LOAD SHARING BASED ANALYSIS OF HELICAL GEAR USING FINITE ANALYSIS METHOD

Energy storage and stress analysis

G. VenkatKumar,CH. Sarath Chandra, K. Krishna Prasad, P. Chengaiyan

Associate Professor, Student, Student, Student
Mechanical Engineering,
Prathyusha Engineering College, Thiruvallur, India

Abstract: In the gear design the bending stress and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in a gear set. Thus, the analysis of stresses has become popular as an area of research on gears to minimize or to reduce the failures and for optimal design of gears in this paper bending and contact stresses are calculated by using analytical method as well as Finite element analysis. To estimate bending stress modified Lewis beam strength method is used. Pro-e solid modeling software is used to generate the 3-D solid model of helical gear. Ansys software package is used to analyze the bending stress. Contact stresses are calculated by using modified AGMA contact stress method. In this also Pro-e solid modelling software is used to generate contact gear tooth model. Ansys software package is used to analyze the contact stress. Finally, these two methods bending and contact stress results are compared with each other.

***IndexTerms*–Helical Gear, Stress, ANSYS, Failure, Energy.**

I. INTRODUCTION

It is one of the best methods of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. The rapid development of industries such as vehicle, shipbuilding and aircraft require advanced application of gear technology. Customers prefer cars with highly efficient engine. This needed up a demand for quite power transmission. Automobile sectors are one of the largest manufacturers of gears. Higher reliability and lighter weight gears are the bending and surface stresses of gear tooth are major factor for failure of gear. Pitting is a surface fatigue failure due to repetitions of high contact stresses. This paper investigates finite element model for monitoring the stresses induced of tooth flank, tooth fillet during meshing of gears. The in volute profile of helical gear has been modelled and the simulation is carried out for the bending and contact stresses and the same have been estimated. To estimate bending and contact stresses, 3D models for different helical angle, face width are generated by and simulation is done by finite element software packages. Analytical method of calculating gear bending stresses uses AGMA bending equation and for contact stress AGMA contact equation are used. It is important to develop appropriate models of contact element and to get equivalent result by using Ansys and compare the result with standard AGMA stress necessary to make automobile light in weight as lighter automobiles continue to be in demand. The success in engine noise reduction promotes the production of quieter gear pairs for further noise reduction. The best way of gear noise reduction is attained by decreasing the vibration related with them. In this paper real involutes gear pair with transmission ratio is analysed.

A.FUNCTIONS OF A GEARBOX:

The teeth on helical gears are cut at an angle to the face of the gear. When two teeth on a helical gear system engage, the contact starts at one end of the tooth and gradually spreads as the gears rotate, until the two teeth are in full engagement.This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears. For this reason, helical gears are used in almost all car transmissions.Due to the angle of the teeth on helical gears, they create a thrust load on the gear when they mesh. Devices that use helical gears have bearing that can support this thrust load.

B.TYPES OF HELICAL GEARS:

There are three types of transmission system.

- Parallel axis helical gear
- Crossed helical gear
- Herring bone (or) double helical teeth

PARALLEL AXIS HELICAL

The gears operate in two parallel shafts. The magnitude of helical angle for pinion & gear they have opposite helix angle.

CROSSED HELICAL GEAR

That operate on two nonparallel shaft Gears having same or opposite hand of helix.Automatic transmission is a type of gearbox, especially used in the automobile industry for changing gear ratios automatically.The pair of crossed helical gear is known as spiral gear. The spiral gearis used to connect and transmit motion in between two nonparallel shaft and nonintersecting shaft. In spiral gear the contact between mating teeth is always consider as a point. This spiral gear is suitable only for transmit small amount of power. In order for two helical gear are operate as crossed helical gear, they having same normal diameter pitch and normal pressure. But the gear do not need the same helix angle or being opposite of hand. The most of crossed gear application should be having same hand.

DOUBLE HELICAL (OR) HERRING BONE

The herringbone gear or helical gear having consist of teeth right and left helix cut on the same blank as shown in figure. The main drawback of the herringbone gear is single helical gear for existence of axial thrust load. They will be eliminated by herringbone configuration, because of the thrust force of right hand is balanced by the, that of left hand helixreduces fuel consumption significantly.

