Model Analysis of helical gear train using Ansys

Submitted in partial fulfilment of the requirements
Of the degree of

MASTER OF TECHNOLOGY
IN
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By

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CERTIFICATE

This is to certify that the Research work titled **Model Analysis of Helical Gear Train using Ansys** that is being submitted by **Anunay Kumar** in partial fulfilment of the requirements for the award of **Master of Technology** is a record of bonafide work done under my guidance. The contents of this research work, in full or in parts, 0 neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma.

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Approval Sheet

This dissertation report entitled **Model Analysis of Helical Gear Train using Ansys** by **Anunay Kumar** is approved for the degree of bachelor of technology in mechanical engineering.

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ABSTRACT

Helical gear is one of the parts a machine which undergoes mechanical operation with some loading condition acting upon it. Helical gear deals with high contact and friction which reduces the slippage compared to spur gears. The load may cause damage to the gears generally to the tooth surface and breakage of gear tooth and other damages to the gear that may include deterioration of plastic material and the rim or web breakages. When the gears are used in assemblies are named as gear train.

The leading factor of gear failures are the stress and surface strength of gear tooth. So, it has been interesting in the research area to minimize the stress acted on the gear and optimal design of gear. In this paper the design of gear train at specific parameter is done in Sodidworks and the aluminum alloy ally material is considered. The further analysis is done in Ansys 18.0 where some loading condition is applied for the analysis. Two types of analysis are done on the simulation which is vibration and stress analysis. It is 500 N-m of moment is applied at gear train and the stress in tooth and shafts are determined that whether the result analysis obtained is within the yield tensile limit of the used material.

Modal analysis is simulated on the two different types of combination of gear train. The two gear trains have been designed to analyse the gear trains in order to study the gear teeth bending stress and contact stress behaviour of the gear trains. Also, single and double teeth contact has been considered for the analysis. For this purpose the cylindrical boundary condition has been applied for the modal analysis and stress analysis. This methodology approached the noble behaviour for the evaluation of gear train design and gear stress study is much desired in the small scale industries. Further¸ the modelling of gear train assured us the actual motion behaviour of the gear and stress on the shaft and teeth. As, the gear stress analysis for transmission is very important which often requires for bending stress of teeth and contact stress.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Helical gear is one of the mechanical devices which have capability to produce change in torque, speed change and power source direction. The mechanical advantage can be obtained with the producing a change in torque through their gear ratio. The whole mechanism of the gear can be considered as simple machine and the meshing gear generally have equal shape of teeth. If the two or more meshing gear works together in the sequence is considered as gear train or transmission.

Helical gear is one of the important mechanical devices which are used for the power transmission purpose. It is one of the types of cylindrical gears having slanted tooth trace. Helical gears have larger contact ratio, excel in quietness, less vibration and capacity to transmit larger force. In general, a pair of helix gear have same helix angle but opposite in helix hand with one-another.

Figure 1. Helical gear

1.2 Formation of Helical gear

In general gear can be manufactured by using various methods like casting, forging, extrusion, powder metallurgy and blanking but there are some machining methods which are used in finishing the surface of the gear. In order to produce helical gears, it can be used as tilting of hobbing tools if the reference section of the gear is in the normal plane. In such situation spur gear hobbing tool and hobbing machine can be used for the production of helical gears. Due to the twisted teeth in helical gears which impact the disadvantage of difficult in the production.

With the reference section of the gear, helical gears can be categorized into two groups being in the rotating plane i.e. transverse module and normal plane i.e. normal module. The reference section of the helical gear is in rotating plane at some condition which might have same centre distance kind of spur gears; even they are in same module and equal number of teeth as a result of ease of swapping with spur gears. For such type of condition there is the requirement of special hobbing tools and grinding stones which lead to higher production cost. In contrast, let the reference section of the gear in the normal plane, then the spur gear hobbing tools and grinding tools can be used. It can't have match longer match with the centre distance of helical gears if the same module and equal number of teeth of the spur gear. One more thing is that it happen difficulties in swapping. Furthermore, it is not necessary that centre distance happen in integers only.

1.3 Gear Train

Gear train is formed when the two or more meshing gear comes together in sequence. The teeth of the gear are designed in such a manner that it can easily roll over on each other when the pitch of the circle compatible with engaged gears, when the pitch of the engaged gears roll over on each other there must be no slipping and provide a smooth transmission from one gear to next gear rotation. Helical gear is often used as power transmitting gear which is helpful in carrying higher load due to its low dynamic load but also it minimize the noise and vibration in operation as compared to the spur gears. In helical gear, the tooth trace is usually diagonal in the line of contact. When the helical gear is meshed, due to the angle of the teeth on helical gears produce thrust load on the gear. To support the thrust bearing devices is used. There are different-different types of gear train which are used for the purposes such as planetary gear train widely used in

the transmission of helicopters, automobiles, wind turbine, aircraft engines and various other projects. Due to high efficiency, compactness, large transmission ratio and large power-to-weight ratio etc., these are the main advantage for transmission.

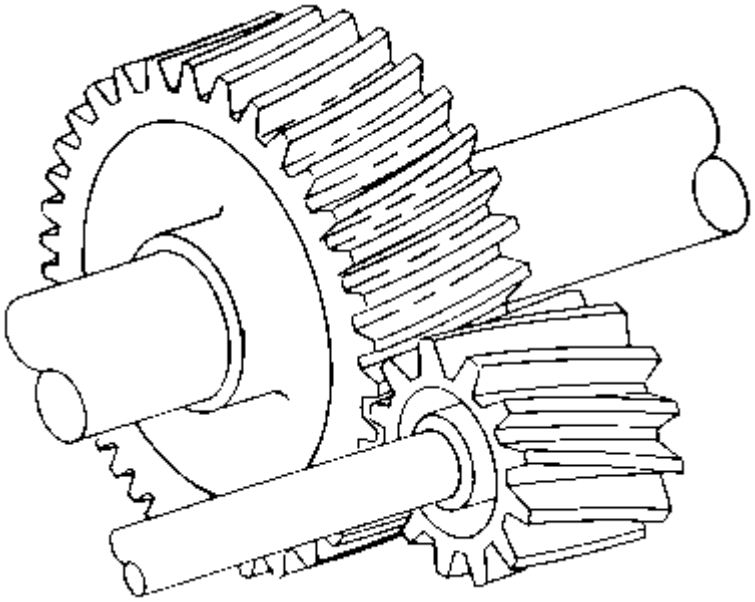

Figure 2. Gear train

1.4 Arrangement of helical gears with shaft

Helical gears are normally alike that of spur gears except the teeth alignment of the helical gear is cut with the angle to that of the axis of the shaft despite cutting the teeth alignment straight and parallel to that of the axis like the spur gear. There is no parallel inclination of line of contact in between two teeth but inclined at angle. Thus, confirming the gradual engagement of teeth from one end of teeth to the other end of helical gear differ with sudden arrangement in that of spur gear teeth arrangement. Due to the gradual teeth arrangement of helical gear, the operation takes place without much noise and works smoothly. The arrangement of meshing of two helical gears can take place in two different ways i.e. either the difference or the sum of helix angle with the orientation of the shaft. These arrangements are assigned as parallel or crossed with shaft oriented helical gears.

