DESIGN, STRUCTURAL ANALYSIS AND COMPARISON OF SPUR AND HELICAL GEAR USING ANSYS

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ABSTRACT

A rotating circular disc containing teeth connected to another part with teeth and is used to transmit torque is called a gear or multilobed cams. Different types of gears include spur gears, helical gears, bevel gears, herringbone gear, rack and pinion, epicyclic gear etc. Gears today are used in almost all the machines ranging from small clocks to large machines. Thus structural analysis of gears has become a popular and vital area of research. Spur gear have teeth cut parallel to the axis and are used for parallel shafts. They have an involute profile which remains same along the face width of the gear. Helical gears, similar to spur gear, have an involute profile although this profile is perpendicular to the tooth element which depends on the helix angle. Since both helical and spur gear are used for radial load it brings forth the question that which gear is better of the two and when to use either one of them. In this paper bending and contact stresses are analyzed on both the gears using the finite element method in ANSYS. Solidworks software was used to design the gear models based on Lewis equation which were then tested in ANSYS. Finally the two gears are compared with each other.

Keywords:*Gear, Pinion, Contact Stresses, Finite Element Method, Von- Mises Stress*

INTRODUCTION

Earliest known gears date back to 4^{th} century BC in China [1]. Since then an innumerable advances have been made including the design, materials, uses etc.

The selection of a proper mechanical drive for a given application depends upon a number of factors such as center distance, velocity ratio, shifting arrangement, maintenance considerations and cost [2] although gears provide an advantage over other methods of torque transfer such as traction belt, pulleys etc. as higher amount of torque can be transferred with higher precision.

A gear is the most common type of transmission [3] hence requires a thorough analysis and research.Gear drives are, however, costly and their maintenance cost is also higher. The manufacturing processes for gears are complicated and highly specialized. Gear drives require careful attention for lubrication and cleanliness. They also require precise alignment of the shafts[4]. Both spur and helical gears are made of involute profile, which is a spiraling curve traced by the end

(IJRST) 2017, Vol. No. 7, Issue No. IV, Oct-Dec **e-ISSN: 2249-0604, p-ISSN: 2454-180X**

of an imaginary taut string unwinding itself from a stationary circle called the based circle, which provides an advantage as the contact between two teeth moves along a fixed plane not depending upon then center to center distance of the respective gears providing greater assembly.

Gears fail as a rule because of tooth breakage or degradation of their working surfaces.Toothbreakage is generally caused at the root of the tooth by a momentary overload or inadequate beam strength and surface pitting. To reduce the probability of failure various methods such as providing undercut applying lubrication and increasing the surface hardness of the gear material are used; although it may still fail due to overloading. The scope of this paper is to analyze the bending and dynamic failure due to contact stresses which is done using the finite element method in ANSYS.

A brief approach of modelling and analysis undertaken is as follows:

- We first prepared a model of spur and helical gear using Lewis theory for a given value of torque and power using Solidworks 2017.
- The model was then transferred to ANSYS and analyzed for stresses using Finite Element Method (FEM).
- The results obtained using ANSYS for both the gears werethen compared.

FINITE ELEMENT ANALYSIS

Developed in the 1940s finite element analysis (FEA) divides (discretizes) the structure into small but finite, well-defined, elastic substructures (elements)By using polynomial functions, together with matrix operations, the continuous elastic behavior of each element is developed in terms of the element's material and geometric properties [5].Using this approach Finite Element Method (FEM) is used to numerically solve problems of engineering. Since this is a long and time consuming process software such as ANSYS, NASTRAN, Algor etc. are used. In this ANSYS 12.1 is used for the analysis.

MODELLING

Both the gears were modelled in Solidworks 2017. The material selected for the modeling of the gear is 40Cr4Mo2 due to its high ultimate tensile strength and Brinell hardness. The material property is summarized in the table below.