C.MATERIAL USED FOR HELICAL GEAR:

1. Cast iron
2. Aluminum
3. Beryllium
4. Carbo n steel

II. SOFTWARE

The software will start (by default) with all toolbars docked to the edges of the main window. The toolbars contain buttons, which when clicked, open the various information windows or operate features in the software. The toolbars and windows can be freely moved around inside the main program window, to create your own screen layout.

A.INRODUCTION TO CATIA

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avion Marcel Dassault, at that time customer of the CADAM software to develop Dassault's Mirage fighter jet. It was later adopted by the aerospace, automotive, shipbuilding, and other industrie s. Initially named CATI (*conception assistée tridimensionnelle interactive* – French for *interactive aided three-dimensional design*), it was renamed CATIA in 1981 when Dassault created a subsidiary to develop and sell the software and signed a non-exclusive distribution agreement with IBM. In 1984, the Boeing Company chose CATIA V2 as its main 3D CAD tool, becoming its largest customer. In 1988, CATIA V3 was ported from mainframe computers to UNIX. In 1990, General Dynamics Electric BoatCorp chose CATIA as its main 3D CAD tool to design the U.S. Navy's Virginia class submarine. Also, Lockheed was selling its CADAM system worldwide through the channel of IBM since 1978.In 1992, CADAM was purchased from IBM, and the next year CATIA CADAM V4 was published. In 1996, it was ported from one to four UNIX operating systems, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS, and Hewlett-Packard HP-UX. In 1998, V5 was released and was an entirely rewritten version of CATIA with support for UNIX, Windows NT and Windows XP (since 2001). In the years prior to 2000, problems caused by incompatibility between versions of CATIA (Version 4 and Version 5) led to $6.1B in additional costs due to years of project delays in production of the Airbus A380. In 2008, Dassault Systèmes released CATIA V6. While the server can run on Microsoft Windows, Linux or AIX, client support for any operating system other than Microsoft Windows was dropped. In November 2010, Dassault Systèmes launched CATIA V6R2011x, the latest release of its PLM2.0 platform, while continuing to support and improve its CATIA V5 software. In June 2011, Dassault Systèmes launched V6 R2012. In 2012, Dassault Systèmes launched V6 2013x. In 2014, Dassault Systèmes launched 3DEXPERIENCE Platform R2014x and CATIA on the Cloud, a cloud version of its software.

B. INTRODUCTION TO ANSYS WORKBENCH

ANSYS mechanical is a finite element analysis tool for structural analysis including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS mechanical also includes thermal HYPER LINK and coupled analysis capabilities acoustics, piezoelectric, thermal –structural and thermos electric analysis.

III.DESIGN

DESIGN CALCULATION:

Gear material,

For pinion:

Structural steel

- Density = 7850 kg/m3
- Young modulus = 200 GPa

- Poisson's ratio = 0.3
  - Ultimate Tensile Strength = 460 MPa
- Yield Tensile Strength = 250 MPa
- Bulk modulus = 166 GPa

For gear:
Structural steel

- Density = 7850 kg/m3
- Young modulus = 200 GPa
- Poisson's ratio = 0.3
- Ultimate Tensile Strength = 460 MPa
- Yield Tensile Strength = 250 MPa
- Bulk modulus = 166 GPa

Assume,

- Input Shaft Power = 10KW
- Speed Of Input Shaft Np = 1250rpm
- Speed Of Input Shaft Ng = 500rpm

Gear Ratio I = N_p/N_g
=1250/500
= 2.5

Teeth On Gear ,
Z_p= 18
i = Z_g/Z_p
2.5 = Z_g/18
Z_g= 45

From the No of Teeth Select Pressure Angle,
Pressure angle = 20°
Module = 6
D1 = m x $Z_g/\cos\beta$
= 6 x 45 /cos 20^{o}
= 287.32 mm
D2 = m x $Z_p/\cos\beta$
= 6 x 18 /cos 20^{o}
= 114.93 mm
a = (D1+ D2) /2
= 201.125mm
b = φa
= 0.5 x 201.125
= 100.5625