1. Arrangement of parallel shafts connecting helical gears

   As the parallel meshing of the helical runs more smoothly and without making much noise than spur gear if it is assured with the helix angle that is good enough to make continuous contact with the one tooth to the another teeth respectively. There

must have same pitch, helix angle and pressure angle of helical gears which is used to connect parallel shaft but ensure that they will be hand gears in opposite to one another. The opposite hand gears i.e. if one of the gear be left-hand gear other should be right- hand gear.

2. Arrangement of non-parallel shafts helical gears

   When the helical gears connect with non-parallel shaft is generally considered as spiral gars or crossed axis helical gears. In such case the shaft angle is 90 degree generally, required same hand gear and the sum of the helix angle will be equal to the shaft angle i.e. 90 degree. With line of contact of the gears there is a point of contact between the two gears. During the action, the point of contact gets change and the some considerable sliding between the teeth. The spiral gear has very low efficiency.

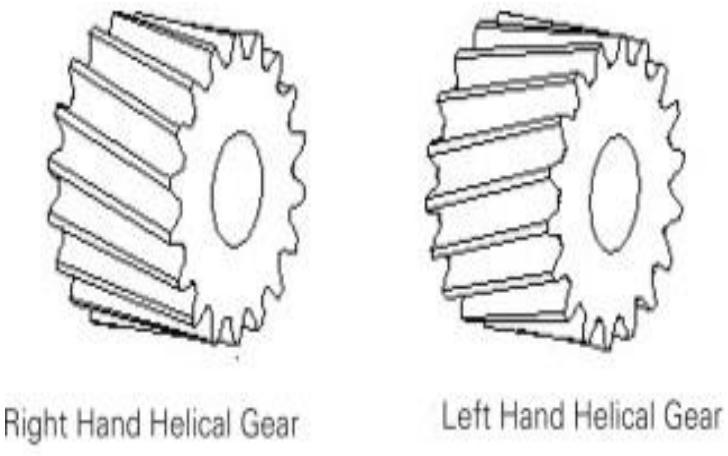

Figure 3. Right and left hand helical gear (https://www.sciencedirect.com/topics/engineering/helical-gears)

Common terms used in helical gears:

1. Outside Circle – The outside circle of the helical gear is defined as outer circle which bounded the teeth of gear and the distance between the outside two points of circle is known as the outside diameter.
2. Pitch circle – The pitch circle is defined as the imaginary circle to the point where the meshing of the teeth of the gear takes place.
3. Pitch diameter - Pitch diameter is known as the diameter of the pitch circle.

4. Helix angle – The helix angle of helical gear is defined as the between the axis of a helical gear and the tangent line to teeth of the gear. The angle of the helical gear lies in between 0° and 90.

1.5 Material selection

There are three main basic things for selection of material used for the manufacturing i.e. durability, strength and cost of manufacturing. More importantly the mechanical properties and the characteristics of the gear materials have the properties like high tensile strength, elongation properties, drawability, hardness HB, and high heat treatment applicability. The commonly used for helical gears are

- Stainless steel
- Steel
- Cast iron
- Brass
- Aluminum alloy

Gears are the mostly used for the transmission commonly in all modern devices. There are different purposes of gears and mostly the aluminum alloy manufactured gear is used for weight reduction. Hence, such kind of weight reduction in gear is highly applicable in aerospace and marine applications and effectively applicable where the weight reduction is requirement in the devices.

The material used for the gear manufacturing should have the following characteristics underlined as

- Material should have high tensile strength and resist failure against static load; so that under some loading conditions the material resist the failure
- Should have high endurance strength against dynamic load; when the impact of load on the shaft under dynamic load it must have capability of high endurance.
- Coefficient of friction should be low; cause less wear and tear in gear if the coefficient of friction is low.
- Good manufacturability; during machining must be applied to get the accurate dimensions, shape and surface finish.

1.6 Engineering aspects

When two or more gear comes in contact after meshing stress are evolved and it is important to determine by using some experiment evolution, software or other means. There would be non-conjugate action due to the variation in the gear profile, tooth alignment and circular pitch. (Conjugate action means for constant speed input would be constant output speed). Manufacturing variations will produce undetectable dynamic loads at low speed but at higher speed exhibit more loads. Secondly, the teeth are basically cantilevered beams so that under some high loading conditions may be deflection in the teeth of the gear. Due to the deflection it may affects the proper meshing conditions and lead to add some additional dynamic load.

The meshing of the gear for the genuine teeth load comprise two types of component i.e. static component which is corresponding to the transmitted power (It is closely equal to the total load when it rotates at low speed) and other dynamic component where the dynamic action provides dynamical increment fluctuations. It has been studied earliest with investigations that dynamic increment included by the dynamic factor result in penalty on the gears for load carrying capacity at the time when the speed is increased.

Although in the model the flexibility of gear teeth due to time variation or constant mesh stiffness has been investigated and according some group of studies implies that the flexibility of gear teeth neglected, later with the rigid gear modifications a torsional model gear system with the help of torsionally flexible shafts attached with rigid gears. In some studies there is the only requirement to find of system natural frequencies and mode shapes, only free vibration is analysed.

1.7 Motivation

Helical gear is often utilized as force transmitting gear which is useful in conveying higher load because of its low power powerful burden yet additionally it limit the clamour and vibration in activity when contrasted with the spike gears. In helical gear, the tooth follow is normally slanting in the line of contact. At the point when helical gear apparatus is fit, because of the edge of the teeth on helical gear produce push load on the gear. To help the push bearing gadgets is utilized. There are distinctive various sorts of gear train which are utilized for the reasons, for vehicles, wind turbine, airplane motors and different purposes. Because of high proficiency smallness,

enormous transmission proportion and huge capacity to-weight proportion and so forth, these are the fundamental preferred position for transmission.