Material Properties:

40Cr4Mo2	
Description	**Specification**
Modulus of Elasticity(MPa)	206000
Ultimate Tensile Strength(MPa)	700
Poisson's Ratio	0.290
Density(g/cc)	7.85
Brinell Hardness	559

(IJRST) 2017, Vol. No. 7, Issue No. IV, Oct-Dec **e-ISSN: 2249-0604, p-ISSN: 2454-180X**

MODELING OF SPUR GEAR

The gear was designed with the given ratios and values as summed up in the below table.

Assumptions and values for designing Spur GearMesh:

Gear Ratio	4
Pressure AngleΦ(degree)	20
Service Factor (C_s)	1.5
Pitch line Velocity(m/s)	5
No. of teeth on pinion	24
FOS	2
Face width (b)	10*module
Torque(Nm)	190
RPM	2000

Now according to the Lewis equation, module is given by:

$$m = \left[\frac{60 \times 10^6}{\pi} \left\{ \frac{(\mathrm{kW}) C_s (fs)}{z_p n_p C_v \left(\frac{b}{m}\right) \left(\frac{S_{ut}}{3}\right) Y} \right\} \right]^{1/3}$$

Pitch diameter (D): the diameter of the pitch circle from which the gear is design. An imaginary circle, which will contact the pitch circle of another gear when in mesh. For pinion it is given by, $d_p = m * z_p$.

Face width is calculated as:b=10*m.

Addendum: the radial distance from the pitch circle to the top of the gear tooth. Value is equal to the module.

Dedendum: the radial distance from the pitch circle to the bottom of the tooth. Value is equal to 1.25* module.

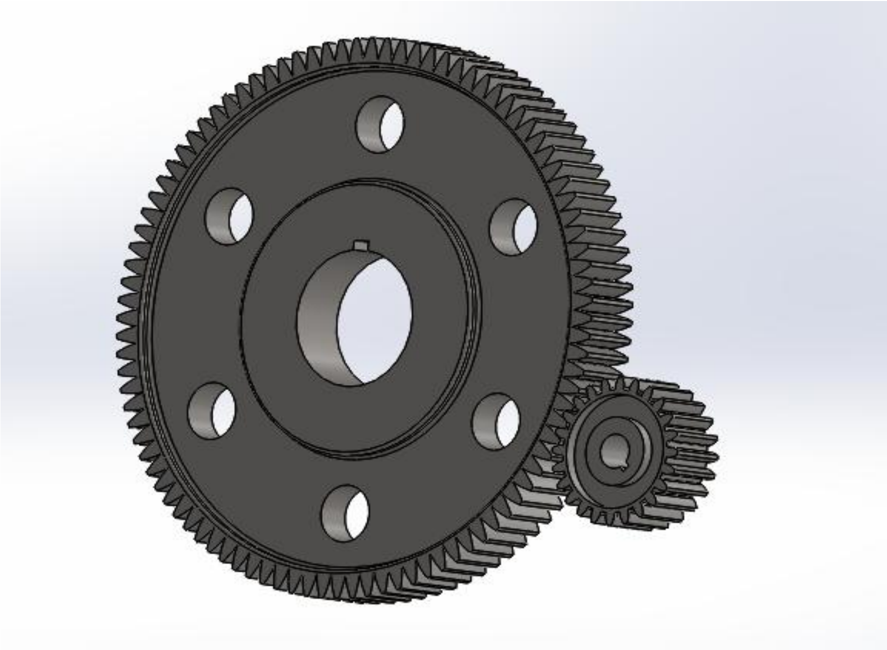
Multiplying the pitch diameter and no. of teeth of the pinion with the gear ratio gives the respective value of the spur gear while the values of Addendum, Dedendum and the face width remains same.

The spur gear and pinion parameter so obtained are summarized in the table below.

