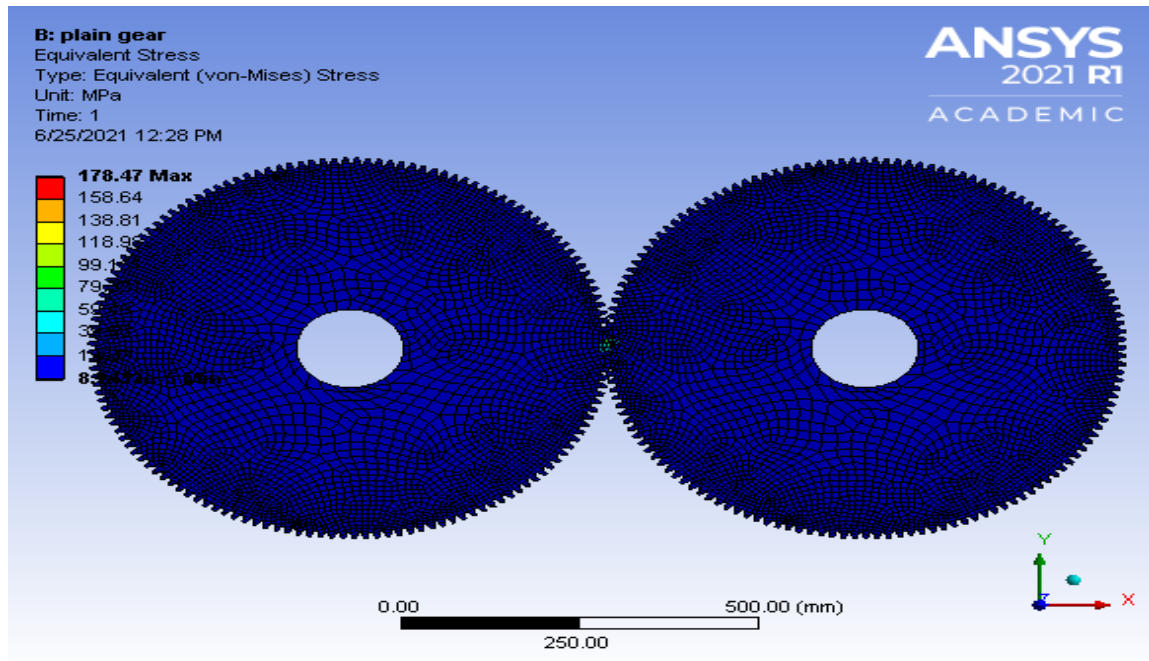


Fig.10.1 eq.stress of initial cast iron gear model

10.1.2  Model 1
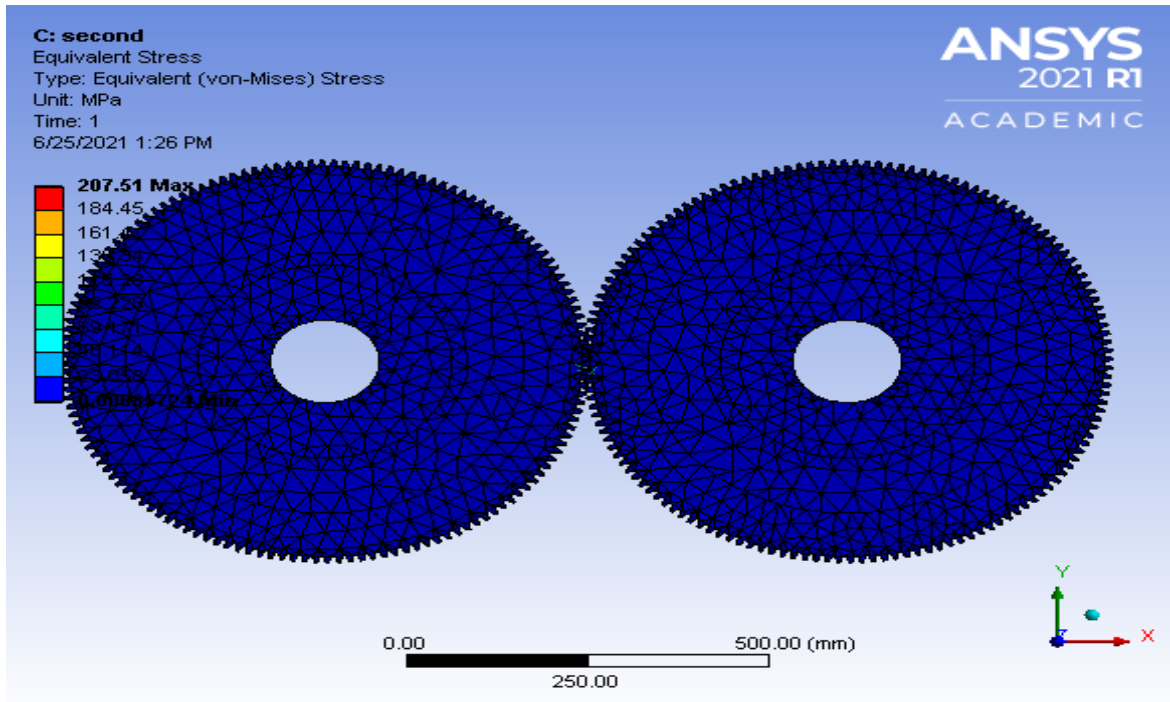


Fig 10.3 eq stress of castiron model 1
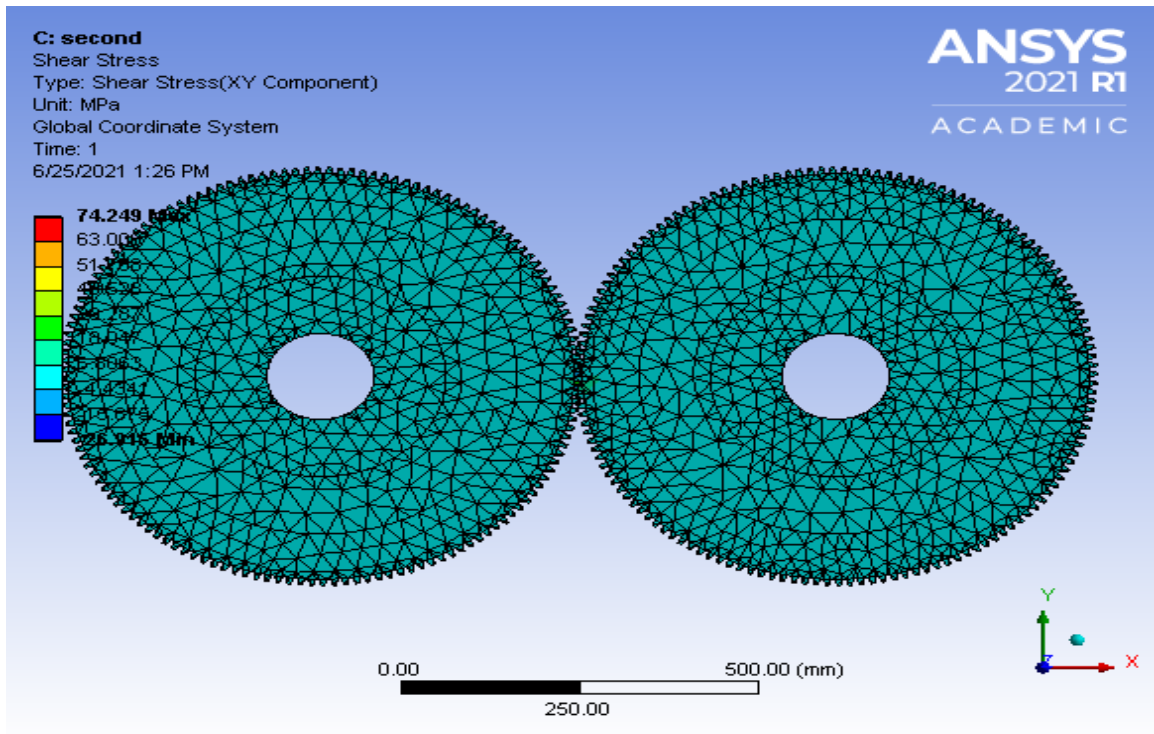


Fig 10.4 shear stress of castiron model 1

### 10.1.3 Model 2
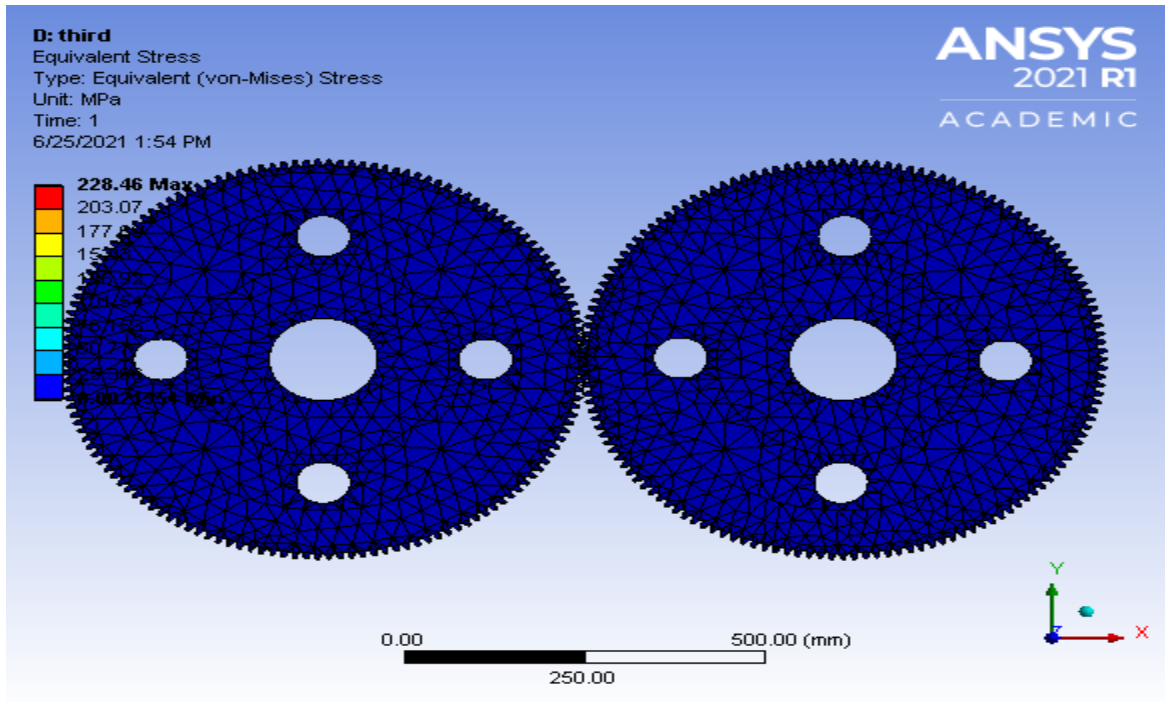


Fig 10.5 eq stress of castiron model 2
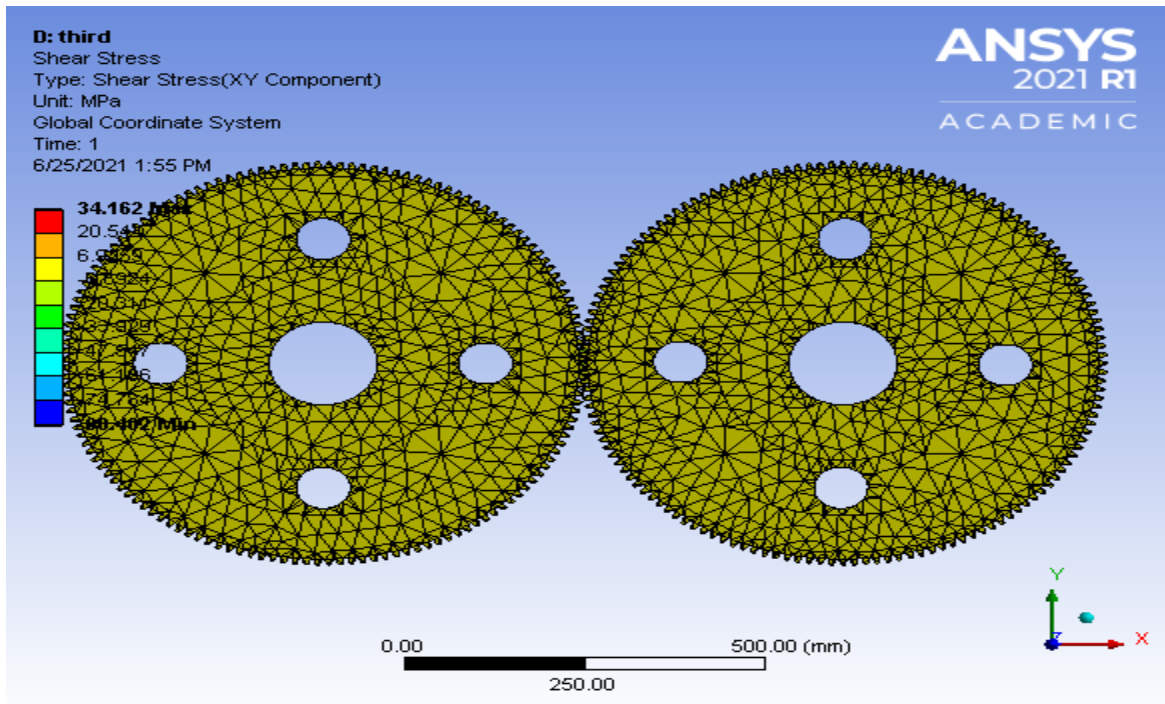


Fig 10.6 shear stress of cast iron model 2

If cast iron used as gear manufacturing material it can be used up to model 2. I t is failed in model 2.
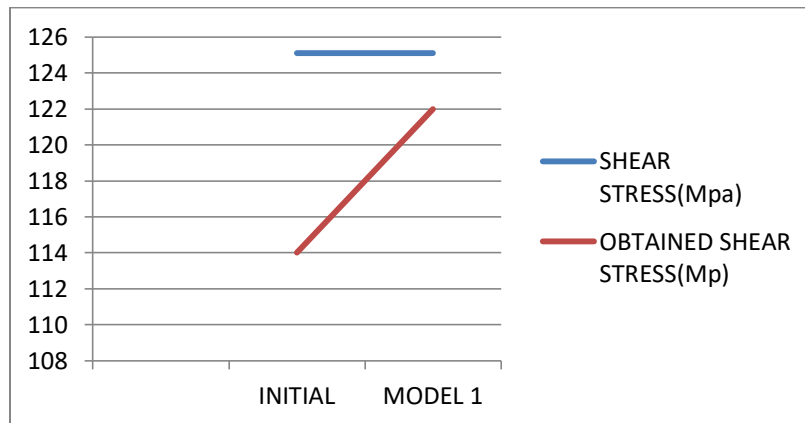
Cast iron analysis:

| NAME | MAX STRESS (Mpa) | SHEAR STRESS(M pa) | OBTAINED STRESS(Mp) | OBTAINED SHEAR STRESS(Mp) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 260 | 75.3 | 178.47 | 57.18 | 69.752 | 0 |
| MODEL 1 | 260 | 75.3 | 257.41 | 74.2 | 54.495 | 21.8 |
| MODEL 2 | 260 | 75.3 | 228.46 | 35.6 | 53.231 | 23.6 |