Chapter 2: Literature review

2.1 Reviews

a) Herscovici Saul et.al made the application for the gear which may work accurately for the gear designing, he provided important formula for design and compatible stress level so that the some geometry of the gear can be designed for the calculations such as gear tooth geometry, bending stress and surface compressive stress over which application the gear operate accurately. According to this it will give the concise ideas to the manufacturer that which type of material should be used sot that tolerate the stress due to load as well the heat treatment, more importantly they will have the complete information about the gear like pressure angle, gear width, number of teeth, diameter of the pitch. He also introduced that Euler was the first to distinguish that the involute shape of the gear keeps providing constant angular velocity. It was not that century only that was the beginning of teeth such involute profile but widely used and now high or low angular velocity used for heavy or light load transfer.[1]

b) P. Templin examined that automotive powertrain is one of the indispensable parts for the transmission of load in the vehicle and according to the requirement dynamic are modeled as per the requirement. For the powertrain model two inertia can be identified; one for the engine and the transmission and other for the represent the vehicle mass and wheel. Simply, the powertrain is vital for the load transmission in the engine that we use for the purpose. The powertrain can be arranged with the help of meshing of gears for the transmission of loads.[2]

c) Kang MR & Ericson TM investigated that gearing is one of the important components which commonly used in automotive, aerospace and gas turbine applications. There are different types of application of gears in the particular area as double helical gear is widely used in aeroengines and rotorcrafts enabling heavy duty working for the requirement that work under high and high speed having unique characteristics like less noise, smooth power transmission and high contact ratio. The double helical gear has the capacity to reduce the rigorous application for bearing that can provide accommodations the axial thrust forces, theoretically. In practice, due to the meshing the axial vibration can’t be neglected which is related to the dynamic analysis under

high speed and loading conditions depends mainly on two parameters. One of them is geometric error while manufacturing, when the gears are manufactured should be the desired tooth accuracy, accurate dimensions and the proper surface finish. The other parameter is with the operation so that at high speed and load may cause the higher the stress and sometimes may convert into breakage situations.[3-4]

d) T. Burns and E. Schafer stated portal axle is normally fitted in between the wheel and the axle shaft which is designed for the off-road vehicles for driving. Hence, the modelling and simulation is one of the important techniques to guess the actual behaviour of motion. The portal axle is gearbox unit which is compatible with at least two gears as input and output gear. The portal axle is normally mounted in 4-wheelers vehicles which effectively help to move in off-road driving conditions, assuring great ground clearance which stops further damages to the underneath components of the vehicles. The portal axle is situated in between wheel and axle shaft just above the ground which is higher than that of simple arrangement of axle. Due to the arrangement of portal gives a great ground clearance of the off-road driving vehicles. This is very helpful in order to predict the actual behaviour and motion with the help of model and simulation.[5]

e) A. Beriloz and P. Tropette examined when the designing for the portal gear is implemented then the gear train contemplation is determined as critical for the dynamic response. The modelling of the portable for dynamic response is set up of periodic or quasi-periodic occurrence for the noise analysis and vibrational analysis for the structure of axle. The modal analysis of the portable axle may represent the resonance due to the dynamic behaviour. The dynamic behaviour may be unpleasant in noise analysis and vibration analysis due to the higher speed and load applied on the axle and at the lower speed and low impact of load may not affect the arrangement.[6]

f) Sinsica inspected after using the finite natural frequencies or resonance frequencies for the double stage helical gear reduction which has been calculated with the help of the FEM modeling and simulation on the eight different gear trains. Then, first eight frequencies is calculated and later compared with impact of operating frequencies at the portal axle. Each gear train represents the combination of the different-different

gears of portal axle which is compared to calculate the relations in between the idle gear train and its natural frequencies. The modal analysis commonly for the gear trains is analyzed under condition of free stress and pre-stessed.[7]

g) J. Lu, F.L.Litvin and J.S.Chen procured that in the transmission application the analysis of the gear as per the requirement to obtained the gear teeth bending stress and contact stress for the analysis. FEM play one of the important roles to determine the stress and strain produced in the complicated structure's design structure even for gear stress analysis. The load share in between the neighbouring teeth is analysed with the position error which is triggered by the mismatch alignment and the elastic deformation of teeth.[8]

h) K.ramberger performed understanding the load and stress distribution when there is interaction of gear with each other will help us to predict the bending fatigue life of the gear. He implemented some of the numerical studies over the bending fatigue life for the thin-rim spur gear of truck gearboxes. The meshing behaviour of the design for transmission should be understand carefully so as to accomplish with high positioning and high precision of the arrangement of the gears. Now, the most popular and effective for the rotation of a system with various gear is in current days rather than the use of conventional belt and chain drives which probably have low speed and low back-lash. The requirement of demand right now is large carrying loads with the use of gear and long fatigue life. It's been interesting for the gear design with the advancement of gear transmission utilities.[9]

i) J. Kramberger M. Sraml, S.Mohammade Nabi and V.Simon all represented that in modelling and simulation FEM has been considered as common practice to determine the stress analysis in gear when subjected to static and dynamic loads. The shortcoming technique of mechanical segments is a material trademark and depends on cyclic malleability, close by misshapening, partition development, advancement of little scope and enormous scope parts and their spread, etc. Devices bomb by contact exhaustion frustration (pitting) as by curving fatigue disillusionment (tooth breakage). Bowing exhaustion is of an unfathomable criticalness in building employments of riggings, where unequivocal variable weights appear. These operational weights realize nerves, which can be comparable to or lower than the

yield stress of a device material. In any case, bowing shortcoming can be normally isolated into two essential stages: (I) commencement of micro cracks and (ii) causing of parts. The component strategy (FEM) is especially appropriate to contemplate tooth deflections, contact stresses and tooth worries in gears. A large portion of the examination by FEM has been coordinated towards the spike and helical apparatuses, generally with two-dimensional geometry. On account of the trouble of accurately recognizing the three-dimensional geometry, just a couple of specialists have researched hypoid and winding slope gears, particularly hypoid gears. For hypoid gears the first endeavour has been made by Wilcox, utilizing the flexibility grid in blend with the component strategy. Handschuh and Litvin built up a logical technique to understand the gear tooth surface arranges and give contribution to a three-dimensional geometric displaying program that empowers pressure examination in winding slope equips by FEM. Mechanical assembly drives transmit development and power by tooth work. Generally as involute profiles, gear tooth work is a complex method including, for instance multi-tooth responsibility, multi-point contact and fluctuating weight conditions. To achieve improved static and dynamic properties of mechanical assembly drives and overhauled load passing on limit and unfaltering quality, definite affirmation of the tooth load scattering, work solidness similarly as the distortion and stress of tooth face is a critical part in gear drive structure. Inferable from the collecting and get together mix-ups and adaptable turning of stacked mechanical assemblies, vibration and uproar are made particularly during the approach and opening of the tooth fitting. Payoff makes sporadic impact the cross segment gears. The work influence is moreover present when the contraption drive is under the conditions of the startling stacking and change of speed. Such work influence realized by the reverse discharge likewise, in light of the procedure and opening of tooth harmonizing has a horrible effect on special characteristics of a mechanical assembly system.[8-10]