Spur Gear Parameters:

Gear Parameters		**Pinion Parameters**	
Number of teeth	96	Number of teeth	24
Pitch Diameter(mm)	480	Pitch Diameter(mm)	120
Pressure Angle(degree)	20	Pressure Angle(degree)	20
Module(mm)	5	Module(mm)	5
Face width(mm)	50	Face width(mm)	50
Addendum(mm)	5	Addendum(mm)	5
Dedendum(mm)	6.25	Dedendum(mm)	6.25
FOS	2	FOS	2

Final Spur Gear Design:



MODELING OF HELICAL GEAR

The design of helical gear is very similar to the spur gear with a slight change in the Lewis equation due to the introduction of the helix angle. The assumptions taken for the helix gear is as follows:

(IJRST) 2017, Vol. No. 7, Issue No. IV, Oct-Dec **e-ISSN: 2249-0604, p-ISSN: 2454-180X**

Gear Ratio	4
Pressure AngleΦ(degree)	20
Helix angleΨdegree)	25
Service Factor (C_s)	1.5
Pitch line Velocity(m/s)	5
No. of teeth on pinion	24
FOS	2
Face width (b)	10*module
Torque(Nm)	190
RPM	2000

Due to the presence of helix angle new factor of transverse module are introduced.

Normal module (m_n)remains the same i.e. 5

Transverse module is given by: $m= m_n/ \cos \Psi$

Pitch diameter of pinion: $d_p= (m_n*z_p)/ \cos \Psi$

Face width is calculated as: b=10*m.

Addendum: the radial distance from the pitch circle to the top of the gear tooth. Value is equal to the module.

Dedendum: the radial distance from the pitch circle to the bottom of the tooth. Value is equal to 1.25* module.

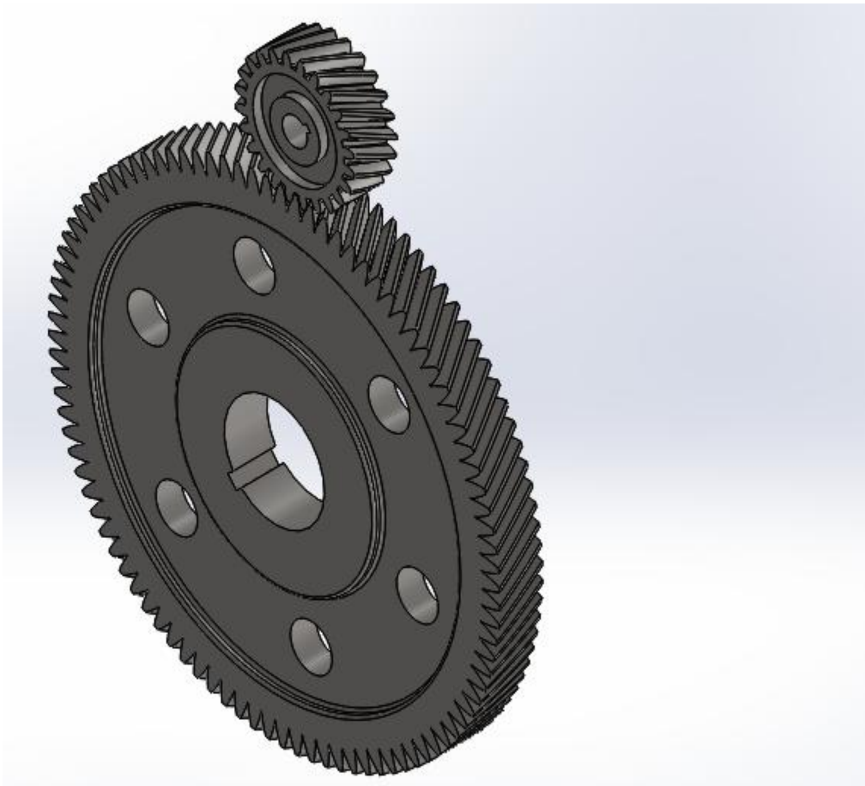
Multiplying the pitch diameter and no. of teeth of the pinion with the gear ratio gives the respective value of the spur gear while the values of Addendum, Dedendum and the face width remains same.