TABLE 10.1 ANALYTICAL DATA PF GEARS MADE OF CAST IRON
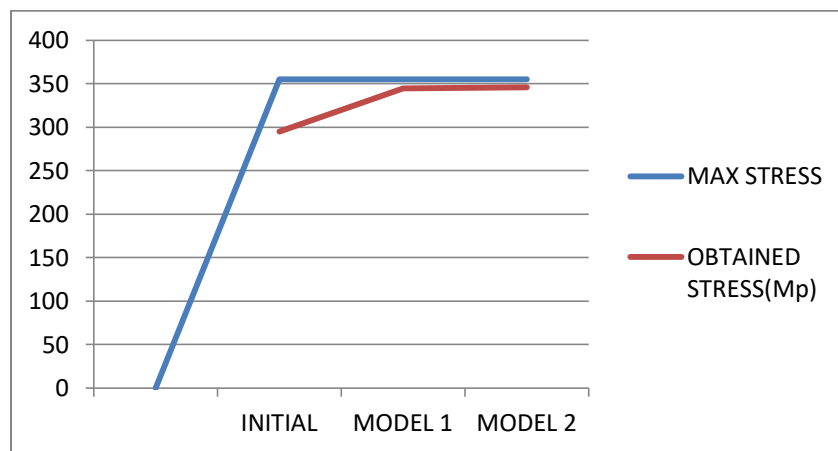


GRAPH 10.1 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF CASTIRON
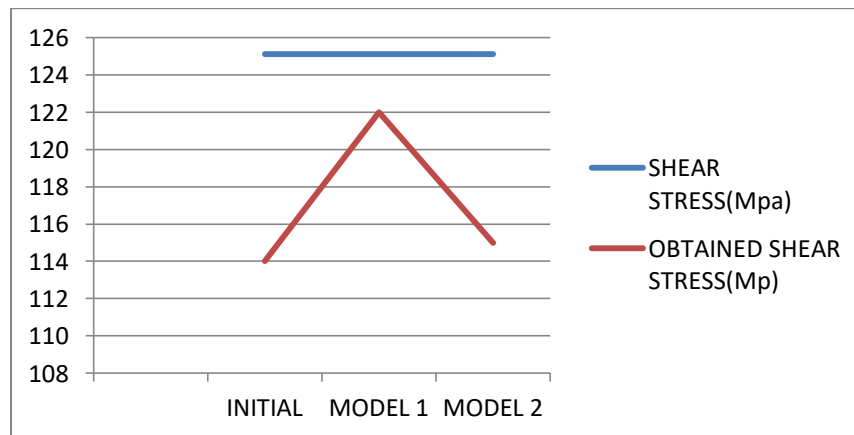


GRAPH 10.2 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF CAST IRON

## 10.2 COPPER:

### 10.2.1 Initial model
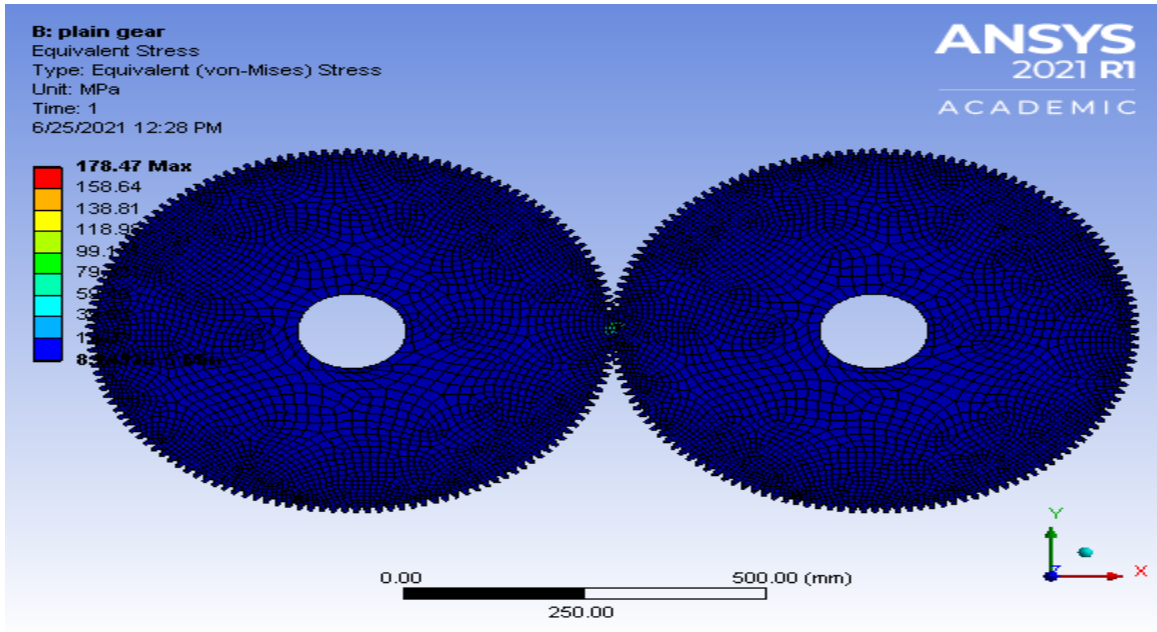


Fig 10.7 eq stress of copper initial model
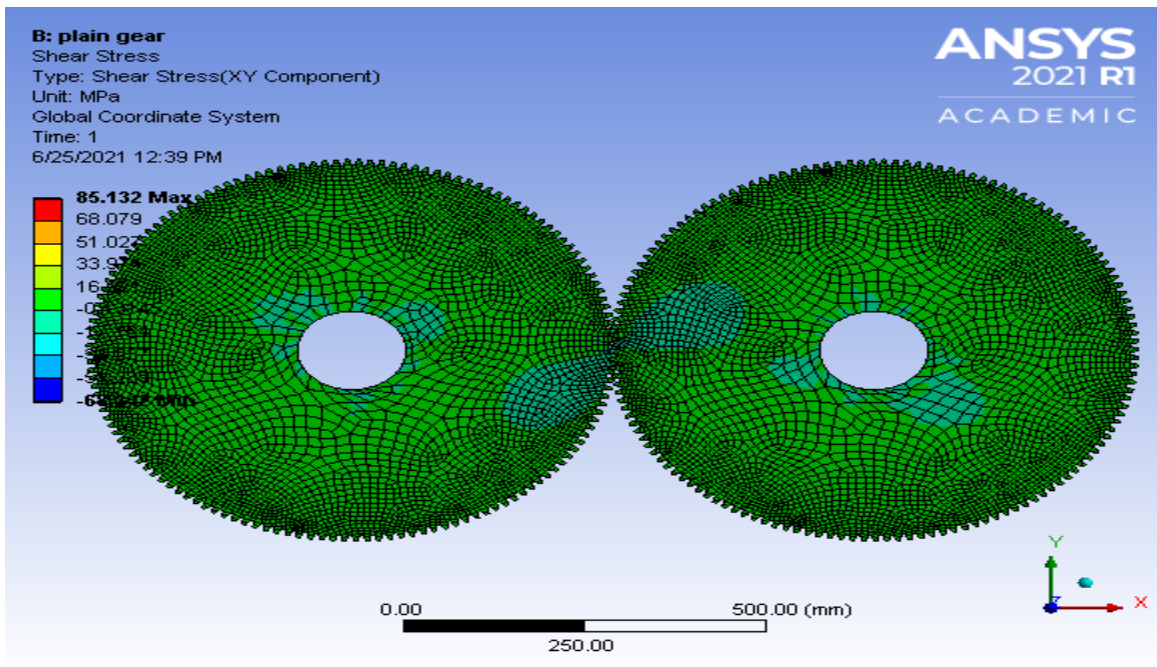