j) Wei and Zu developed an analysis for the study of effect of bending stress and contact stress of the gear teeth using FEM for two and three dimensional. Under operation it is very important to understand the how the stress are distributed from one meshing gear to another. Nearby present quick amassing industry headway, gears are used by

and large in various applications going from vehicle transmission to robot and avionics engines. As such, the dynamic assessment is progressively increasing noteworthy in propelled collecting. Different sorts of metallic devices are by and by being created for various current purposes. Deng utilized tooth contract examination, stacked tooth contact investigation and limited component technique to dissect the lattice conduct, tooth surface agreement stress, greatest elastic bowing pressure and most extreme compressive twisting pressure.[13-14]

k) Chen and Tsay who conducted the stress analysis on helical gear after studying on influence of design parameter and contact surfaces. Helical gears are generally utilized in power transmission between parallel shaft. Standard equal helical gear with involute teeth are obtuse toward focus division get together blunders and have line of contacts under a perfect get-together condition. In any case, involute helical gears are flimsy to focus point misalignments, causing unpredictable transmission errors (TE) and edge contacts, happening in clack and vibration. Thus, the teeth of helical gear congregations are continuously changed to accomplish a constrained point contact and to keep away from edge contacts. Livin proposed change to get a pre-composed illustrative TE comparably as an obliged bearing gear set.[15]

l) Abdullah investigated in powertrain transmission that the use of root stress of the gear by FEM analysis and root stress are analysed on the confinement of mesh refinement, no. of teeth reduction and rim thickness reduction. The contraception vibration dynamic showing was investigated by various experts yet the strategy of coupling understanding and rotate vibrations has been managed so to speak starting late. For an undeniably common sense and closer to preliminary regards into account the versatility of the post direction as well as the distortions of the teeth work. Besides, the bearing immovability altogether influences the prepared structure vibration into the account.[16]

CHAPTER 3: Model Description

3.1- Introduction

Gear is one of the needed components in the modern days for all the applications where there is requirement of power transmission such as automobile industries, industrial equipment, aircraft industry, aerospace industry, marine vessels and in many other projects. Due to the involute teeth of the gear which is manufactured at low cost is highly used in the industries in the industries. The helical gear is more efficient for transmitting power from one shaft to another. The gears are most commonly used in transmitting toque and angular velocity.

In the modern days, helical gear is seeking attention for any type power transmission with enormous capabilities. Helical gear is using as the power transmission equipment because it has the capacity to carry heavy load with higher working velocity, having quiet and smooth operation, and high contact ratio of teeth engagement. It has the capacity to exchange power in between the two non-parallel shafts which is highly effective. When the two or more gear comes together in sequence for the power transmission is known as gear train. As for the power transmission two or more gear comes together in sequence and the engagement of the gear takes place. Sometimes, there is misalignment in the engagement of gear due to geometry of the gear while manufacturing. So, there is need to be desired accuracy of teeth, accurate dimension and proper surface finishing. Due to misalignment and surface contact of the gear stress are induced in the teeth and shaft of the gear.

The meshing of the gear for the genuine teeth load comprises two types of component : statical and dynamical component. The statical component means when there is equality in input power is corresponding to output load. The dynamic component means causing of dynamic fluctuation in the gear, when the movement of the shaft takes at higher speed there is dynamic fluctuation in the gear and shaft inducing stress. In the transmission application the analysis of the gear as per the requirement to obtained the gear teeth bending stress and contact stress for the analysis. FEM play one of the important roles to determine the stress and strain produced in the complicated structure’s design structure even for gear stress analysis. The load share in between the

neighbouring teeth is analysed with the position error which is triggered by the mismatch alignment and the elastic deformation of teeth.

3.2 Parametric modeling

For the parametric modeling, we design 2D/3D model of the helical using the Solidworks software (version 2016). The design in the Sodiworks software simply manipulate by three dimensional models which is further for better use in future aspect. The two gears are designed along with the shaft in the Solidworks.

For designing, first two gear is designed according to the parameter and further engaged with the shaft as one with smaller shaft and other is with larger shaft. The smaller shaft of length 10mm and the larger one is taken as of 20mm length. These are the following nomenclature of the helical gear shown fig. 4.

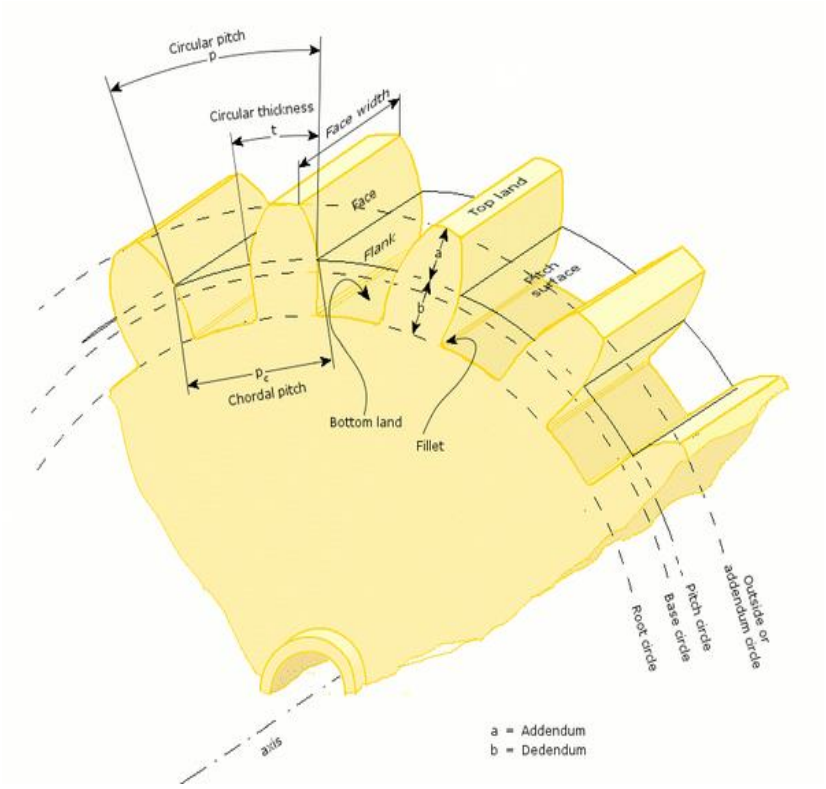

Fig. 4. Nomenclature of the helical hear

3.3 Design parameter of the Helical gear

The model is designed in the Solidworks with specific parameter which is given below in Table 1. In this way, gear is designed with these parameter in the Solidworks and further the model is attached with the shaft.