The helical gear and pinion parameter so obtained are summarized in the table below.

HELICAL GEAR PARAMETERS:

Gear Parameters		**Pinion Parameters**	
Number of teeth	96	Number of teeth	24
Pitch Diameter(mm)	529.621	Pitch Diameter(mm)	132.405
Pressure Angle(degree)	20	Pressure Angle(degree)	20
Helix angle(degree)	25	Helix angle(degree)	25
Normal Module(mm)	5	Normal Module(mm)	5
Transverse Module(mm)	5.51	Transverse Module(mm)	5.51
Face width(mm)	50	Face width(mm)	50
Addendum(mm)	5.51	Addendum(mm)	5.51
Dedendum(mm)	6.89	Dedendum(mm)	6.89
FOS	2	FOS	2

Final Helical Gear Design:



FINITE ELEMENT ANALYSIS USING ANSYS

The gear assembly was imported to ANSYS 12.1 and the conditions were then applied to analyze total deformation and equivalent (von-Mises) stress and strain in the pinion and gear for the applied tangential and radial applied moment.

Stress analysis in Spur and Helical Gear and Pinion using ANSYS

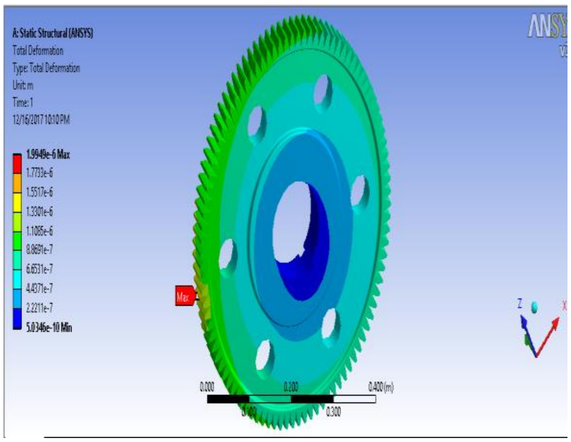


Figure 1 Total Deformation (Spur Gear)

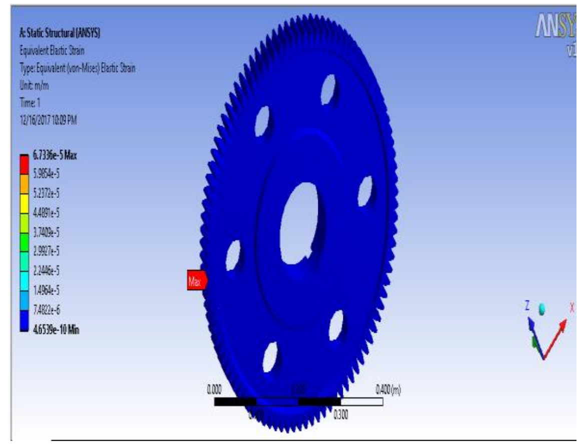


Figure 2 Equivalent Strain (Spur Gear)

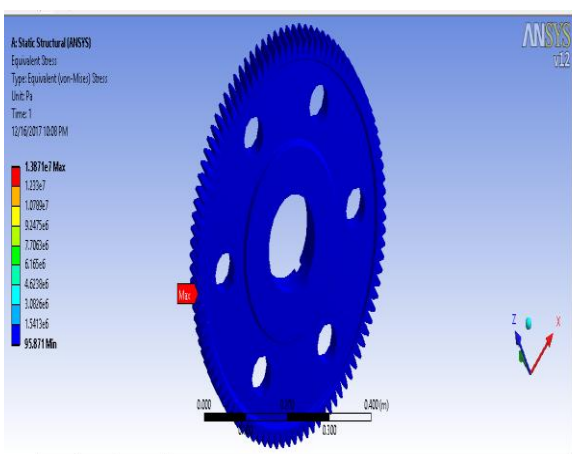


Figure 3 Equivalent Stress (Spur Gear)