Fig 10.8 shear stress of copper initial model

10.2.2 Model 1
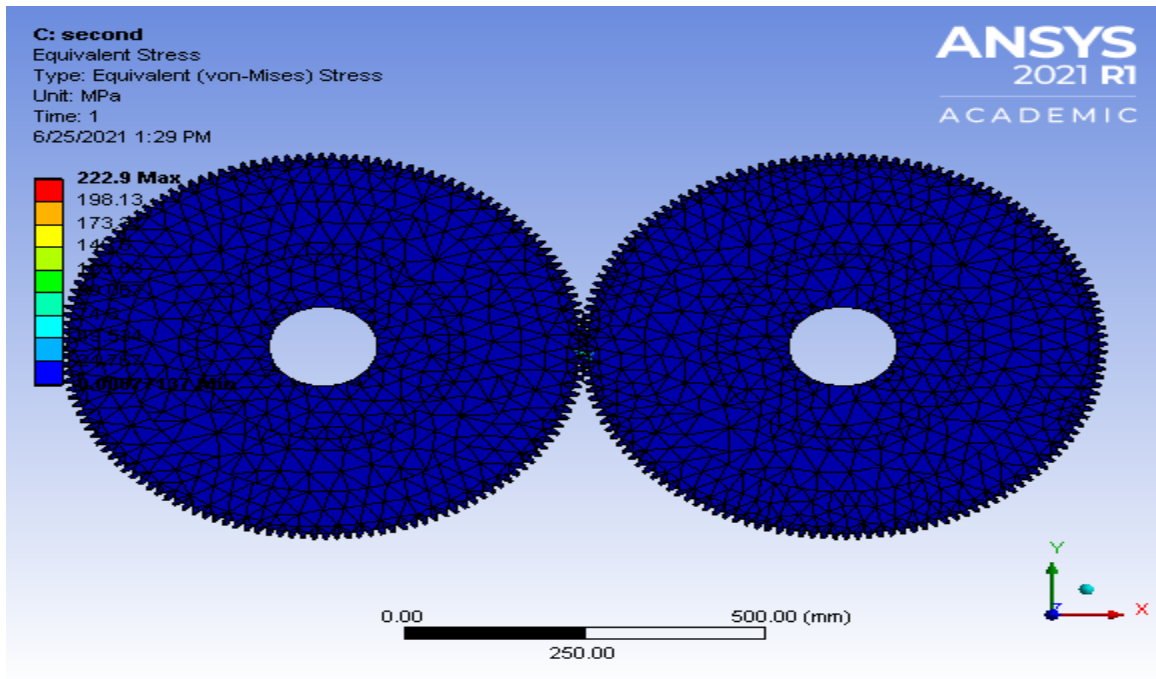


Fig 10.9 eq stress of copper model 1
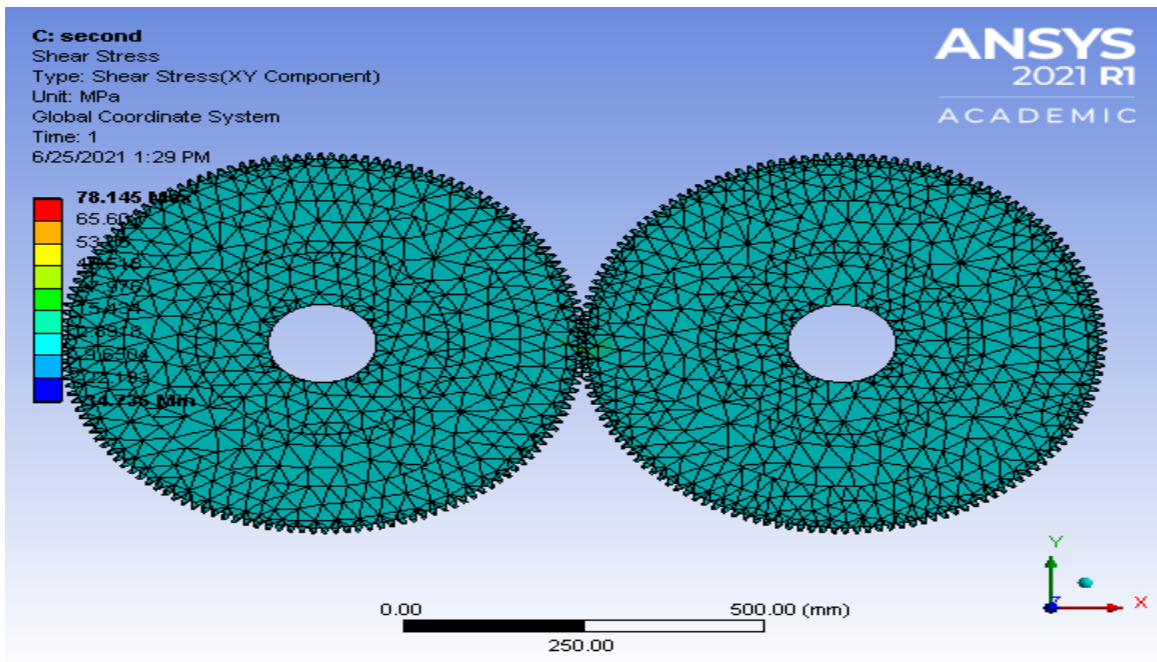


Fig 10.10 shear stress of copper model 1

### 10.2.3 Model 2
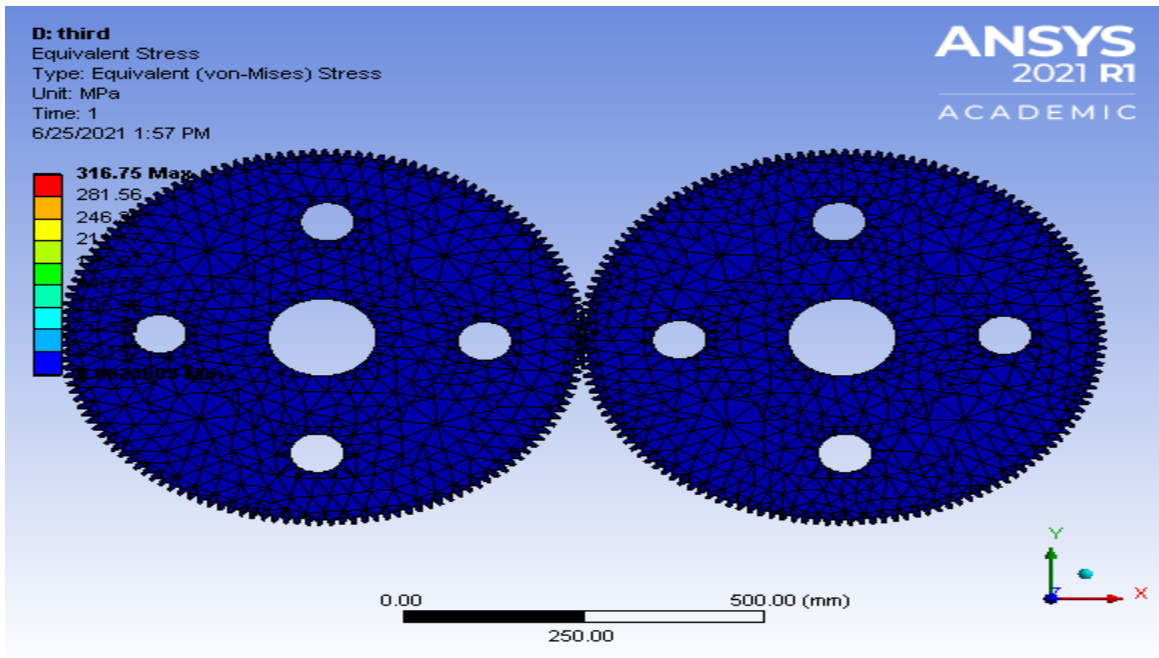


Fig 10.11 eq. stress of copper model 2
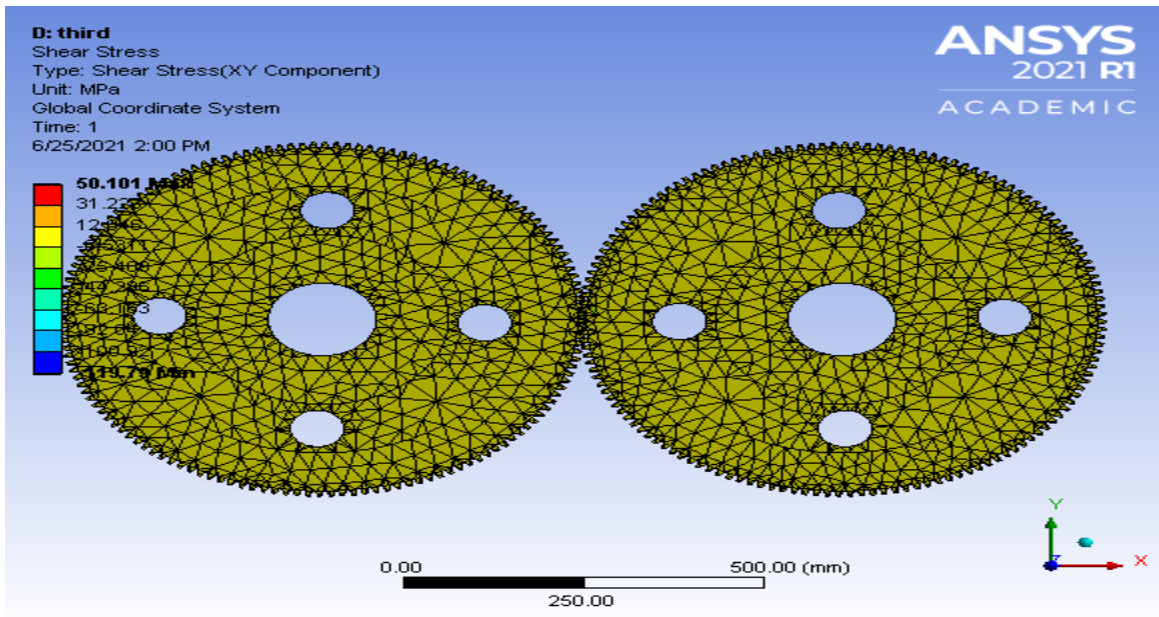


Fig 10.12 shear stress of copper model 2

If copper used as gear manufacturung material it can be used upto model 2. I t is failed in model 2.

COPPER analysis

| NAME | MAX STRESS (Map) | SHEAR STRESS(Mpa) | OBTAINED STRESS(Mp) | OBTAINED SHEAR STRESS(Mp) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 250 | 81.8 | 178.47 | 81 | 86.541 | 0 |
| MODEL 1 | 250 | 81.8 | 222.9 | 75 | 67.611 | 21.8 |
| MODEL 2 | 250 | 81.8 | 316.75 | 59 | 66.043 | 23.6 |

TABLE 10.2 ANALYTICAL DATA PF GEARS MADE OF COPPER
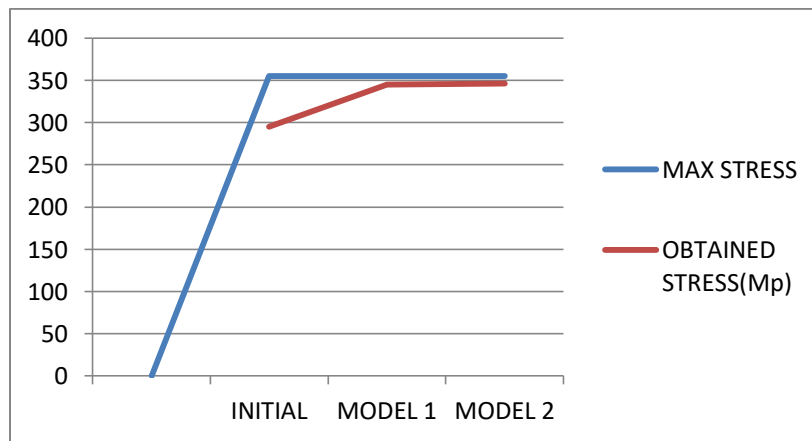


GRAPH 10.3 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF COPPER
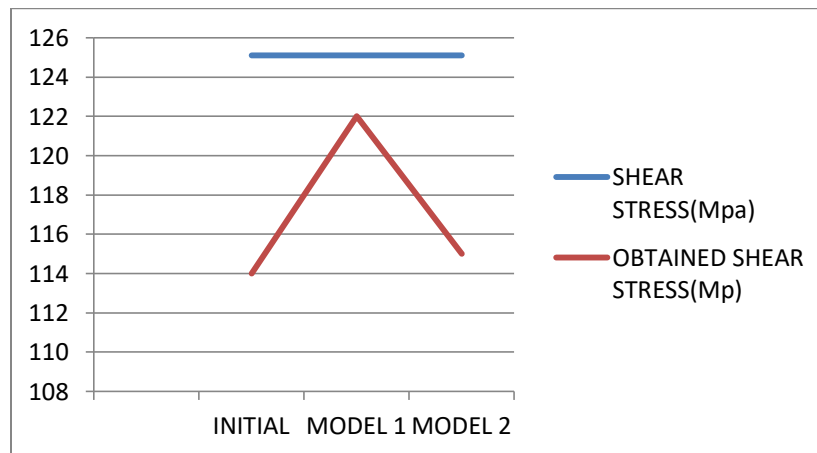


GRAPH 10.4 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF COPPER

10.3 Bronze

10.3.1 Initial model
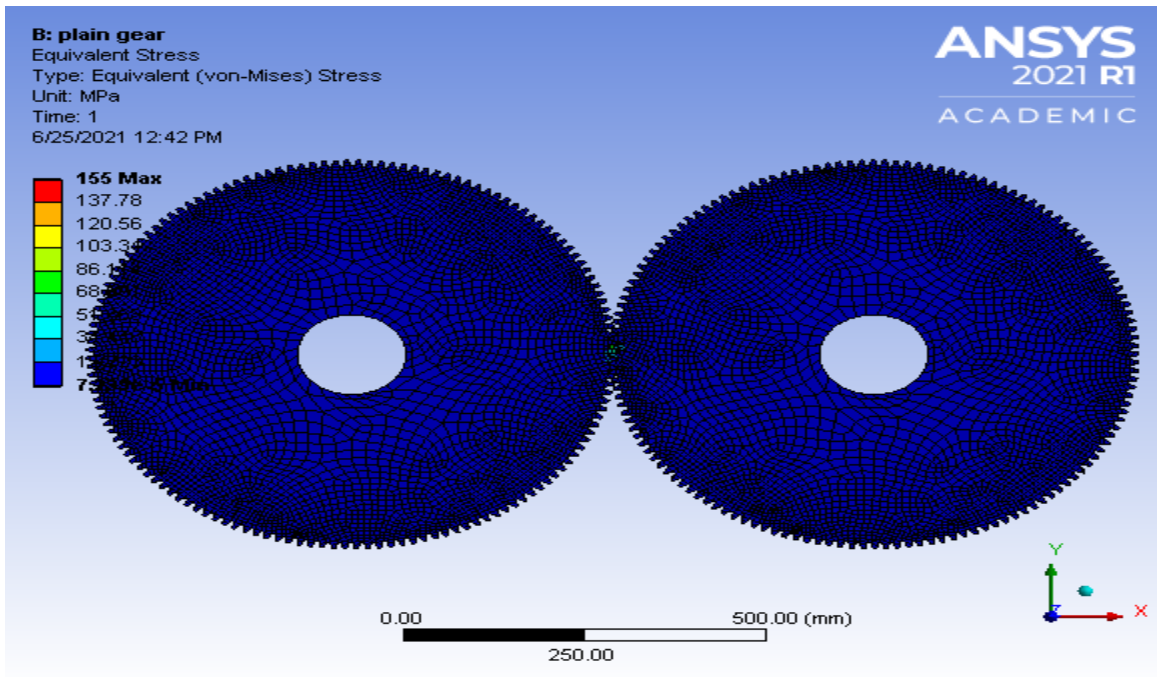


Fig 10.13 eq stress of bronze initial model
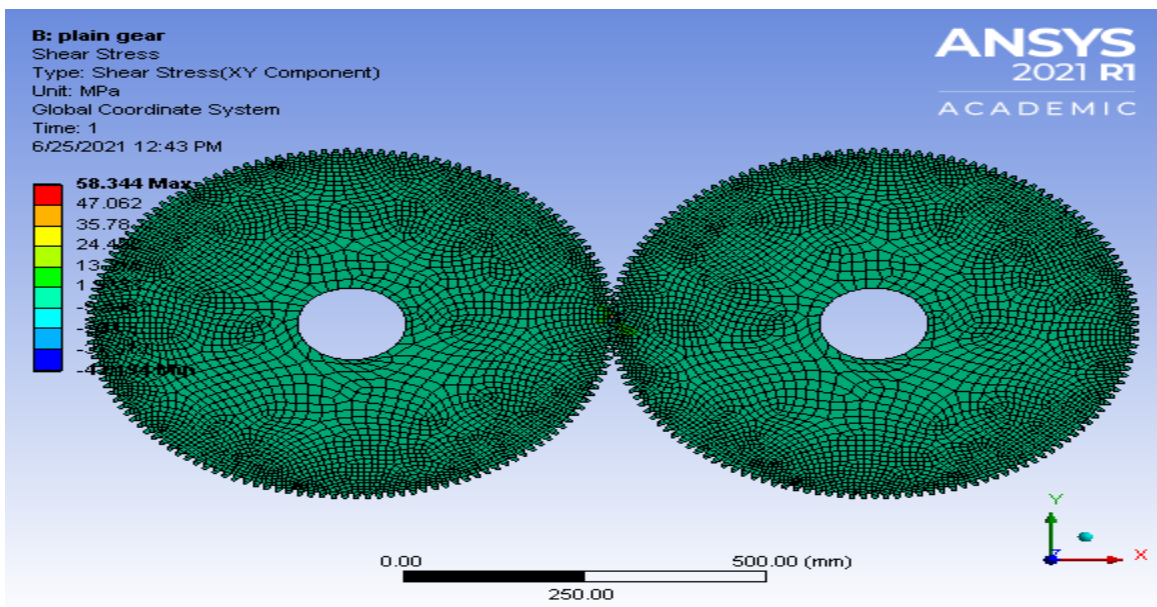