Parameter	value
No. of teeth (N)	30mm
Module (M)	10mm
Pressure angle (PA)	20 deg.
Helix angle (Ha)	15 deg.
Face width (T)	100mm
Addendum (a)	10mm
Dedendum(d)	1.25*M
Pitch dia.(D)	300mm
Shaft length (l)	10&20mm

Table 1. Design parameter of the helical gear

From this parameter the model of the gear is designed in the Solidworks and the figure is given below

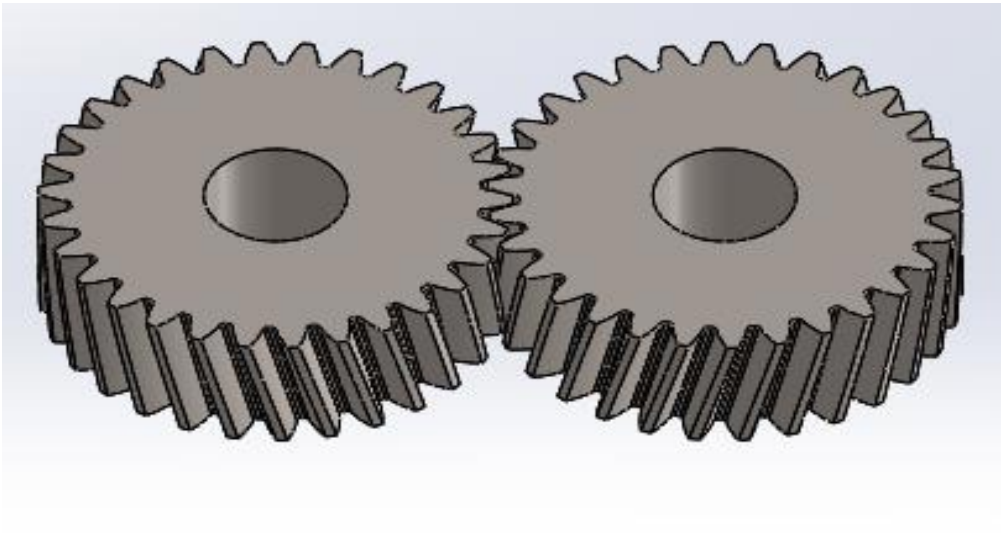

Figure 5. Helica gear made in Sodiwords

Further the model is attached with shaft in the solidworks which is as shown in figure below

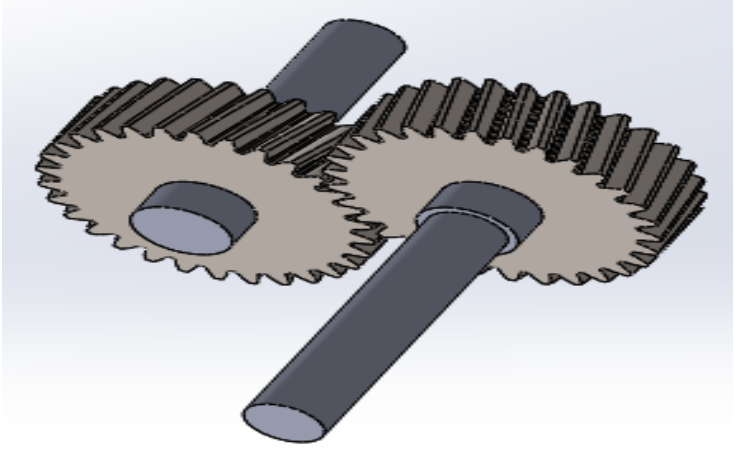

Figure 6. Helical gear with shaft

In above fig. 5 & fig. 6 these are two figures which have been designed in the solidworks with and without shaft according to the specific above design parameter. After this the further simulation is done in the Ansys.

3.4 Finite element modeling

The finite element method is one of the important simulation technique amongst the predominant techniques in solid mechanics. The simulation technique of finite element ha various scope in different-different field such as utilized in the industrial, biomedical, automotive and aviation fields. The finite element method can be used to build up another structure and analyze further or analyzes the existing model using finite element method. Finite element analysis changes the model into subdivisions and enhancing the utilizing of mathematical equations. The subdivisions of geometrical segments are called elements accomplished by meshing the preferred geometry for FEA analysis.

Material	Aluminum alloy
Young Modulus of Elasticity	71 Gpa
Poisson Ratio	0.3
Density	2770 Kg/m^3
Ultimate Teinsile Strength	310 Mpa
Tensile Yield Strength	280 Mpa

Table 2. Properties of material gear

3.5 Boundary condition and loading condition

The boundary condition is applied on the helical gear without shaft which is frictionless support and meshing of helical gear is done. The input is provided in one of the gear and output is obtained at the other gar as per the analysis shown in fig. below

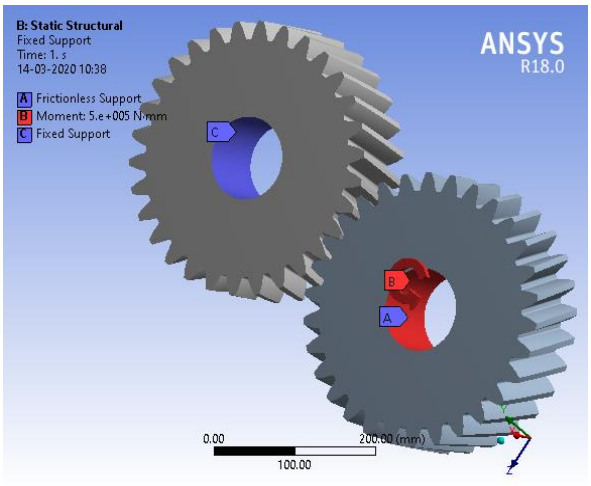

Figure 7. Boundary condition applied in helical gear without shaft

Further, there are two types of analysis is done vibration analysis as well as stress analysis. For the vibration analysis, modal system done in Ansys is used and the boundary conditions are applied to the design. The shaft at the gears is applied with the cylindrical support which is show in fig. 8.