➢ **MODELING OF HELLICAL GEAR IN CATIA:**

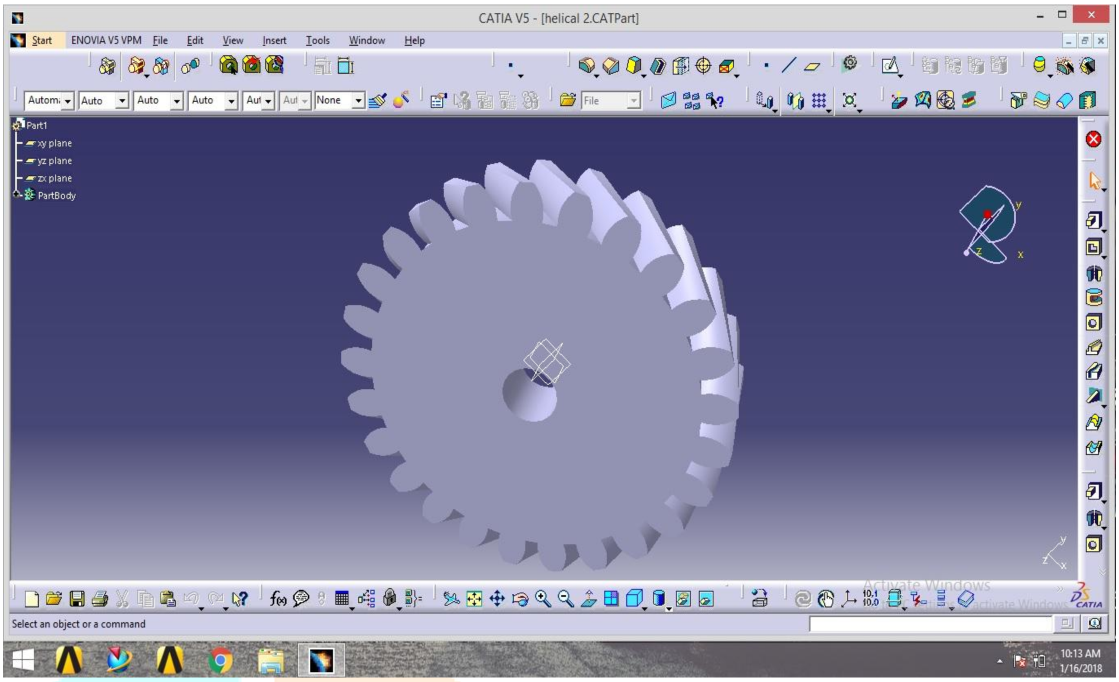

Fig: Helical Gear sketch

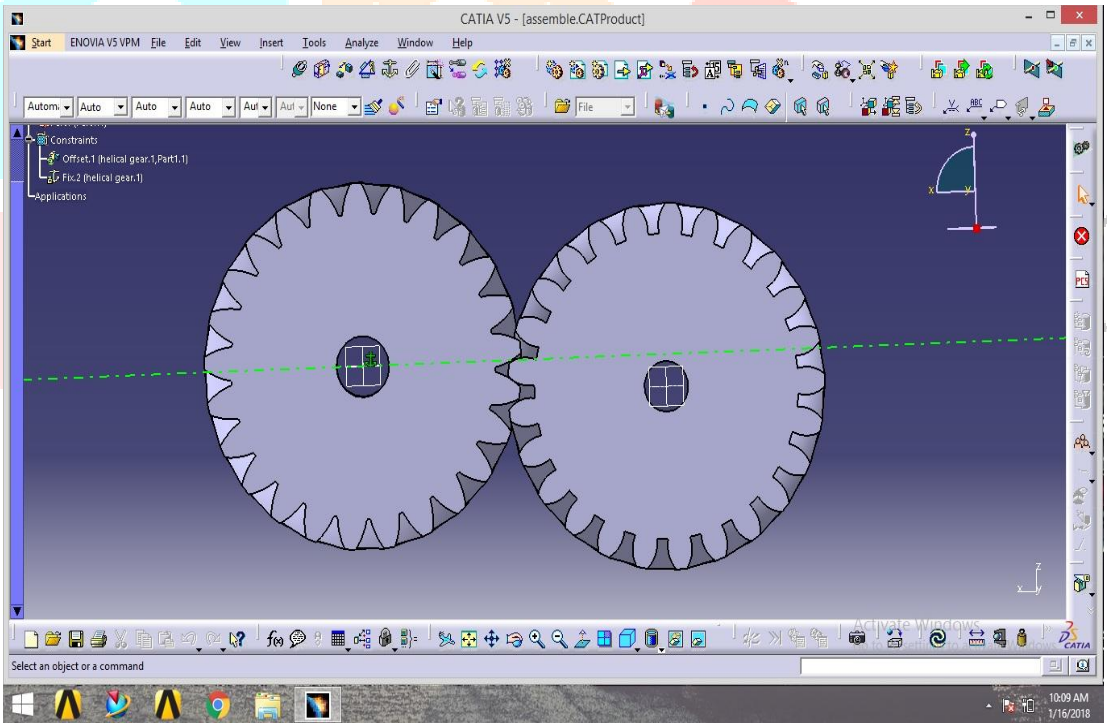

Fig: Mating of two helical gears

IV.LITERATURE SURVEY

1) Kailash Bhosale had done the Analysis of bending strength of helical gear by FEM. In this work bending strength of helical gear is found out with the help of three dimensional photo elasticity. A helical gearbox with 2.2 kW power transmitting at 760 rpm and Number of Teeth = 30mm, Pitch circle Diameter = 60mm, Module = 2mm, Pressure Angle =20°, Helix Angle = 12054', Addendum = 64mm, Base circle Diameter = 56.38mm, Dedendum = 55mm. A solid modeling is done with Catia and then by using the hyper mesh meshing is done. Analysis is done with Ansys Workbench 12.1. The analysis of bending stress in gear tooth was done by Mr. Wilfred Lewis known as Lewis equation. In the Lewis analysis, the gear tooth was treated as a cantilever beam. The tangential component (Pt) causes the bending moment about the base of tooth. The Lewis analysis was based on the following assumptions: The effect of radial component (PR) was neglected. The effect of stress concentration was neglected. Atany time only one pair of teeth was in contact and takes the total load.

2) Tribhuvan singh,Mohd. parvez had carried out the analysis of helical gear using AGMA standards and FEM. In this work a parametric study was conducted by varying the face width and helix angle to study their effect on the bending stress of helical gear. This thesis investigates the characteristics of an involute helical gear system mainly focused on bending and contact stresses using analytical and finite element analysis.To estimate the bending stress, three- dimensional solid models for different number of teeth are generated by Pro/Engineer that is a powerful and modern solid modeling software and the numerical solution is done by ANSYS, which is a finite element analysis package. The analytical investigation is based on Lewis stress formula. This thesis also considers