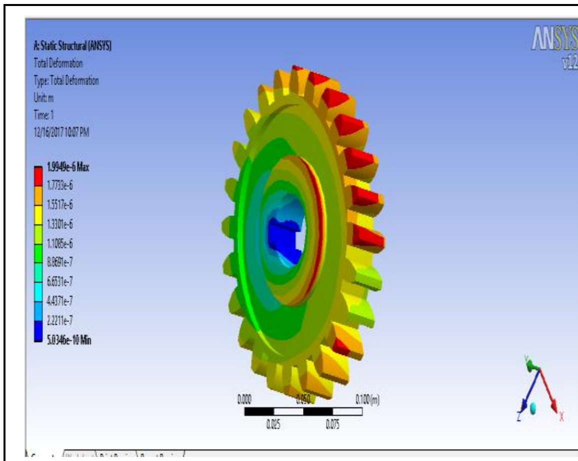


Figure 4 Total Deformation (Spur Pinion)

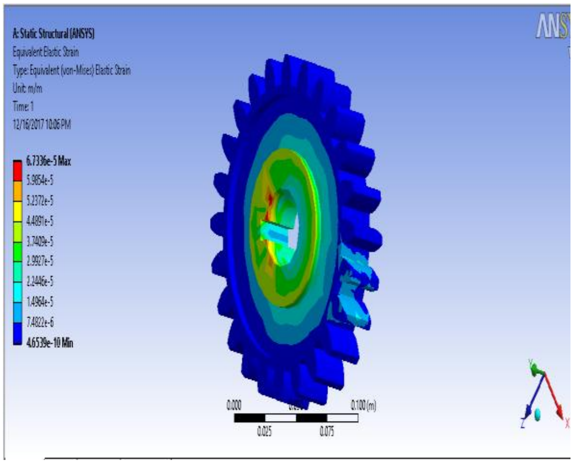


Figure 5 Equivalent Strain (Spur Pinion)

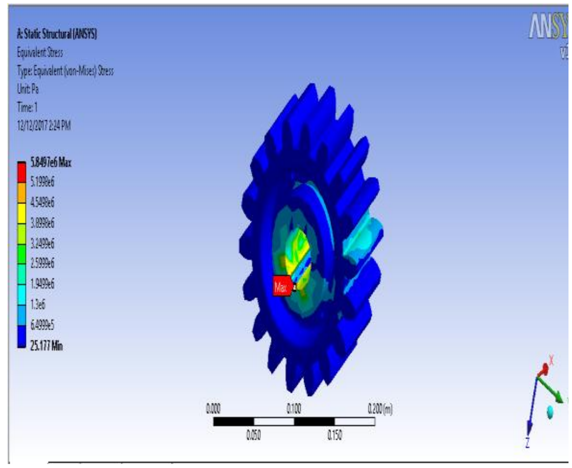


Figure 6 Equivalent Stress (Spur Pinion)

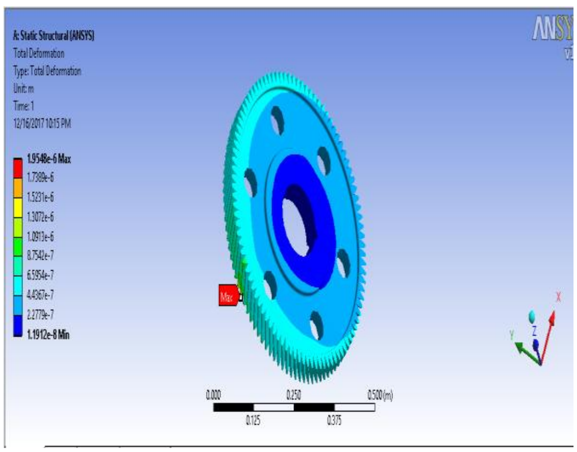


Figure 7 Total Deformation (Helical Gear)