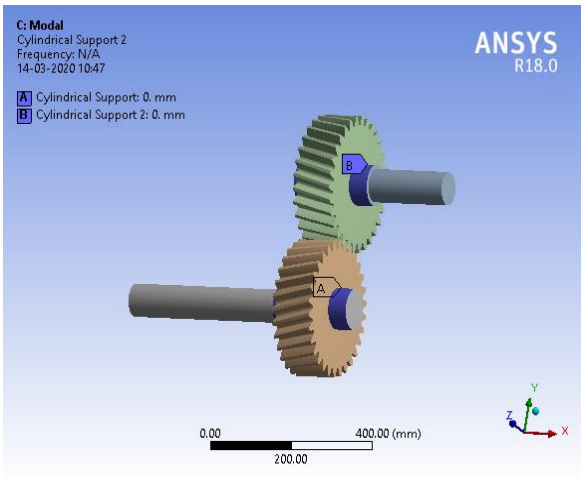

Figure 8.Helical gear with boundary condition for modal analysis

Now, for stress analysis static structural system is used in the Ansys and the boundary condition is applied to the design. The boundary conditions are made at the shaft of the helical gear with the cylindrical support for further analysis shown in fig.

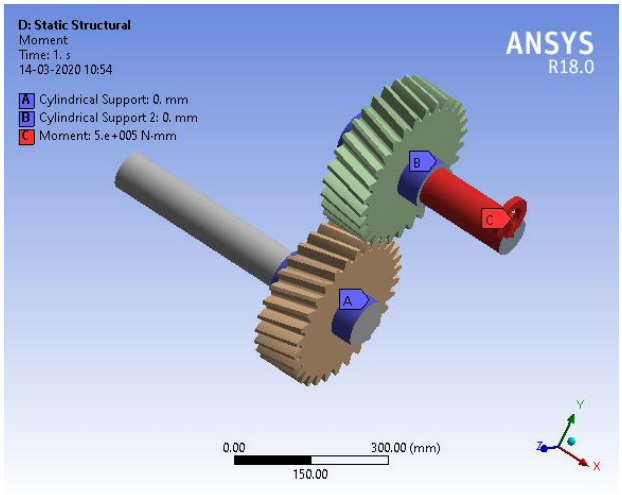

Figure 9. Boundary conditions for stress analysis

CHAPTER 4: Result and discussion

After applying the boundary condition to the gear train, the vibrational analysis is done for the result at different modes. The different types are selected and at each particular mode the analysis is done and the result is obtained as six modes of frequencies.

The shafts at the gear are made to cylindrical support while moment of (500 N-m) is provided to the input shaft. Based on the boundary conditions the stress and deformation at the gear shaft and frequencies for six different modes is obtained. The six different shapes modes has been seen in fig