the study of contact stresses induced between two gears. Present method of calculating gear contact stress uses Hertz's equation. To determine the contact stresses between two mating gears the analysis is carried out on the equivalent contacting cylinders. The results obtained from ANSYS are presented and compared with theoretical values.

3) A. SathyanarayanAchari, R.P.ChaitanyaSriniwasPrabhu had done the work on A comparison of bending stress and contact stress of helical gear as calculated by AGMA standards and FEA. In this paper, bending stress at the root of the helical gear tooth and surface contact stresses are computed by using theoretical method as well as FEA. To estimate the bending stress at the tooth root Lewis beam strength method was applied. NX CAD 8.5 modeling software package was used to create the 3D solid model of helical gear pairs. NX Nastran 8.5 software package was used to analyze the gear tooth root bending stress. Contact stresses were calculated by AGMA standards. In this also NX CAD 8.5 modeling software package was used to generate helical gear tooth contact models. NX Nastran 8.5 software package was used to analyze the surface contact stress. Ultimately, these two methods, tooth root bending stress and contact stress results were compared with respect to each other.

4) B. Venkatesh V. Kamala, A. M. K. Prasad had done the work on Design, Modeling and Manufacturing of Helical Gear. In this work, structural analysis on a high speed helical gear used in marine engines, have been carried out. The dimensions of the model have been arrived at by theoretical methods.

The stresses generated and the deflections of the tooth have been analyzed for different materials. Results obtained by theoretical analysis and Finite Element Analysis were compared to check the correctness. A conclusion has been arrived on the material which was best suited for the marine engines based on the results. Basically the project involves the design, modeling and manufacturing of helical gears in marine applications.