Fig 10.14 shear stress of bronze initial model

10.3.2 Model 1
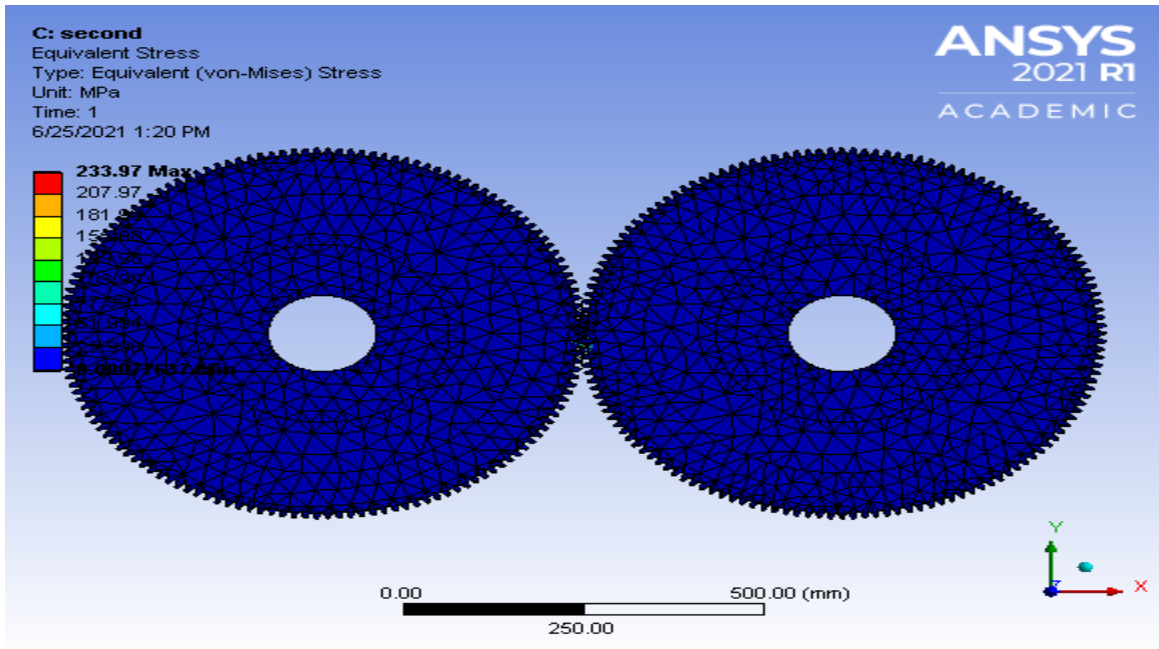


Fig 10.15eq stress of bronze model 1
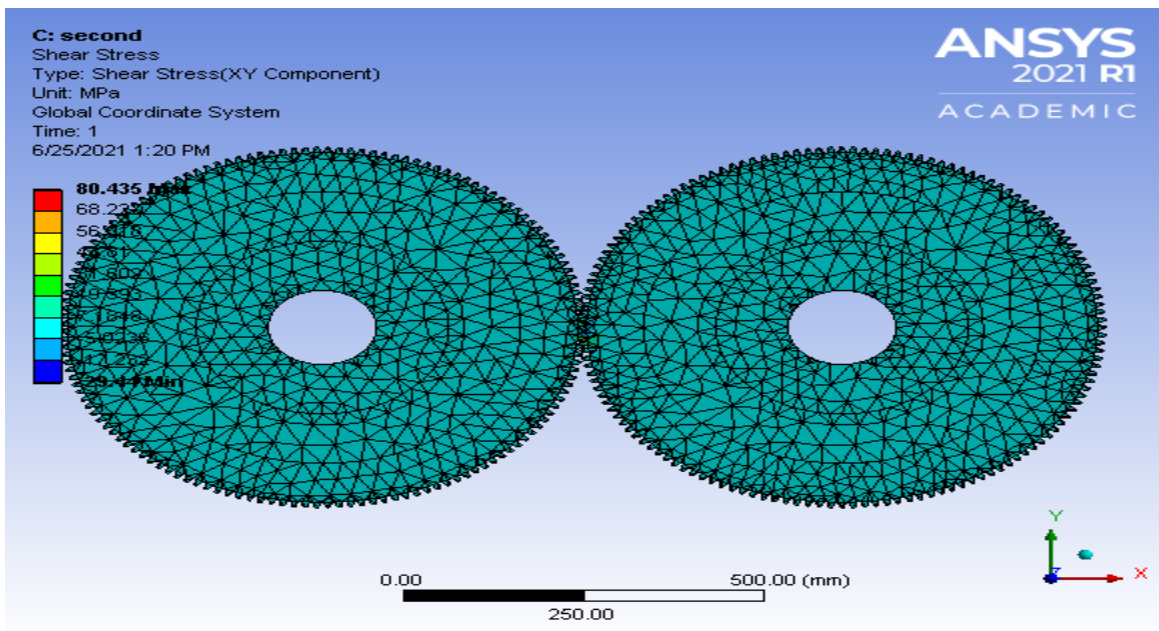


Fig 10.16 shear stress of bronze model 1

If bronze used as gear manufacturung material it can be used upto initial model only. It is failed in further models.

Bronze   analysis

| NAME | MAX STRESS (Mpa) | SHEAR STRESS(Mpa) | OBTAINED STRESS(Mpa) | OBTAINED SHEAR STRESS(Mpa) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 179.8 | 54.1 | 155 | 53 | 86.12 | 0 |
| MODEL 1 | 179.8 | 54.1 | 233 | 80 | 67.286 | 21.8 |

TABLE 10.3 ANALYTICAL DATA PF GEARS MADE OF COPPER
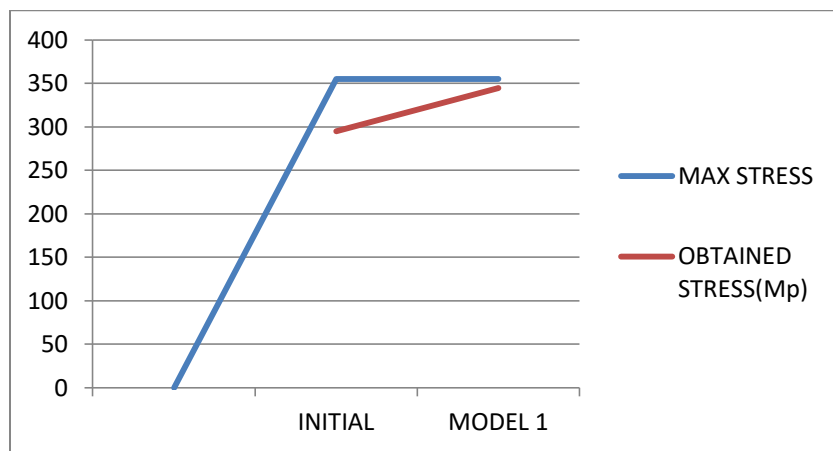


GRAPH 10.5 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF COPPER



GRAPH 10.6 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF COPPER

## 10.4 Aluminum

### 10.4.1 Initial model
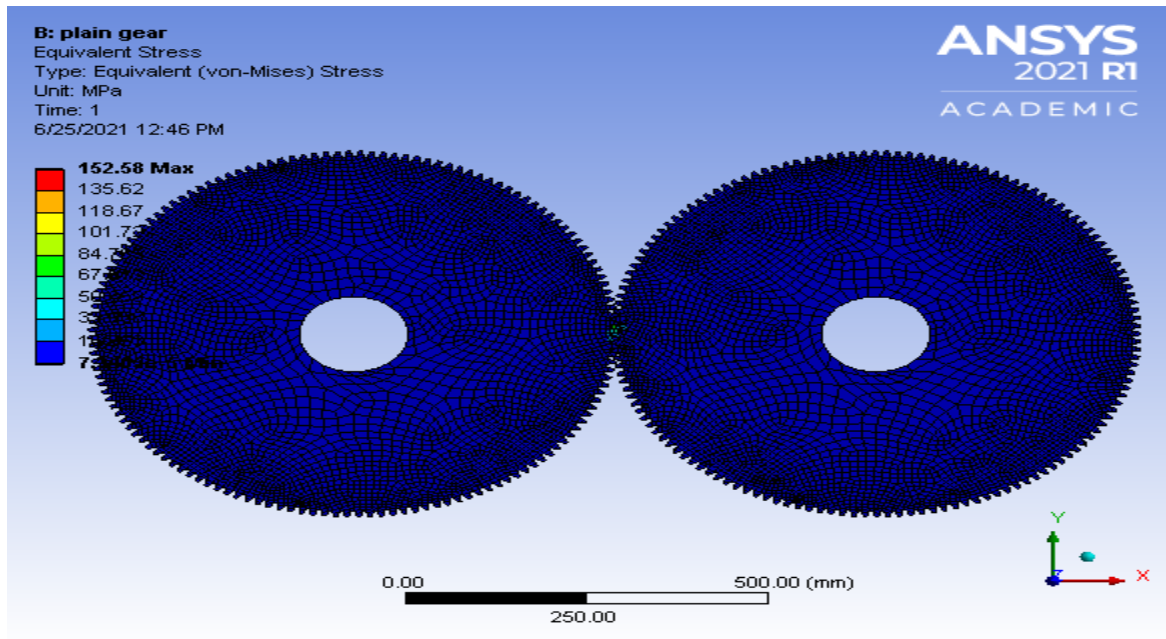


Fig 10.17 eq stress of aluminum initial model
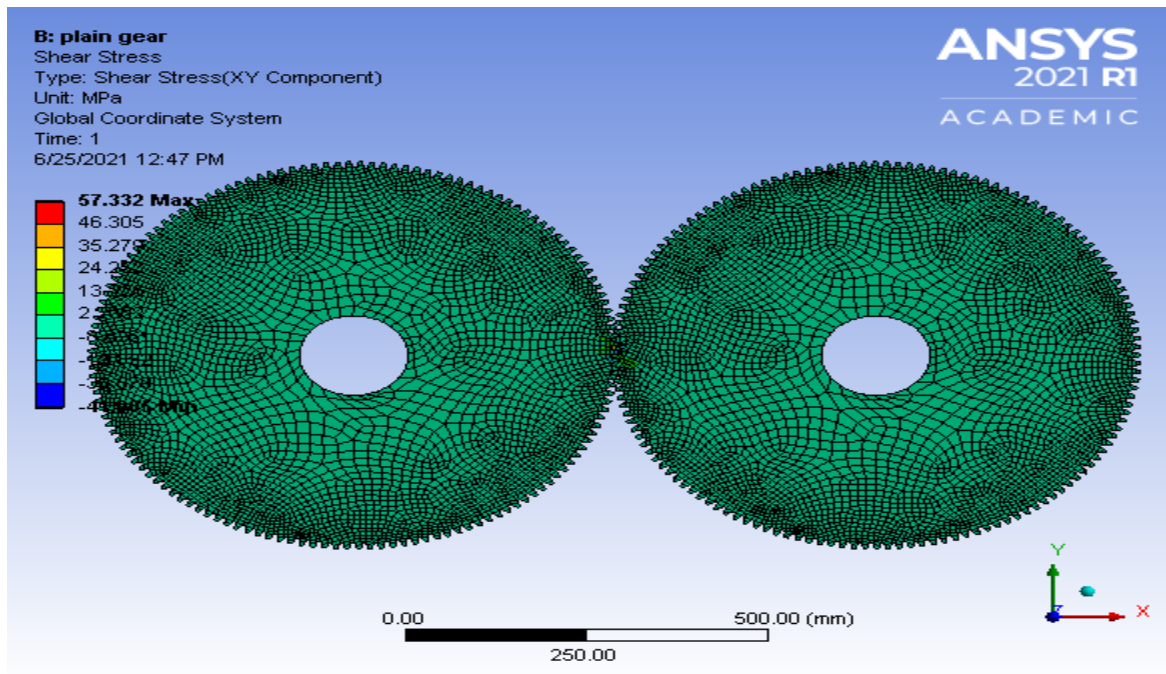