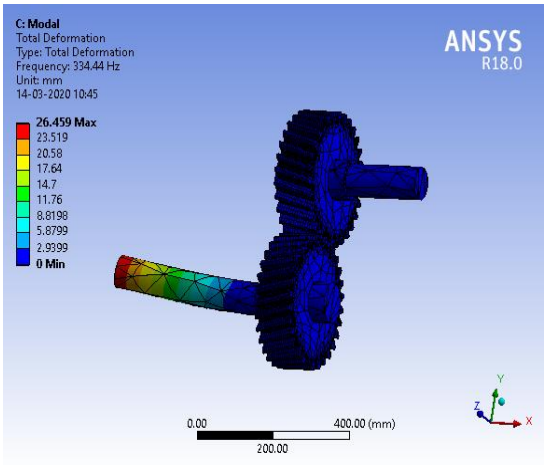

Fig. 10. a) Mode 1 deformation

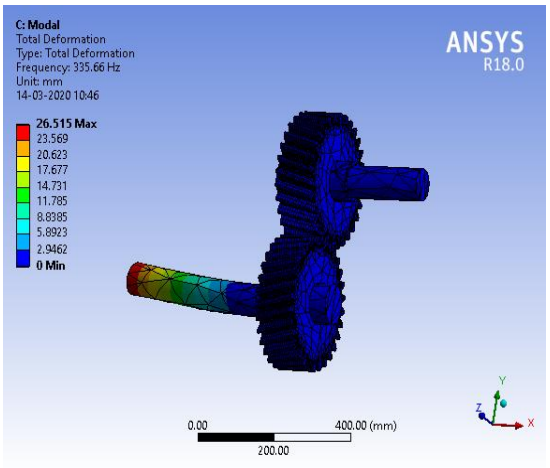

Fig. 10. b) Mode 2 deformation

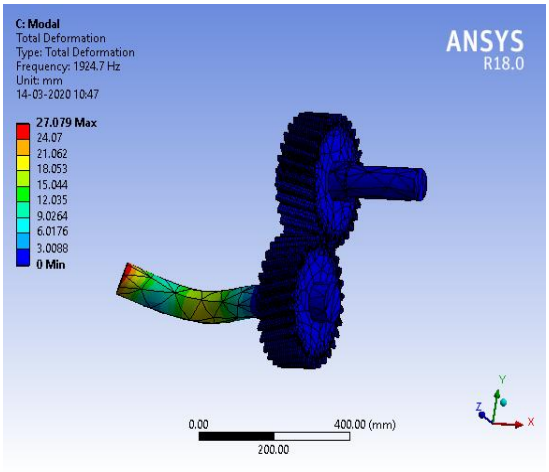

Fig. 10. c) Mode 3 deformation

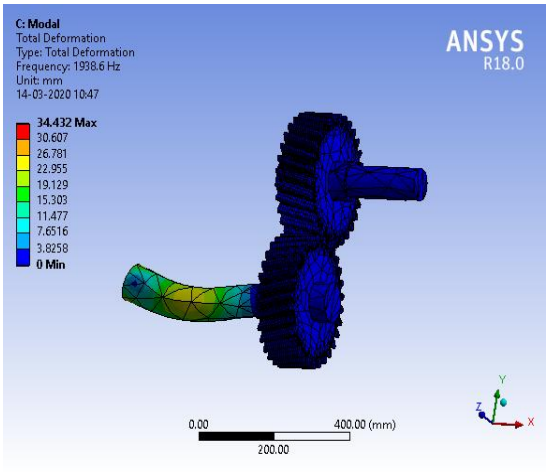

Fig. 10. d) Mode 4 deformation

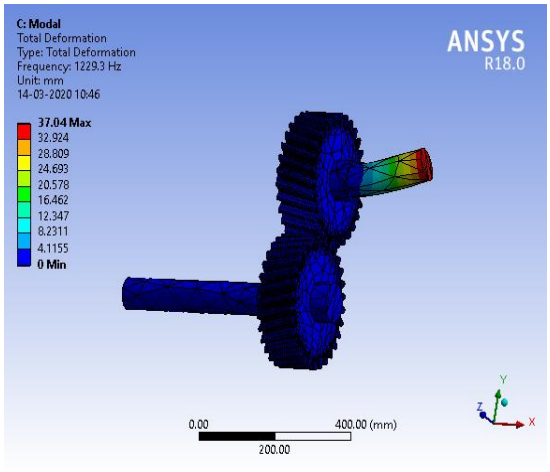

Fig. 10. e) Mode 5 deformation

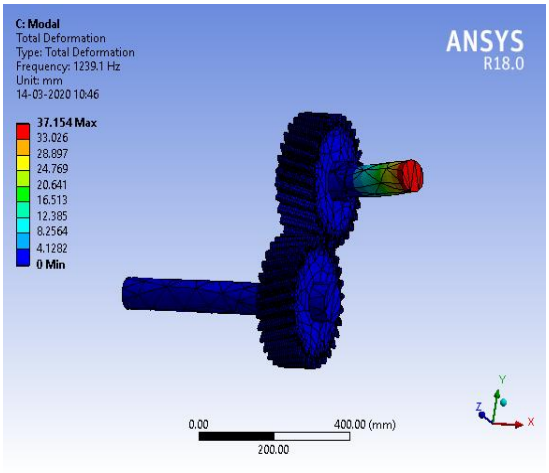

Fig. 10. f) Mode 6 deformation

4.1 Deformation in shapes at six modes

After applying the load on the shaft of the gear train, deformation in shapes at six different modes is obtained which is shown in Table.

Modes	Deformation in mm
1st	26.459
2nd	26.515
3rd	27.079
4th	34.432
5th	37.04
6th	37.432

Table 3. Modes and deformation

4.2 Graph obtained for the modes and deformation

Due to load application there are deformation obtained in the gear train which shows the following graph in between the modes and deformation shown below

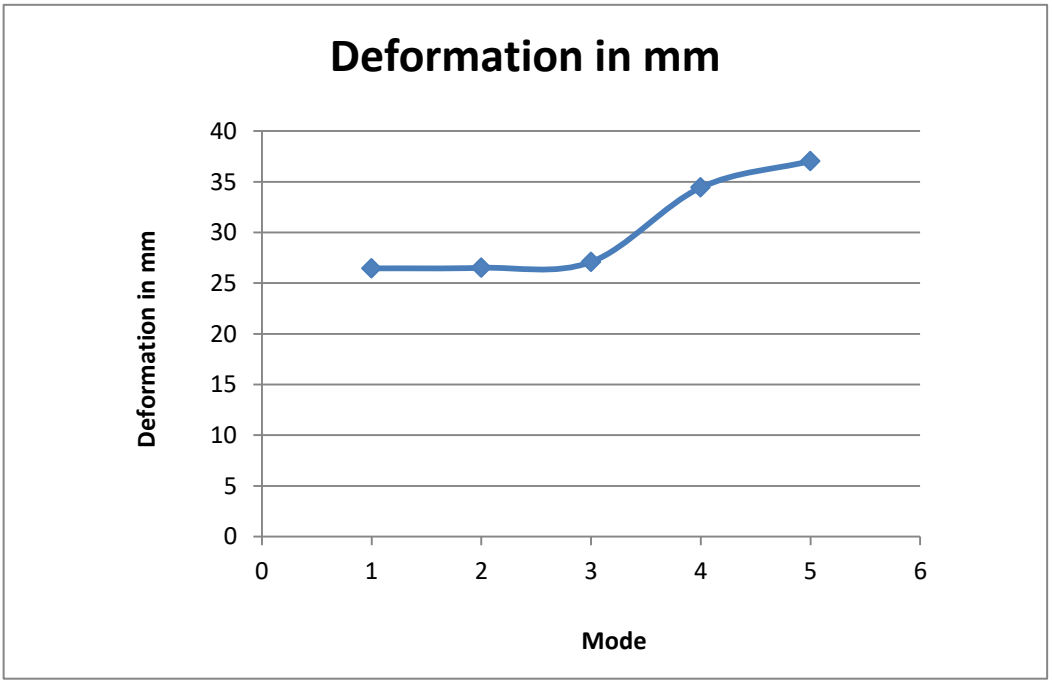

Figure. 11 Graph between modes versus deformation

4.3 Frequencies obtained at six different modes

After the application of load at shaft of the gear train where six different values of frequencies are obtained and frequencies values has been shown below Table

Modes	Frequencies in Hz
1st	334.44
2nd	335.66
3rd	1229.3
4th	1239.1
5th	1924.7
6th	1938.6

Table 4. Modes and frequencies

4.4 Graph obtained for the modes and frequencies

The graph obtained in between the modes and frequencies due to the loading application over the shaft of the gear train.