5) S. Sai Anusha, P. Satish Reddy, P. Bhaskar, M. Manoj had done the investigation to make use of helical gear, by analyzing the contact stresses for differentPressureangles(14.5˚,16˚,18˚,20˚)Helixangles(15˚,20˚,25˚,30˚)and(80mm,90mm,100mm,110mm, 120mm) Facewidth. A Three dimensional solid Model was generated by Pro-E. The numerical solution was done by Ansys by using finite element analysis package. The analytical approach was based on contact stress equation, to determine thecontact stresses between two mating gears. The results obtained from Ansys; Analytical values were compared with theoretical values. The present analysis is useful in quantifying the above said parameters that helps in safe and efficient design of the helical gear. The effect of helix angle on contact stress was studied by varying the helix angle for four different angles were 15˚, 20˚, 25˚, 30˚. A typical trend has been observed when the 15˚ helix angle stress value was 285.7 high when compared to 20˚ helix angle. The effect of face width on Von-Mosses stress was studied by varying the face width for different values were (80mm, 90mm, 100mm, 110mm & 120mm) respectively. The results were indicated that as the face width increases contact stress decreases. When Compare with the ANSYS and AGMA stress values were little higher than theoretical values.

6) Raghava Krishna Sameer, B. V. Srikanth had worked on the Contact stress analysis of modified helical gear using catia&ansysIn this paper parametric study was done by varying the geometry of the teeth to investigate their effect of contact stresses in helical gears. As the strength of the gear tooth was important parameter to resist failure. In this study, it was given that the effective method to estimate the contact stresses using three dimensional models of both the different gears and to verify the accuracy of this method. The two different result obtained by the ansys with different geometries are compared. Based on the result from the contact stress analysis the hardness of the gear tooth profile can be improved to resist pitting failure.

V. RESULT AND DISCUSSION

1.DESIGN RESULT OF HELICAL GEAR IN ANSYS:

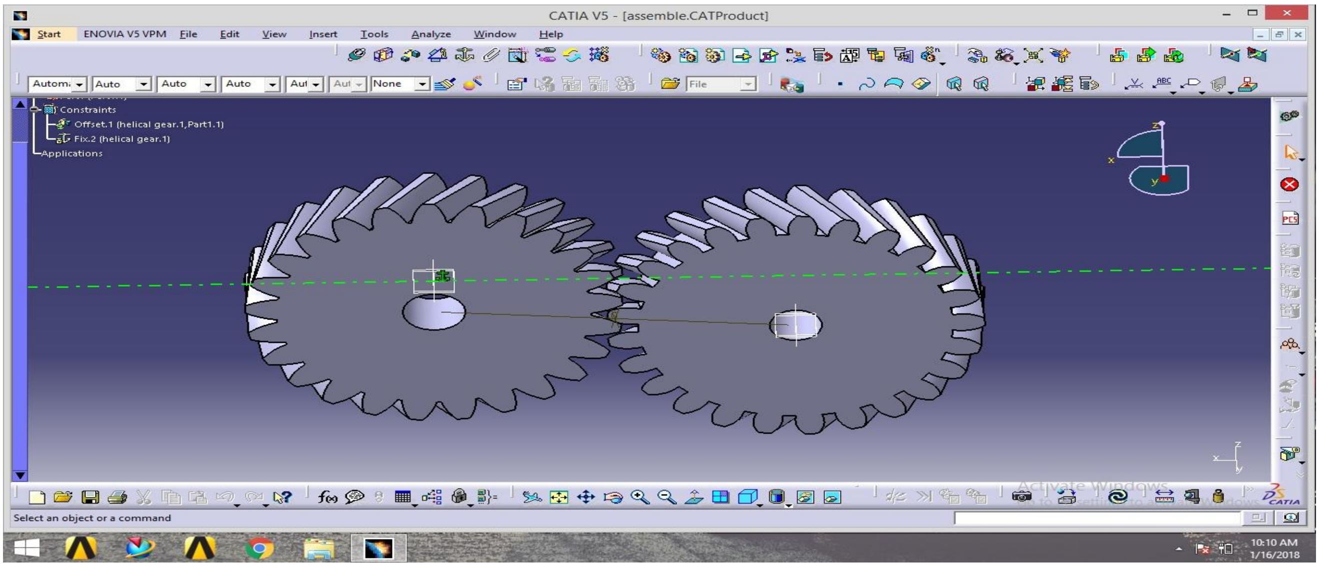

Fig: View of teeth cutting

2.ANALYSIS RESULT OF HELICAL GEAR

IMPORTING OF MATED GEARS TO ANSYS

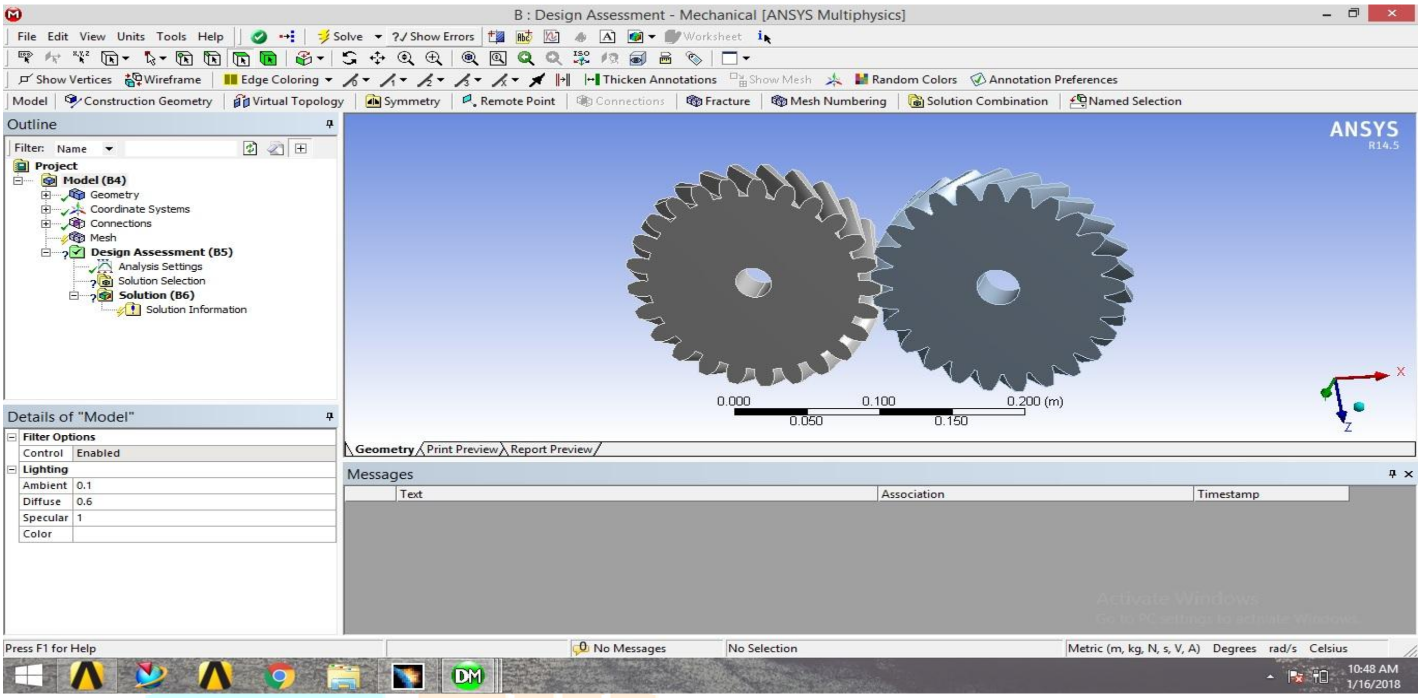

Fig: Importing of mated gears to ansys

BEFORE DEFORMATION OF MATING GEAR

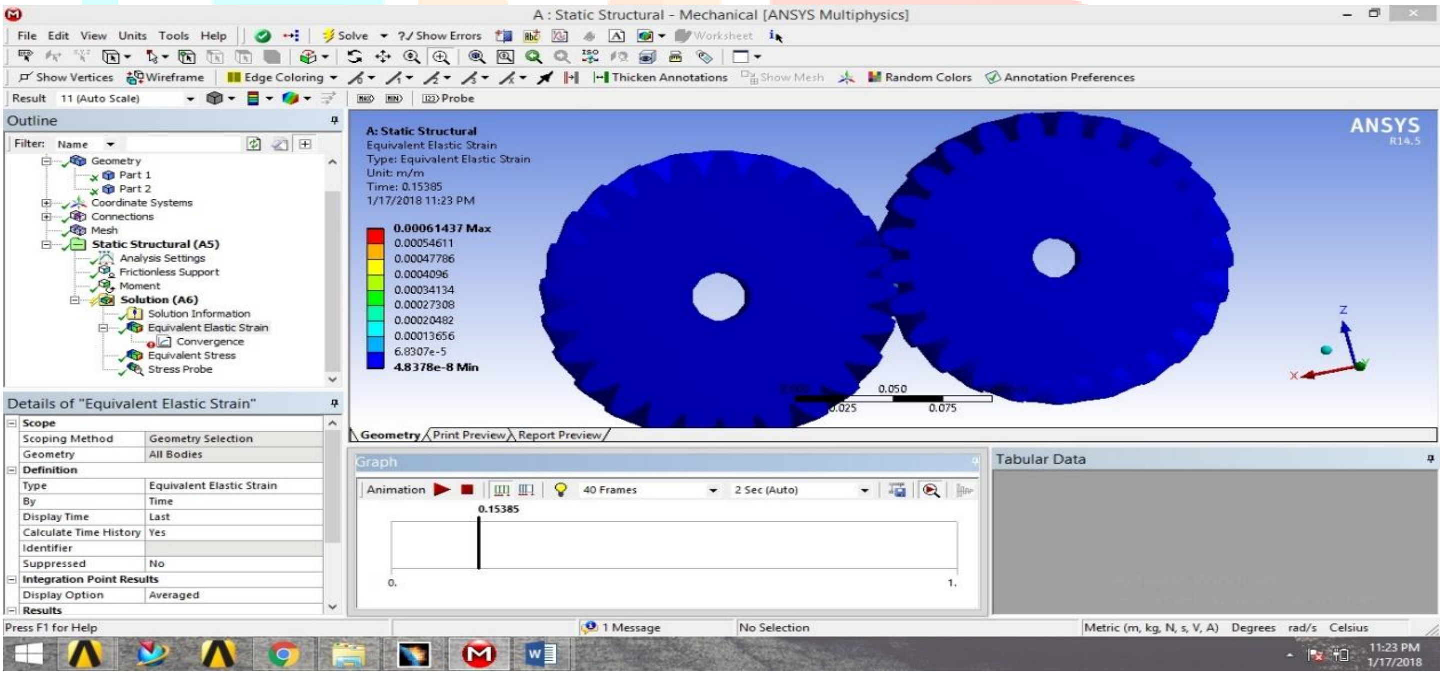

Fig: Load sharing on ansys

AFTER DEFORMATION OF MATING GEAR

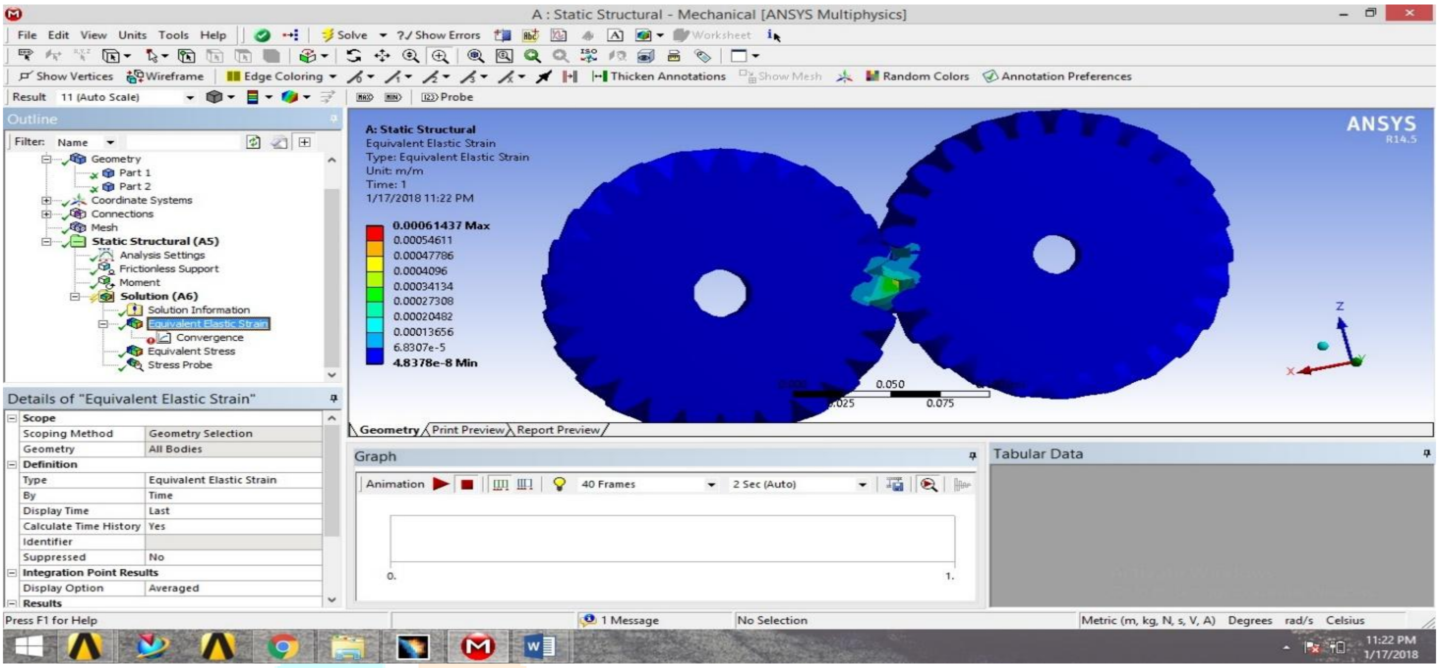

Fig: Load sharing between gears after applying

VI.CONCLUSION

In our project we have designed a helical gear for different materials structural steel and grey Cast Iron. Structural analysis is done on the helical gear to verify the best material by taking in to account stresses, displacements, weight etc.By observing the structural analysis results using Grey cast iron the stress values are within the permissible stress value. So using grey cast iron is safe for gearbox. When comparing the stress values of the materials for all speeds, the values are less for grey Cast Iron than structural steel. Thereby mechanical efficiency will be increased.By observing analysis results, grey cast iron is best material for helical gear.