Fig 10.18 shear stress of aluminum initial model

10.4.2 model 1
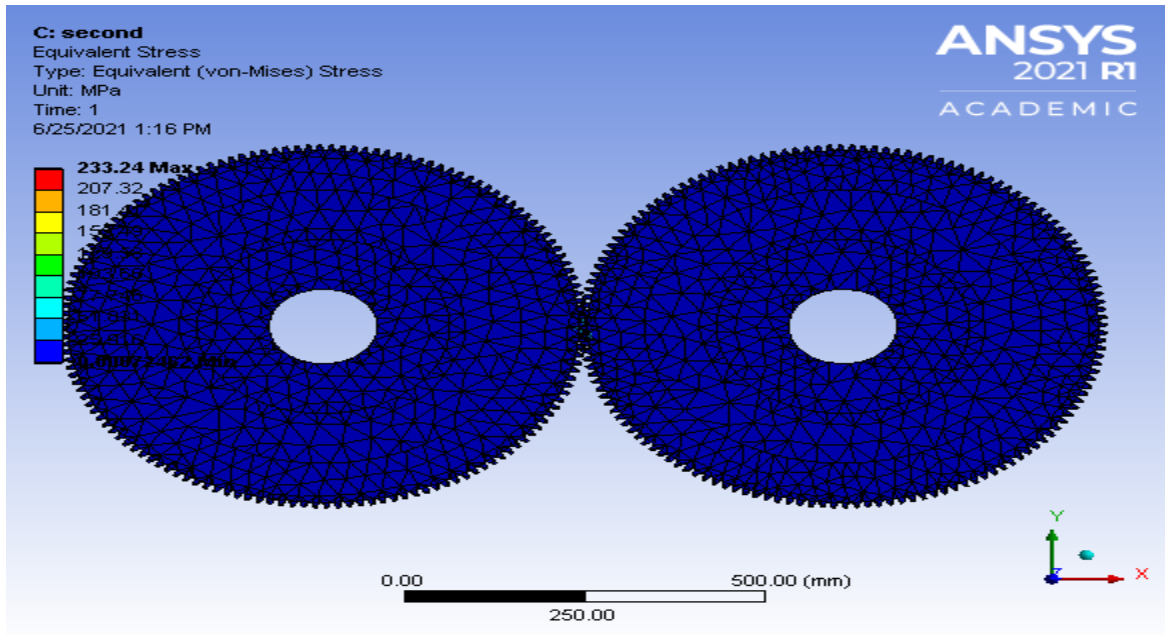


Fig 10.19 eq stress of aluminum model 1
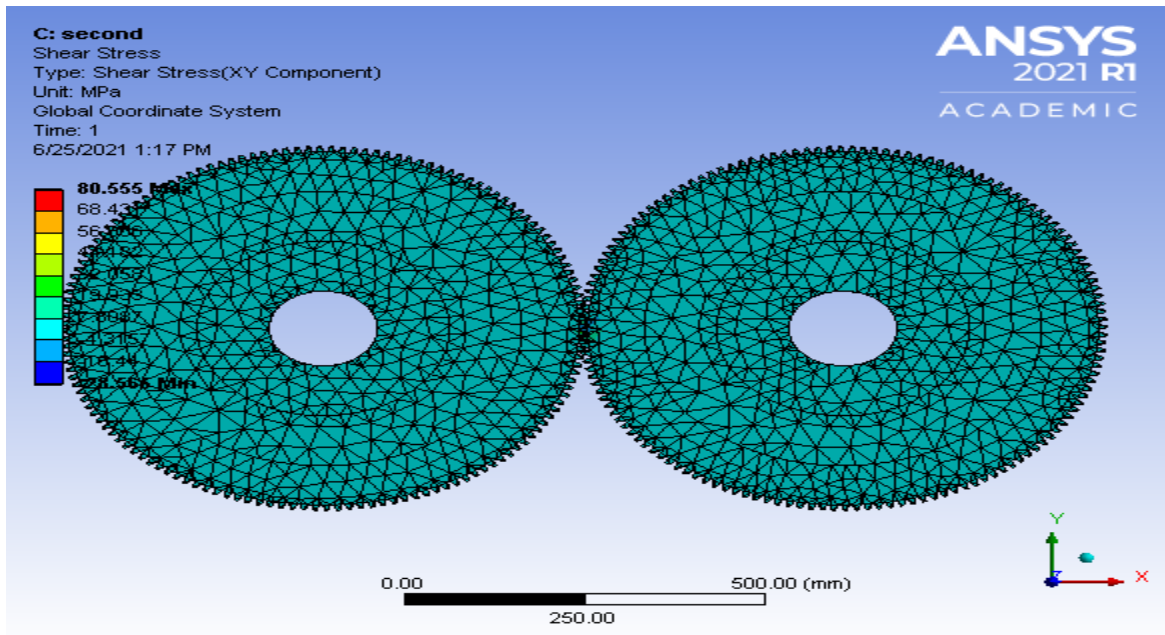


Fig 10.20 shear stress of aluminum model 2

If aluminum used as gear manufacturing material it can be used up to initial model only. It is failed in further models

Aluminum analysis

| NAME | MAX STRESS (Mpa) | SHEAR STRESS(Mpa) | OBTAINED STRESS(Mp) | OBTAINED SHEAR STRESS(Mp) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 174.7 | 53.4 | 152 | 53 | 86.12 | 0 |
| MODEL 1 | 174.7 | 53.4 | 233 | 80 | 67.286 | 21.8 |

TABLE 10.4 ANALYTICAL DATA PF GEARS MADE OF COPPER
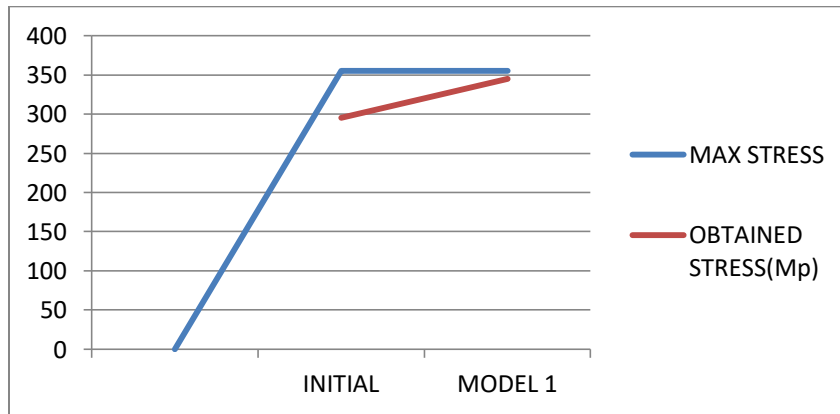


GRAPH 10.7 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF ALUMINIUM
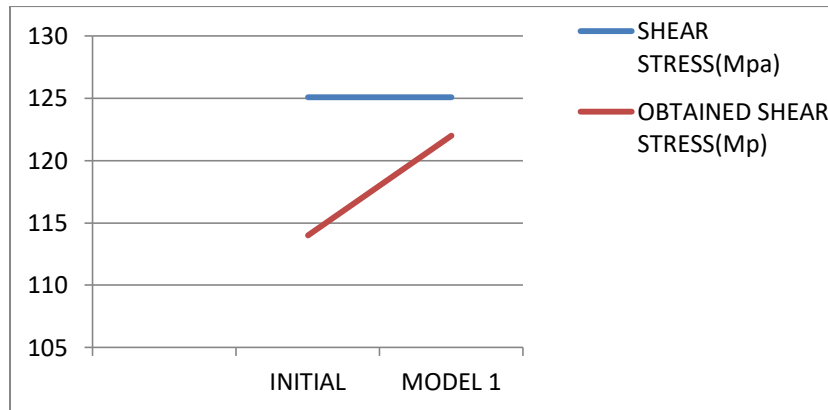


GRAPH 10.8 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF ALUMINIUM

## 10.5 STAINLESS STEEL

### 10.5.1 Initial model
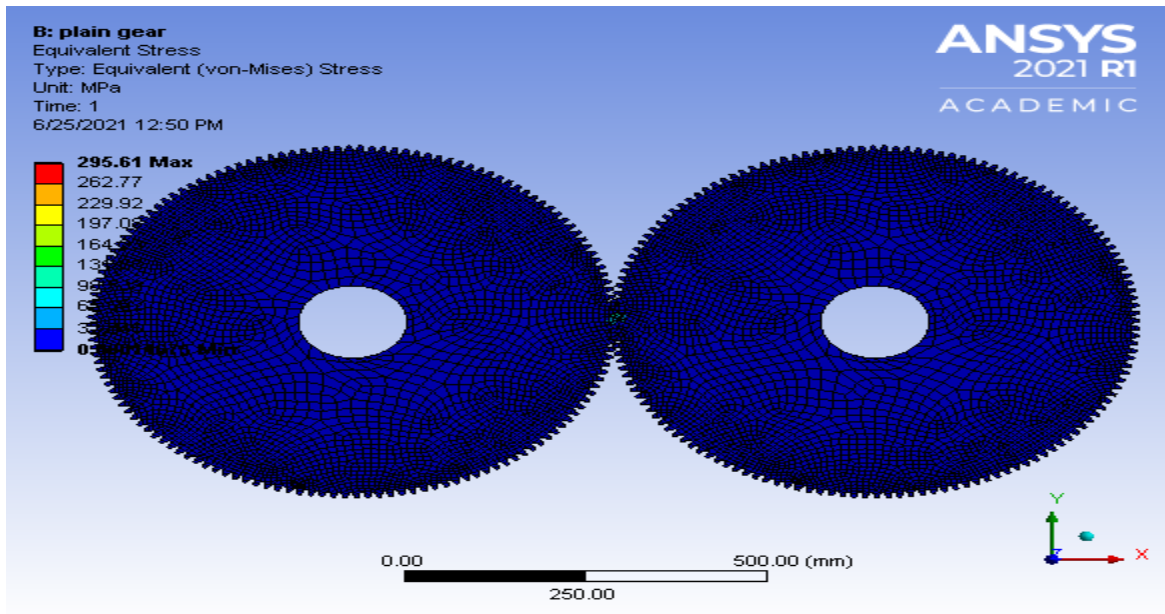


Fig 10.21 eq stress stainless steel initial model
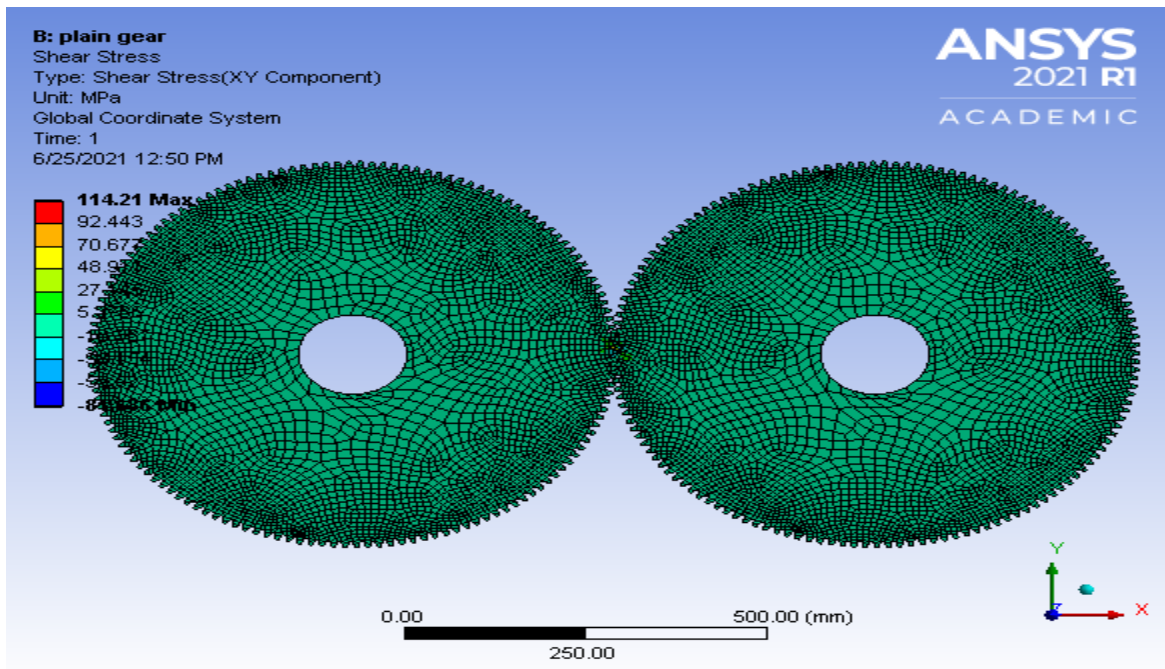