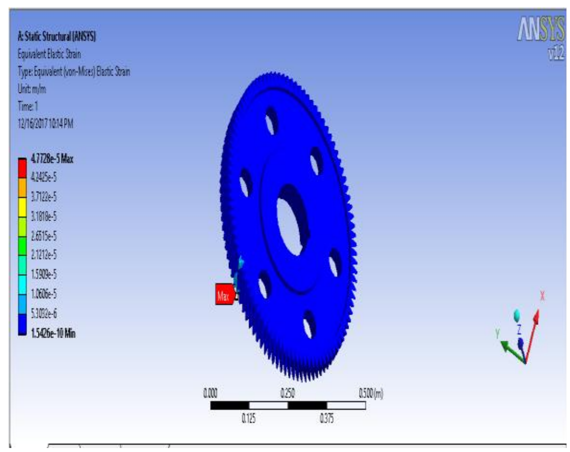


Figure 8 Equivalent Strain (Helical Gear)

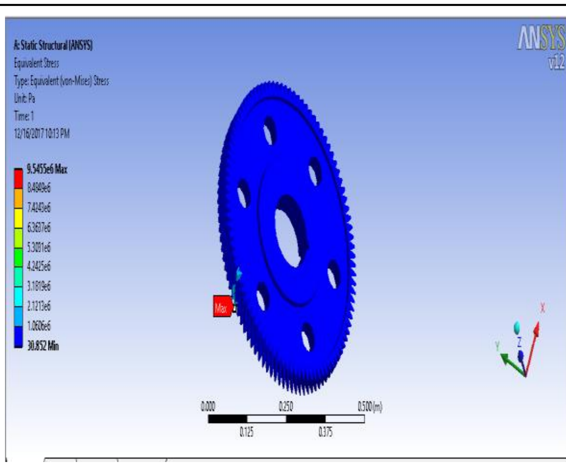


Figure 9 Equivalent Stress (Helical Gear)

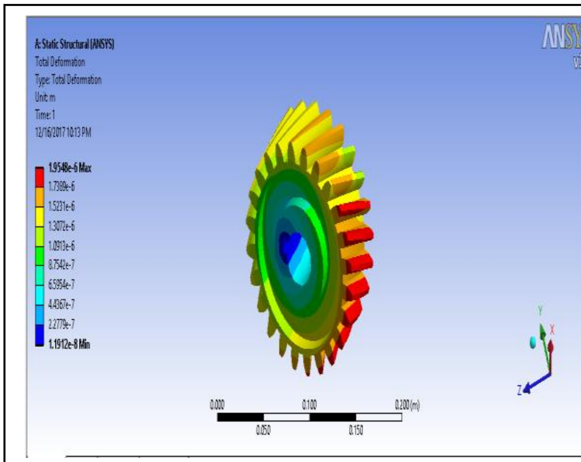


Figure 10 Total Deformation (Helical Pinion)

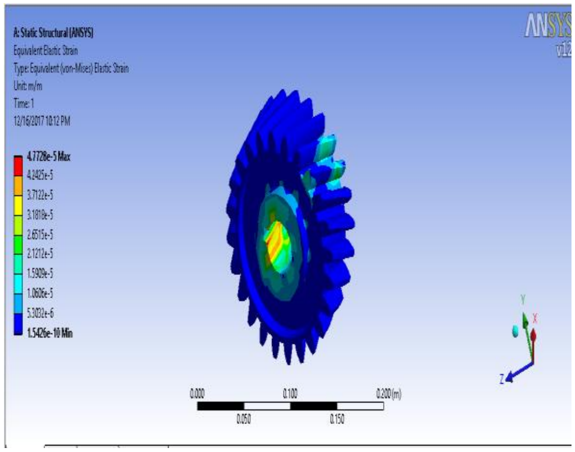


Figure 11 Equivalent Stain (Helical Pinion)