DEFORMATION

S.NO	MATERIAL	ANSYS OF HELICAL GEAR N\m^2 (MAX)	RIM TYPE N\m^2 (MIN)
1	STRUCTURAL STEEL	0.00061437	4.8378e-8

VII.REFERENCES

1. A. SathyanarayanAchari R.P. Chaitanya, SriniwasPrabhu, "A comparison of bending stress and contact stress of helical gear as calculated by AGMA standards and FEA".
2. Engineering, Addis Ababa University
3. http://www.engineersedge.com/gears/gearbox-design.htm
4. http://www.freestudy.co.uk/dynamics/gears.pdf
5. http://www.ncl.ac.uk/gears/services
6. http://www.saia-motor-usa.com/design-tools/gearbox.html
7. http://www.scribd.com/doc/14587108/Ansysdocumentaion
8. http://www.techberth.com/2011/06/ansys-tutorial/
9. Kailash Bhosale, "Analysis of bending strength of helical gear by FEM"
10. Raghava Krishna Sameer B. V. Srikanth, "Contact stress analysis of modified helical gear using catia&ansys".

11. S. Sai Anusha , P. Satish Reddy,P. Bhaskar M. Manoj, "Contact stress analysis of helical gear by using AGMA
12. Stress Analysis of Helical Gears with Pinions Circular arc
13. Teeth and Gear involute teeth, Mech. Of Mach. Theory, 26,
14. Tribhuvan Singh, Mohd. Parvez, "COMPARATIVE STUDY OF STRESS ANALYSIS OF HELICAL GEAR USING AGMA STANDARDS".
15. Tsay, C.B., and Fong, Z.H., Computer Simulation and
16. Using FEM, M.sc. thesis Department of mechanical
17. Yonatan, F., Variable Mesh Stiffness of Spur Gear Teeth
18. B.Venkatesh, V.Kamala, and A.M.K.prasad, Design, modeling and Manufacturing of helical gear, ISSN 0976-4259, 2010.
19. Pushpendra kumar, Mishra and Dr.M.S.Murthy, Comparison of Bending stress for Different Face width of helical Gear Obtained Using MATLAB Simulink with AGMA and Ansys , ISSN 2231-5381, 2013.
20. Prashant patil, Narayan Dharashiwkar, krishna kumar josh and Mahesh Jadhav, 3D Photo elastic and Finite Element Analysis of Helical Gear, ISSN 1821-1259,2011.
21. KhailashC.Bhosale,Analysis of Bending Strength of helical Gear by FEM, ISSN 2222-1727,2011.