Fig 10.22 shear stress stainless steel initial model

## 10.5.2 Model 1
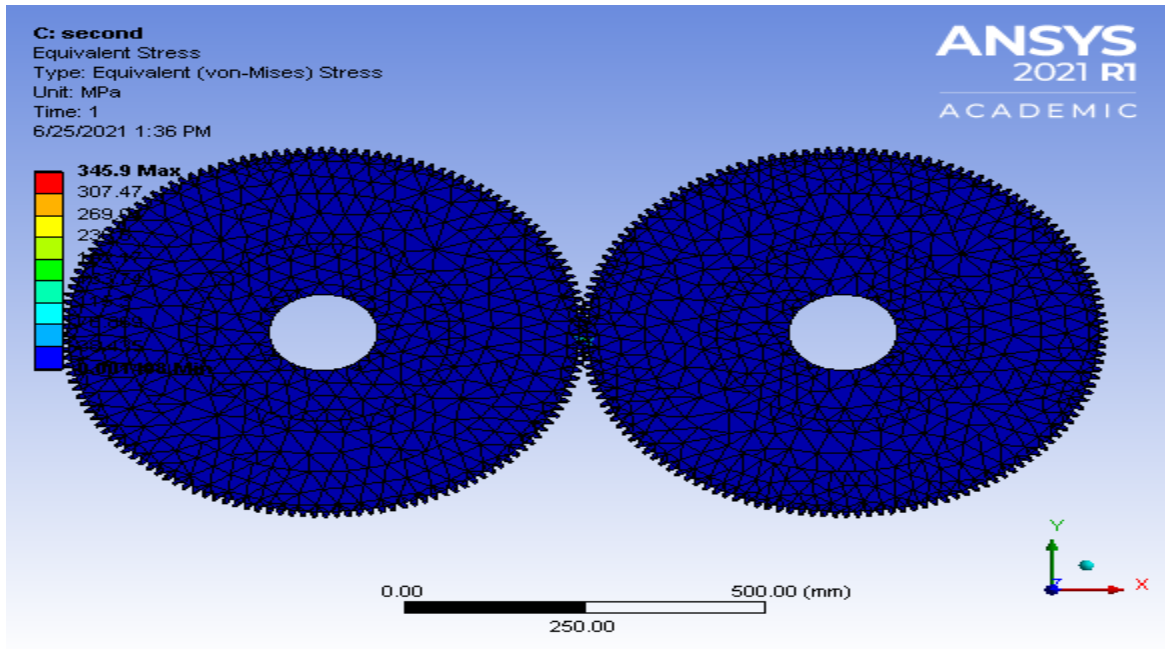


Fig 10.23 eq stress of stainless steel model 1
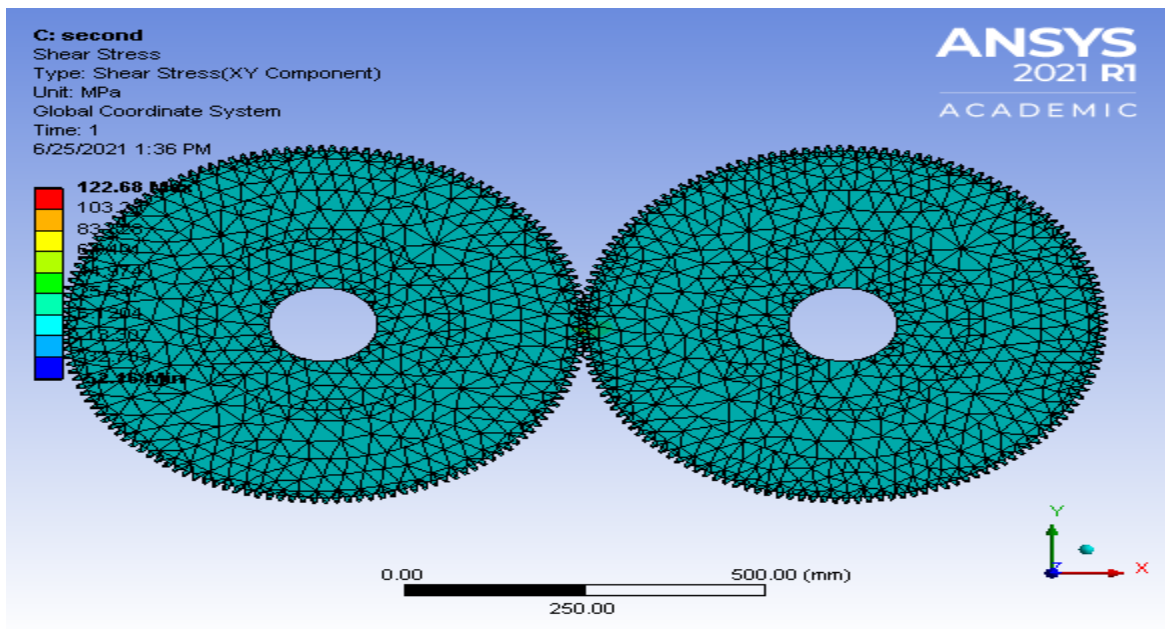


Fig 10.24 shear stress of stainless steel model 1

10.5.3 Model 2
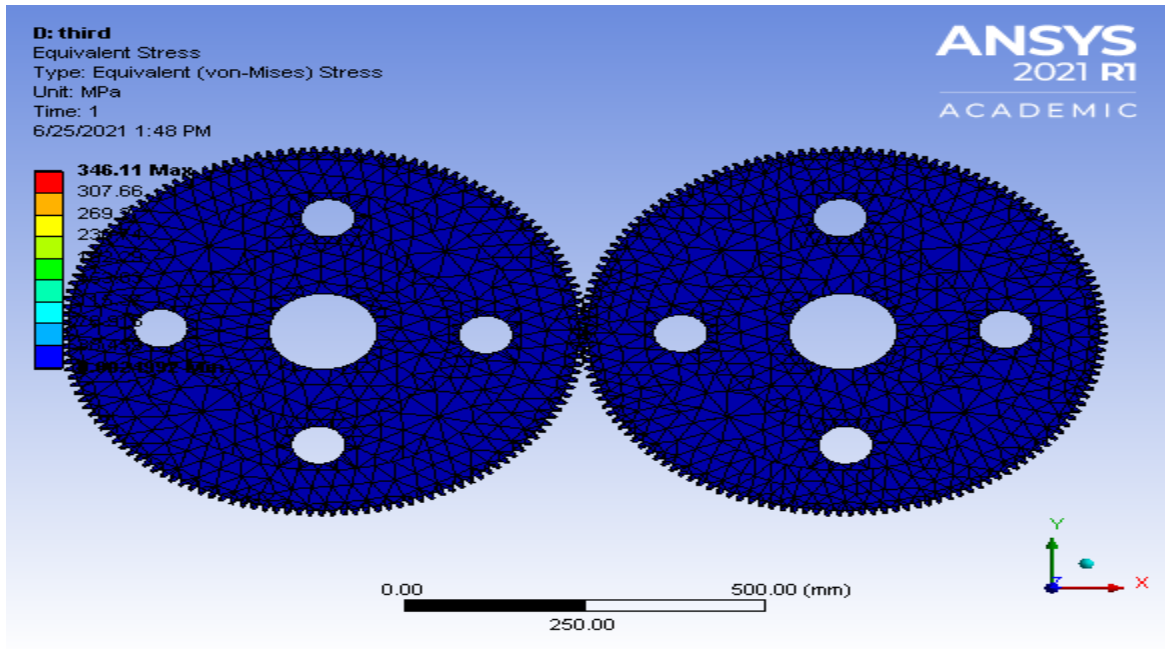


Fig 10.25 eq stress of stainless steel model 2
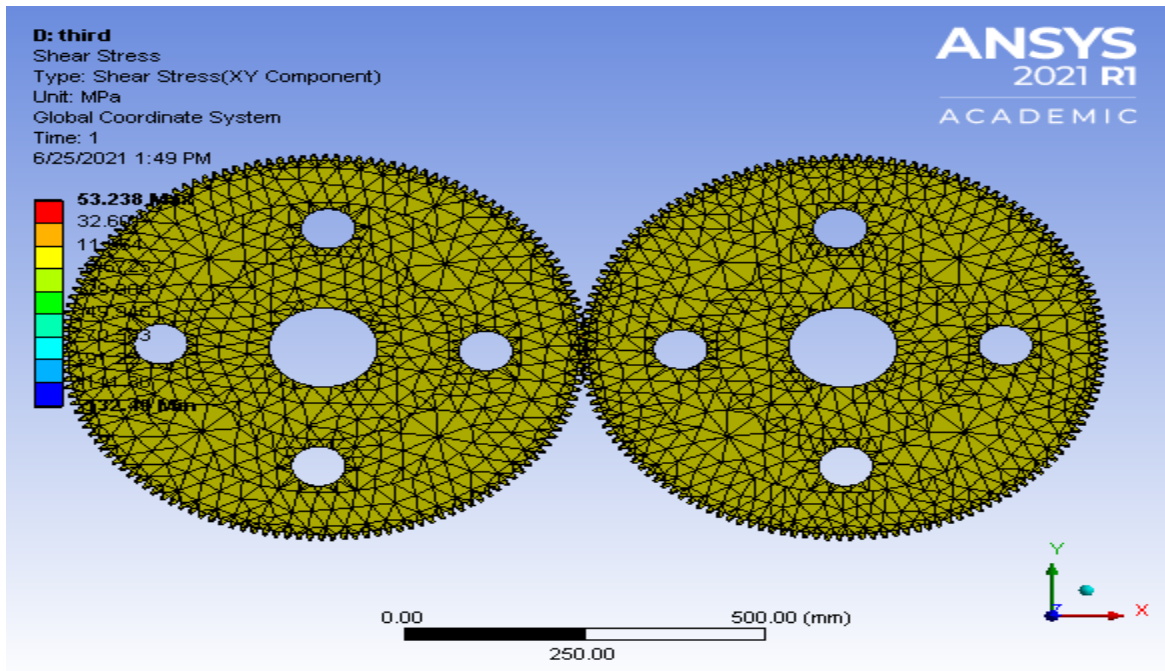


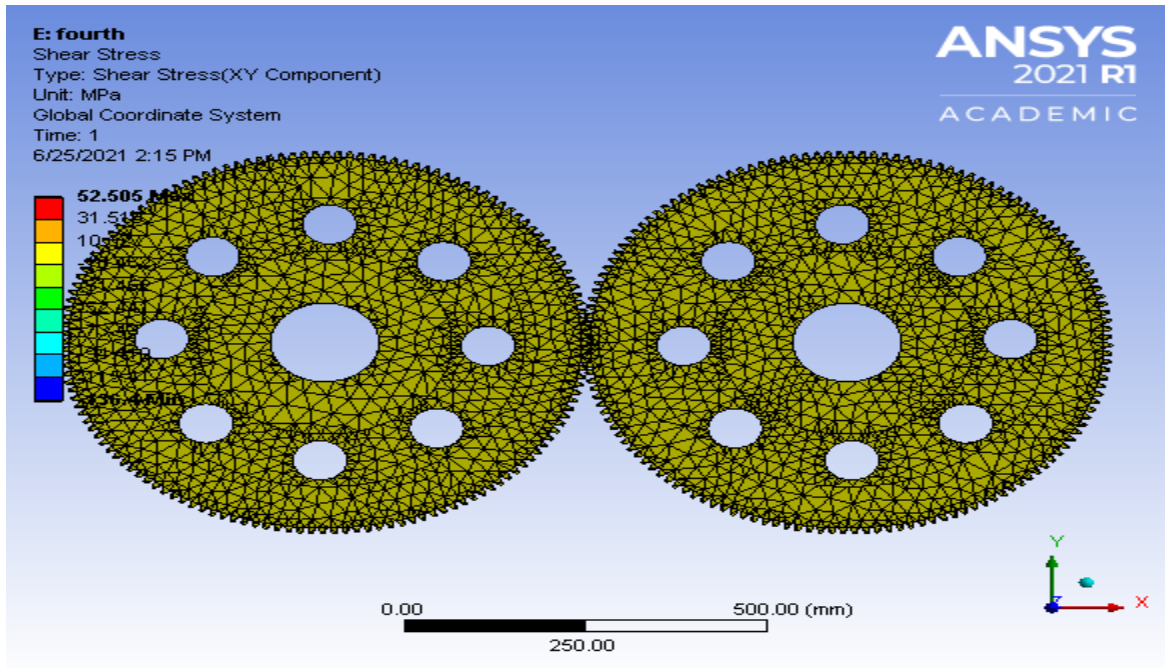Fig 10.26 shear stress of stainless steel model 2

10.5.4 Model 3
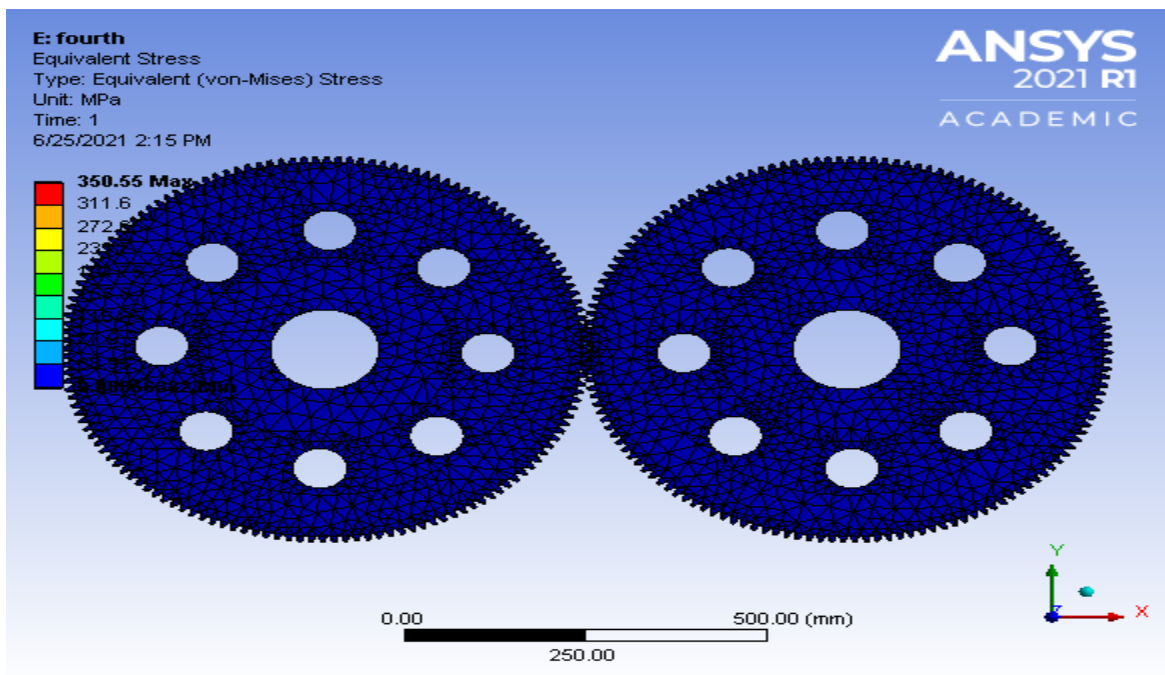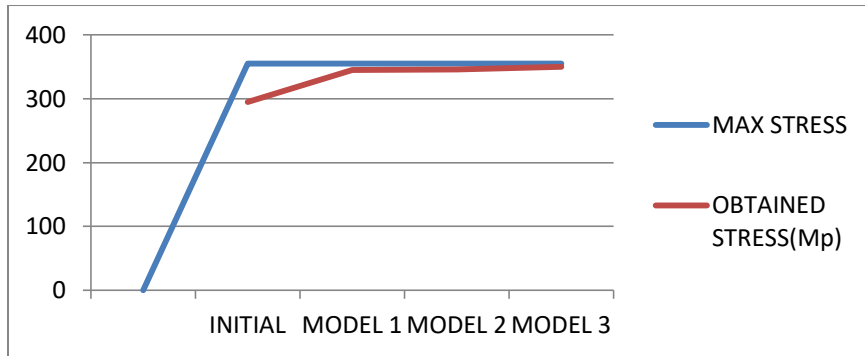


Fig 10.27 shear stress of stainless steel model 3



Fig 10.28 eq stress of stainless steel model 3

If stainless steel is used as a gear material it can withstand all the models without failure.