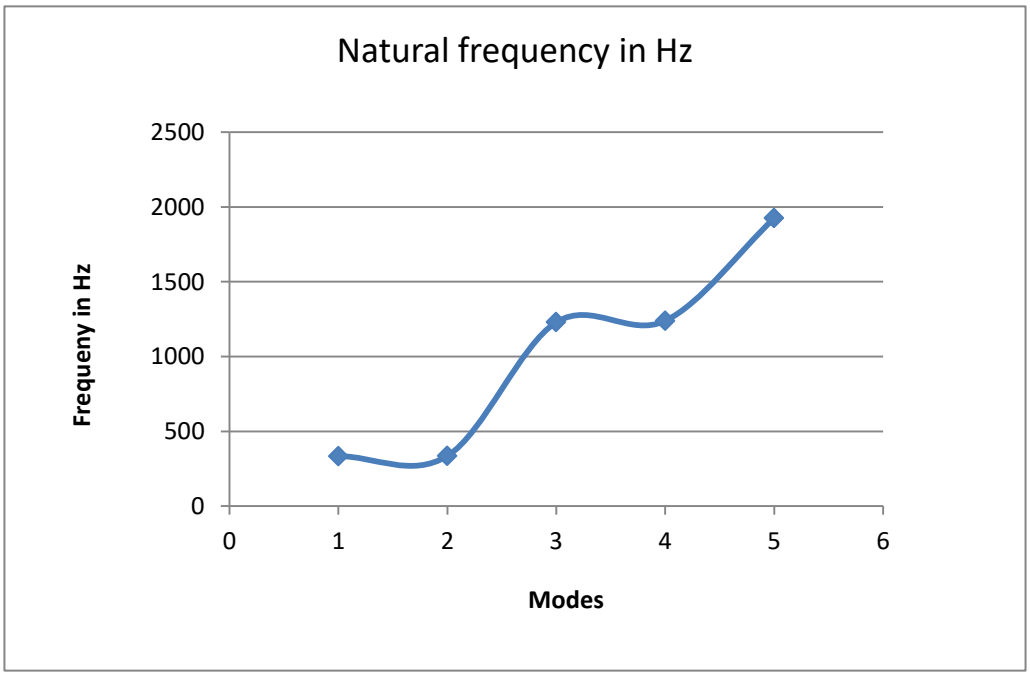

Figure 12. Graph between modes versus frequency

4.5 Stress on teeth and deformation in shaft

This is the result under loading conditions when a moment of 500 N-m applied on one gear under cylindrical support which is provided to the shaft, the deformation in the shaft as well as stress on the gear teeth can be obtained. The stress on the teeth and deformation in the shaft due to applied loading condition is shown fig. 13 and fig.14 respectively.

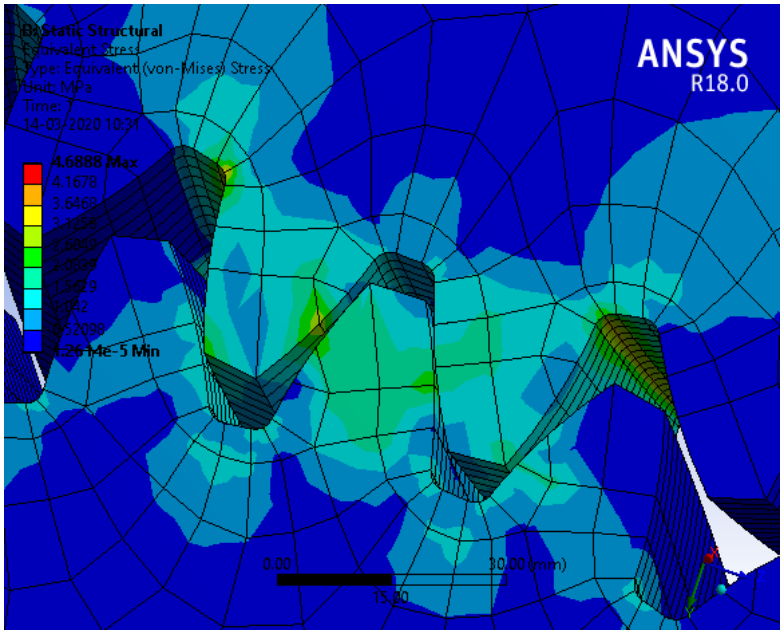

Figure 13. Stress on the teeth under loading condition

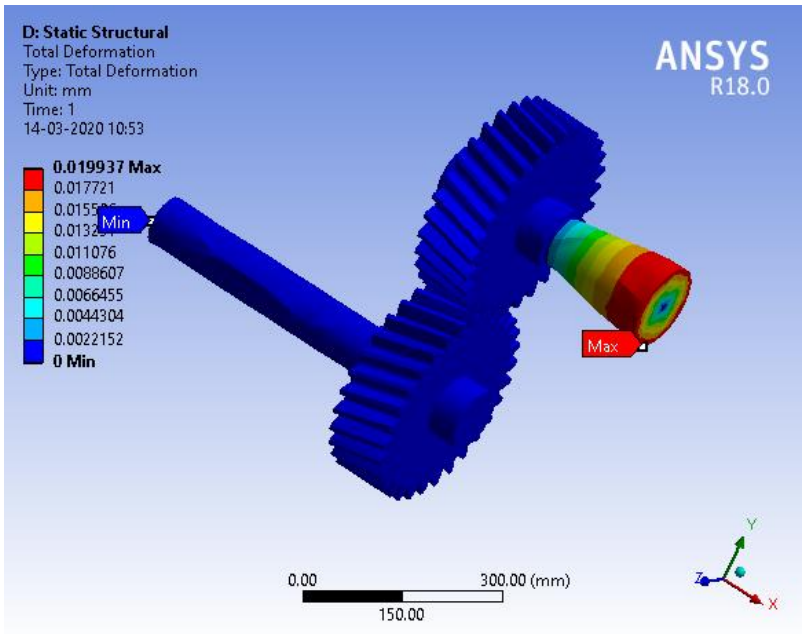

Figure 14. Total deformation in the shaft under loading condtition

Chapter5: Conclusions

As it has been seen, the gear train is first designed in Solidworks. The material aluminum alloy is considered for the analysis. Aluminum alloy reduces 55-67% weight comparison to other materials. Aluminum alloy which have unique property like corrosive resistance and having good surface finishing leading smooth and silent operation. The weight reduction may increase the balance criteria resulting to minimize the balanced force improving the performance of machine. After that the simulation is done in the Ansys and the simulation is analysed with the two analysis i.e. vibrational analysis and stress analysis. At first the vibrational analysis is done with the six modes of frequencies besides deformation of shaft in analysis. In second analysis, the stress analysis is done with the shaft by applying the boundary condition as cylindrical support and one gear is acted by 500 N-m moments to analyse the result. In this paper we find that stresses at shaft are 8.883 MPa which is less than the yield tensile strength of the used material. This shows that gear train will not fail at loading conditions.

It was studied the modal analysis of two different gear trains using FEM simulation under the state of free stress and pre-stressed. Using FEM, the calculation of the maximum bending stress and the contact stress has been calculated for the two different gear trains. It was found that all gear have approximately similar resonance frequencies behaviour when plotted against the first six mode shapes. Under the pre-stressed state the resonance frequencies of the gear trains significantly increases. It was observed that the vibration bending of the shaft and gear rotation, comparatively found more at the input gear rather than the output gear. There is the variation in the bending stress and contact stress when gear are analysed at different angle positions. On the other hand, in real case, there is no constant bending stress and the contact rotation throughout the rotation rather than having zig-zag behaviour.

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PUBLICATIONS DETAILS

1. Paper submitted for IEEE Conference “Modal analysis of helical train using Ansys”