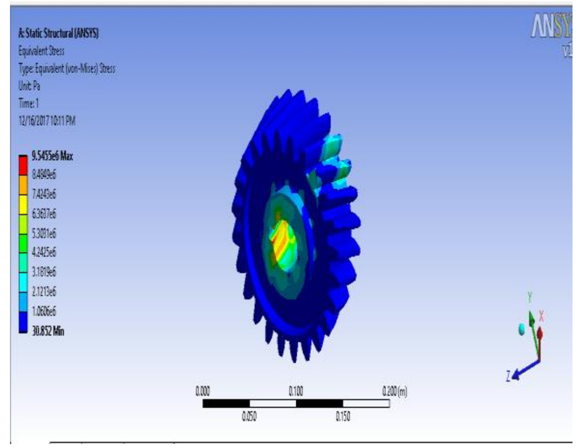


Figure 12 Equivalent Stress (Helical Pinion)

CONCLUSION

In this analysis Finite Element Method was used to predict the deformation, stresses and strain in the helical and spur gear using the ANSYS package.

Comparison of the result is summarized below:

GEAR TYPE	MAX VON MISSES STRESS(ON TOOTH)(Pa)	MAX VON MISSES STRAIN(ON TOOTH)(mm/m)	MAX DEFORMATION(ON TOOTH)(mm)
SPUR GEAR	1.38E7	6.77E-2	1.99E-3
HELICAL GEAR	9.5E6	4.7E-2	1.95E-3

PINION TYPE	MAX VON MISSES STRESS(ON TOOTH)(Pa)	MAX VON MISSES STRAIN(ON TOOTH)(mm/m)	MAX DEFORMATION(ON TOOTH)(mm)
SPUR PINION	3.89E6	2.24E-2	1.99E-3
HELICAL PINION	3.18E6	2.12E-2	1.95E-3

As a result, based on this finding, if same power and moment is applied to spur and helical gear having same no. of teeth on pinion, pressure angle and module, helical gear is preferred.

ACKNOWLEDGMENT

We would like to thank and express our gratitude to Prof. K. Srinivas for his valuable input, Prof. P.K. Jain for his guidance and kind support to write this paper.

REFERENCES

1. Derek J.de Solla Price, On the origin of clockwork, Perpetual motion devices, and the compass ,P 84
2. V.B Bhandari, Design of machine elements 3rd edition, Spur gears, page 646
3. B.M Klebanov, D.M. Barlam,F.E. Nystrom, Machine Elements life and design, gears, page 159
4. R.S.Khurmi, Machine Design,2008
5. R.S.Khurmi (1997), "Theory of Machine", Khanna Publications
6. Rattan S.S (1998), "Theory of Machines", Dhanpat Rai Publication
7. Shigley, J.E. and Mischke, C.R., Standard Handbook of Machine Design, McGraw-Hill, USA, 1996.
8. Shigley, Richard G Budynas , Keith J Nisbett , Mechanical Engineering Design, McGraw-Hill, USA, 2008
9. Pradeep Kumar Singh, ManwendraGautam, Gangasagar and ShyamBihariLal (2014), "Stress Analysis Spur Gear Design By Using ANSYS Workbench", *International Journal of Mechanical Engineering and Robotics Research (IJMERR)* ISSN 2278 – 0149
10. J. Venkatesh, Mr. P. B. G. S. N. Murthy (2014), "Design and Structural Analysis of High Speed Helical Gear Using ANSYS", *International Journal of Engineering Research and Applications (IJERA)* ISSN : 2248-9622
11. Shailendra Kumar Bohidar, Prakash Kumar Sen, MadhuLataDhruwe (2015), "Review of Design and Analysis Of Spur And Helical Gear", *International Journal for Technological Research in Engineering(IJTRE)* ISSN: 2347-4718
12. ModiPrashant (2017), "A Review Paper on Design And Analysis of Helical Gear Using ANSYS, FEM and AGMA Standards", *International Research Journal of Engineering and Technology(IRJET)* ISSN : 2395-0072