Stainless steel analysis

| NAME | MAX STRESS (Mpa) | SHEAR STRESS(Mpa) | OBTAINED STRESS( Mp) | OBTAINED SHEAR STRESS( Mp) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 355.3 | 125.1 | 295 | 114 | 78.035 | 0 |
| MODEL 1 | 355.3 | 125.1 | 345 | 122 | 60.966 | 21.8 |
| MODEL 2 | 355.3 | 125.1 | 346 | 115 | 59.552 | 23.72 |
| MODEL 3 | 355.3 | 125.1 | 350 | 112 | 58.138 | 25.64 |

TABLE 10.5 ANALYTICAL DATA PF GEARS MADE OF STAINLESS STEEL



GRAPH 10.9 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF STAINLESS STEEL
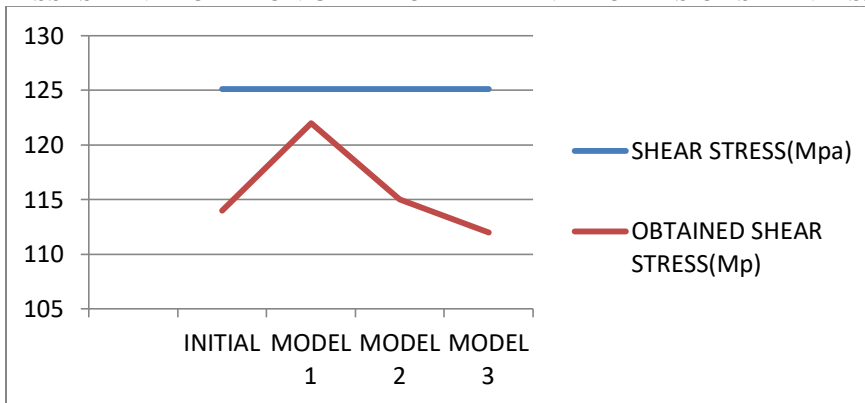


GRAPH 10.10 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF STAINLESS STEEL

## 10.6 STRUCTURAL STEEL

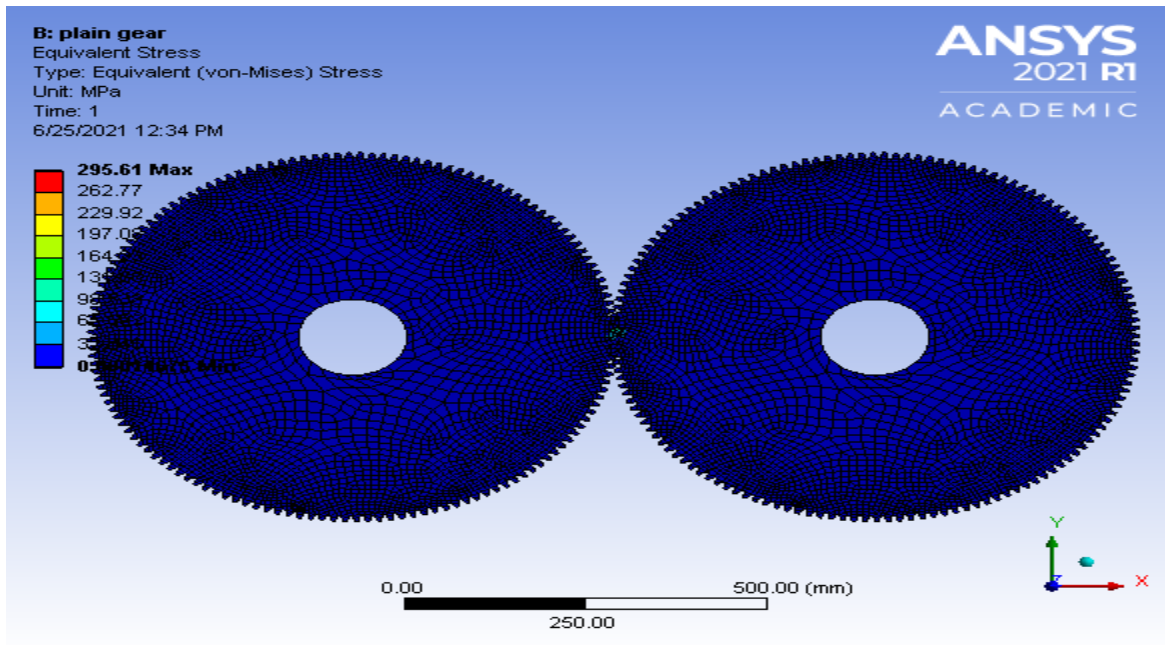### 10.6.1 Initial model



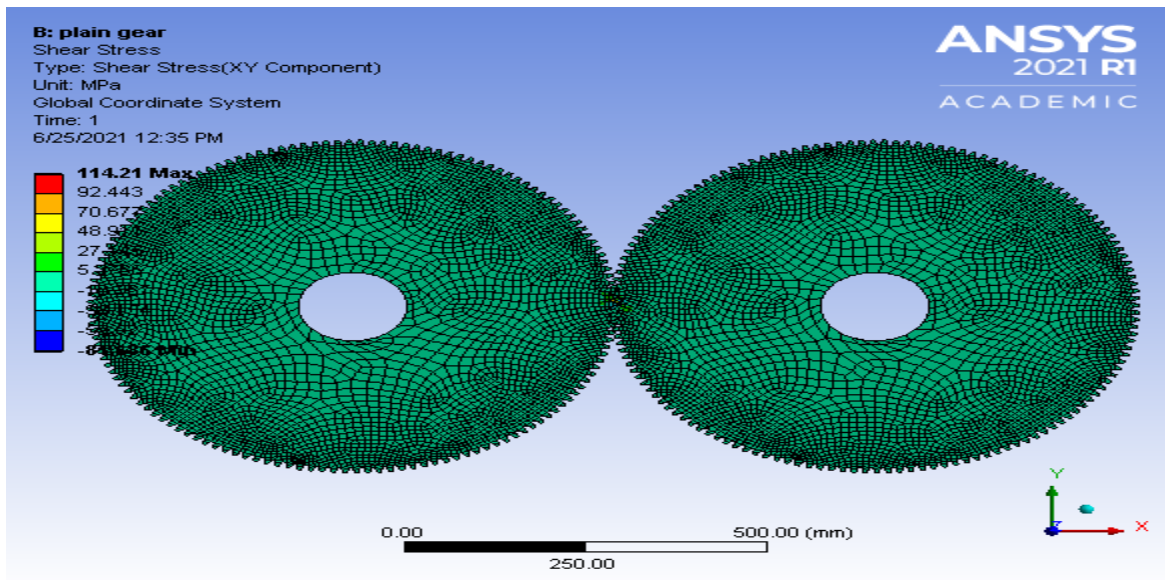Fig 10.29 eq stress of structural steel initial gear



Fig 10.30 shear stress of structural steel initial gear
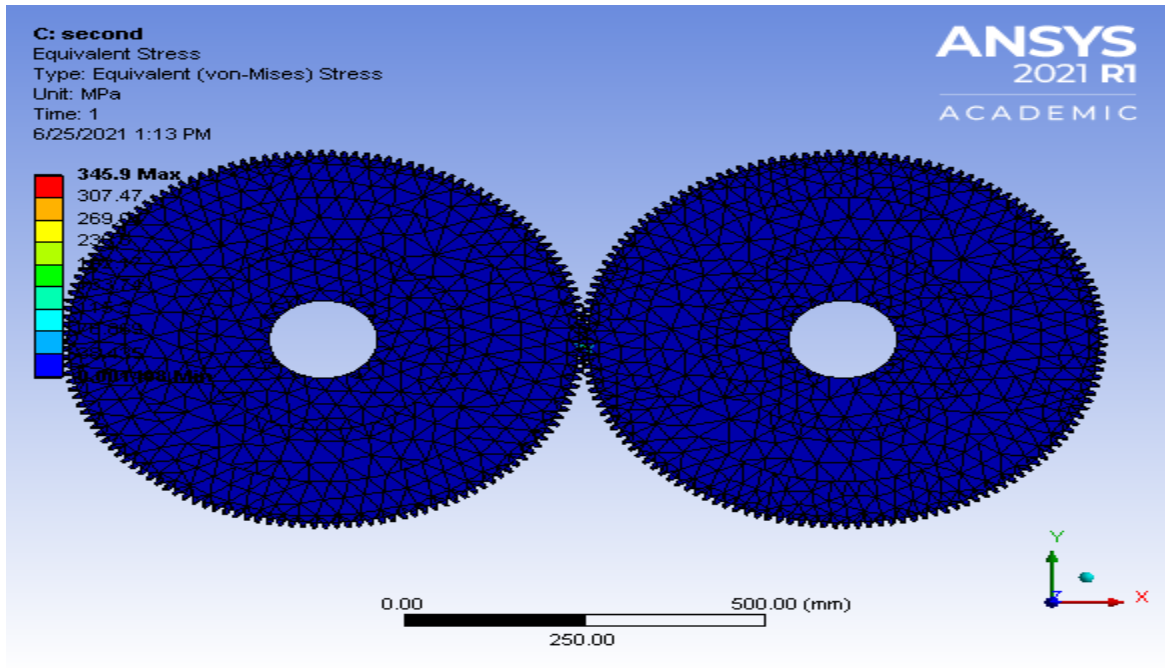
10.6.2 Model 1



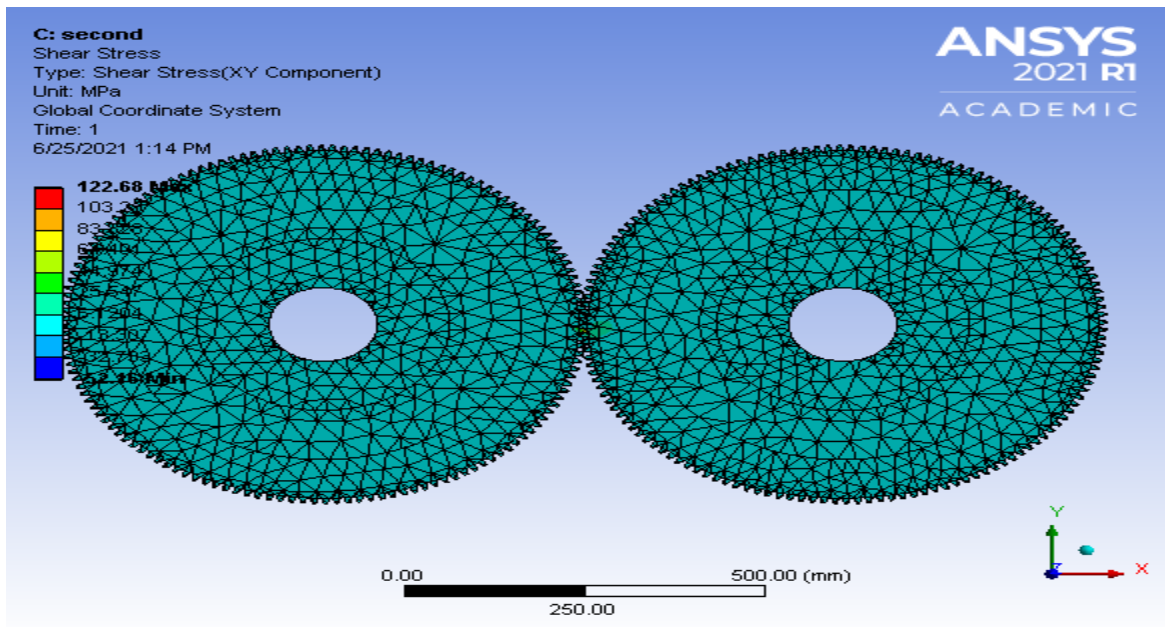Fig 10.31 eq stress of structural steel model 1



Fig 10.32 shear stress of structural steel model 1
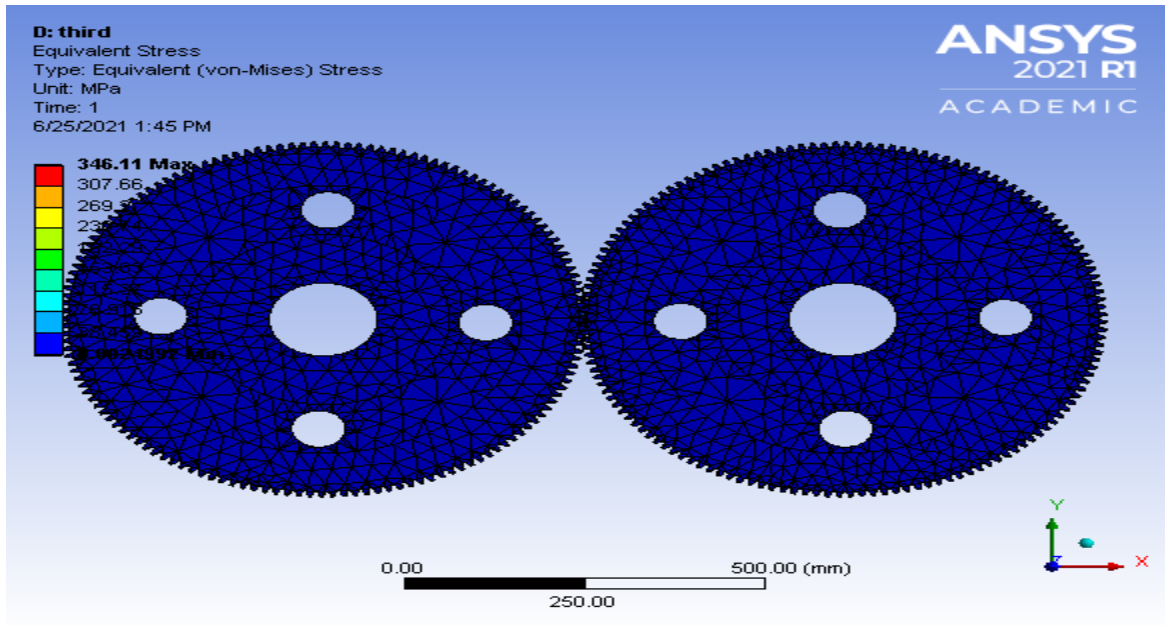
## 10.6.3 Model 2



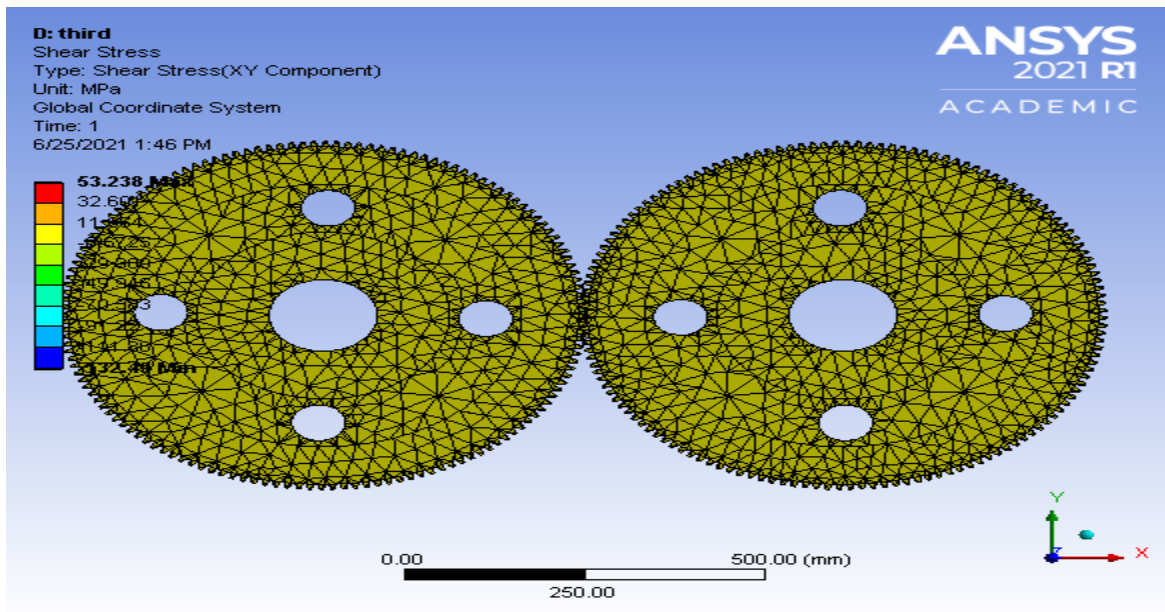Fig 10.33 eq stress of structural steel model 2



Fig 10.34 shear stress of structural steel model 2
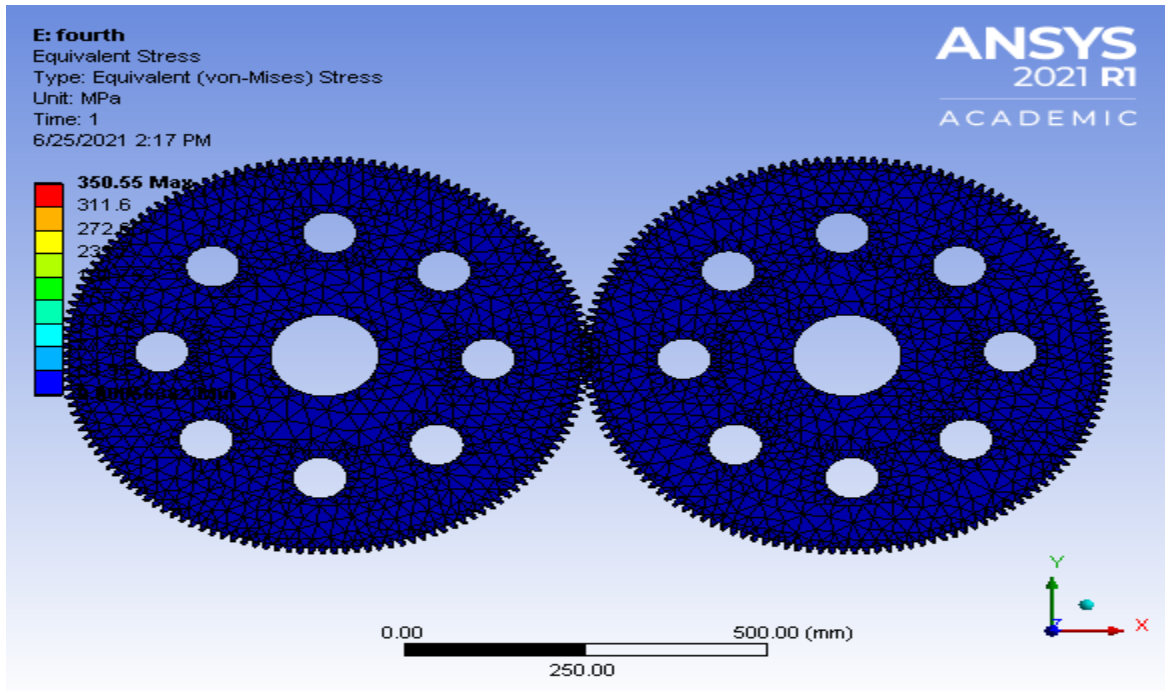
## 10.6.4 Model 3



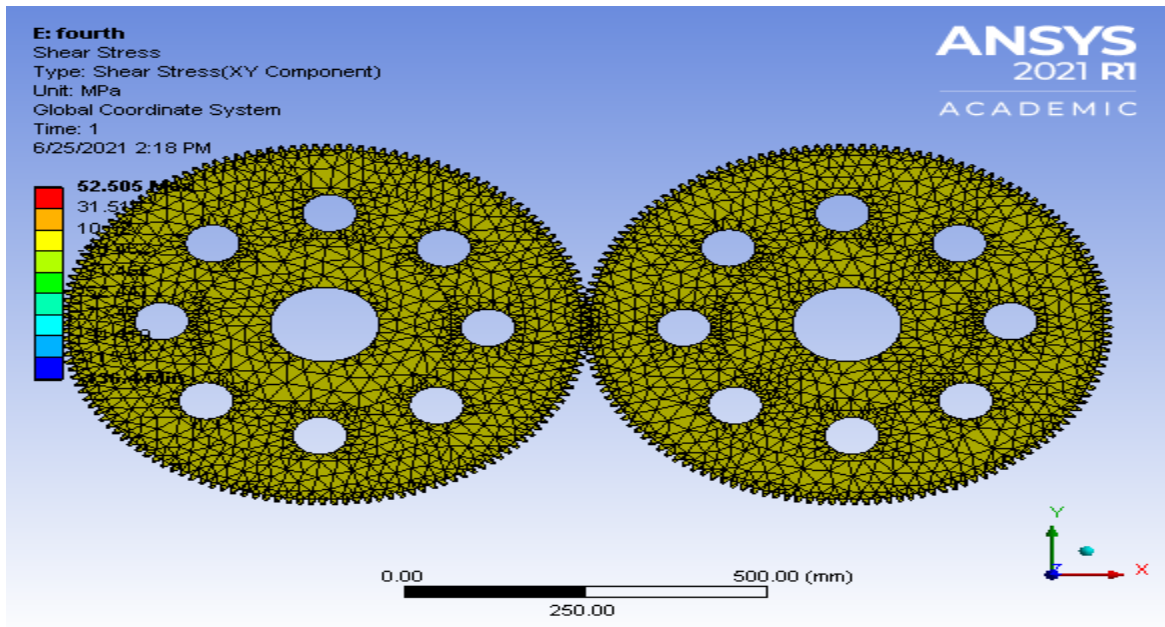Fig 10.35 eq stress of structural steel model 3



Fig 10.36 shear stress of structural steel model 3

If stainless steel is used as a gear material it can withstand all the models without failure.

Structural steel analysis

| NAME | MAX STRESS (Mpa) | SHEAR STRESS(Mpa) | OBTAINED STRESS(Mp) | OBTAINED SHEAR STRESS(Mp) | WEIGHT OF GEAR | % OF WEIGHT REDUCED |
|---|---|---|---|---|---|---|
| INITIAL | 355.3 | 125.1 | 295 | 114 | 78.035 | 0 |
| MODEL 1 | 355.3 | 125.1 | 345 | 122 | 60.966 | 21.8 |
| MODEL 2 | 355.3 | 125.1 | 346 | 115 | 59.552 | 23.72 |
| MODEL 3 | 355.3 | 125.1 | 350 | 112 | 58.138 | 25.64 |

TABLE 10.6 ANALYTICAL DATA PF GEARS MADE OF STAINLESS STEEL
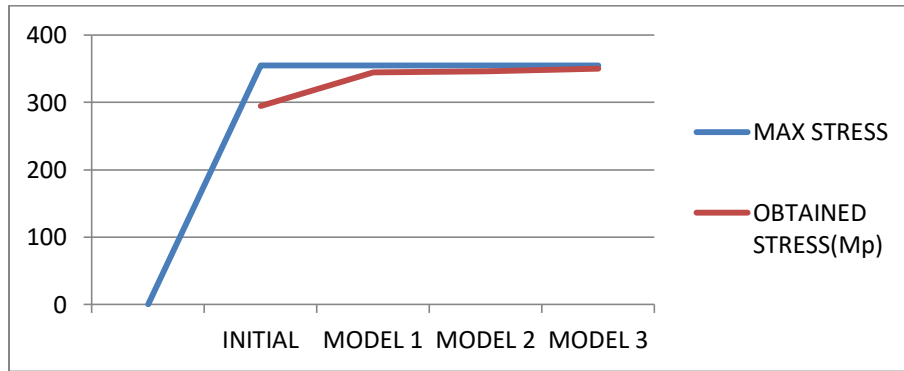


GRAPH 10.11 STRESSES DEVELOPED ON GEAR TO DIFFERENT MODELS OF STRUCTURAL STEEL
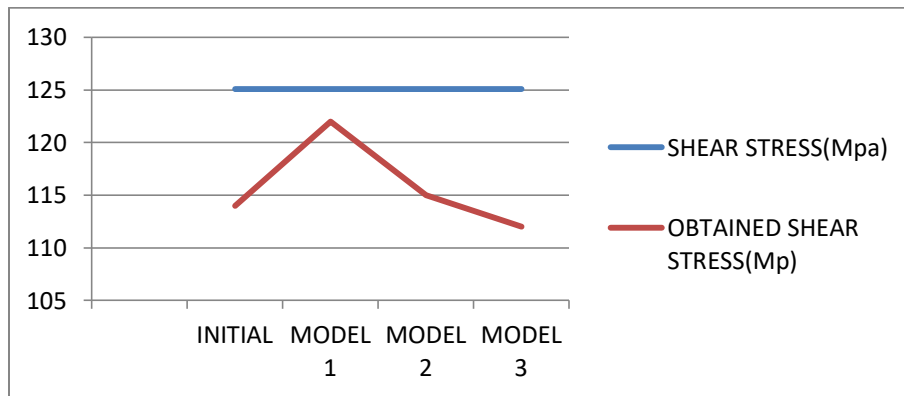


GRAPH 10.12 SHEAR STRESS DEVELOPED ON GEAR TO DIFFERENT MODELS OF STRUCTURAL STEEL

# Chapter-11

# CONCLUSION AND FUTURE SCOPE

Based on the study made on the different models of gears with different materials, the results obtained have been analyzed and summarized below.

The FE models of the gear pairs are compatible in evaluating the contact stresses and the results obtained are in good agreement with analytical problems.

1. It is obtained that aluminium and bronze are used only in initial model.
2. Cast iron and copper can be used effectively up to model 1 without failure.
3. Structural steel and stainless steel are effectively used for all the 3 models without failure.

But in place of cast iron initial gear model stainless and structural steel gears of model1,model 2,model 3 can be effectively used by reducing the weight and as well as increasing the strength.

FUTURE SCOPE:

Contact stress analysis can be performed on pair of mating gears by applying different materials of alloy materials changing for both pinion and gear. This study helps to decide which pair of spur gear gives us minimum contact stresses for respective values of frictional factor and face width.

Applying changes in frictional factor and face width for a given spur gear gives decreased values of contact stress in mating gears and decrease in weight of gears along with decrease in cost of the gear material.

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