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Design, Modeling and Structural Analysis of Helical Gear for ceramic and steel material by using ANSYS

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Abstract*— This project mainly deals with the design and analysis of helical gear with involutes profile. The involutes gear profile is the most commonly used system for gearing today. In an involutes gear, the profiles of the teeth are involutes of a circle. In involutes gear design contact between a pair of gear teeth occurs at a single instantaneous point. Rotation of the gears causes the location of this contact point to move across the respective tooth surfaces. 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 power transmissions. One interesting thing about helical gears is that if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees. Under this project the Helical gear with involutes profile is designed with the help of CATIA V5R16 software , modal and static structural analysis is carried by the ANSYS software .

***Keywords*— Gear Specification, Gear modeling, Modal & Structural analysis**

I. INTRODUCTION

Gears are most commonly used for power transmission in all the modern devices. These toothed wheels are used to change the speed or power between input and output. They have gained wide range of acceptance in all kinds of applications and have been used extensively in the high-speed marine engines. In the present era of sophisticated technology, gear design has evolved to a high degree of perfection. The design and manufacture of precision cut gears, made from materials of high strength, have made it possible to produce gears which are capable of transmitting extremely large loads at extremely high circumferential speeds with very little noise, vibration and other undesirable aspects of gear drives. A gear is a toothed wheel having a special tooth space of profile enabling it to mesh smoothly with other gears and power transmission takes place from one shaft to other by means of successive engagement of teeth. Gears operate in pairs, the smallest of the pair being called “pinion” and the larger one “gear”. Usually the pinion drives the gear and the system acts as a speed reducer and torque converter.

II. HELICAL GEAR SPECIFICATION

Helical gears offer a refinement over spur gears. The leading edges of the teeth are not parallel to the axis of rotation, but are set at an angle. Since the gear is curved, this angling causes the tooth shape to be a segment of a helix. Helical gears can be meshed in a *parallel* or *crossed* orientations. The former refers to when the shafts are parallel to each other; this is the most common orientation. In the latter, the shafts are non-parallel. The angled teeth engage more gradually than do spur gear teeth causing them to run more smoothly and quietly. With parallel helical gears, each pair of teeth first make contact at a single point at one side of the gear wheel; a moving curve of contact then grows gradually across the tooth face to a maximum then recedes until the teeth break contact at a single point on the opposite side. In spur gears teeth suddenly meet at a line contact across their entire width causing stress and noise. Spur gears make a characteristic whine at high speeds and cannot take as much torque as helical gears. Whereas spur gears are used for low speed applications and those situations where noise control is not a problem, the use of helical gears is indicated when the application involves high speeds, large power transmission, or where noise abatement is important. The speed is considered to be high when the pitch line velocity exceeds 25 m/s Quite commonly helical gears are used with the helix angle of one having the negative of the helix angle of the other; such a pair might also be referred to as having a right-handed helix and a left-handed helix of equal angles. The two equal but opposite angles add to zero: the angle between shafts is zero – that is, the shafts are parallel. Where the sum or the difference (as described in the equations above) is not zero the shafts are *crossed*. For shafts *crossed* at right angles the helix angles are of the same hand because they must add to 90 degrees.

a) Helical Gear Nomenclature

Helix angle, ψ

Angle between a tangent to the helix and the gear axis. Is zero in the limiting case of a spur gear.

Normal circular pitch, p_n

Circular pitch in the plane normal to the teeth.

Transverse circular pitch, p

Circular pitch in the plane of rotation of the gear. Sometimes just called "circular pitch". $p_n = p\cos(\psi)$

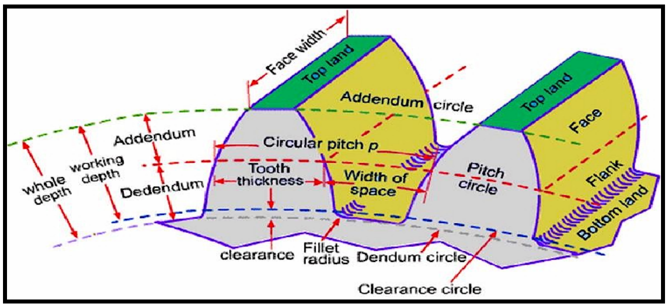

Fig: 1 helical gear nomenclature

Helical gear geometric propotion

p = Circular pitch = $d_g . p / z_g = d_p . p / z_p$

p_n = Normal circular pitch = $p . \cos\beta$

P_n =Normal diametrical pitch = $P / \cos\beta$

p_x = Axial pitch = $p_c / \tan\beta$

m_n =Normal module = $m / \cos\beta$

α_n = Normal pressure angle = $\tan^{-1} (\tan\alpha . \cos \beta)$

β =Helix angle

d_g = Pitch diameter gear = $z_g . m$

d_p = Pitch diameter pinion = $z_p . m$

a =Center distance = $(z_p + z_g) * m_n / 2 \cos \beta$

a_a = Addendum = m

a_f =Dedendum = $1.25 * m$

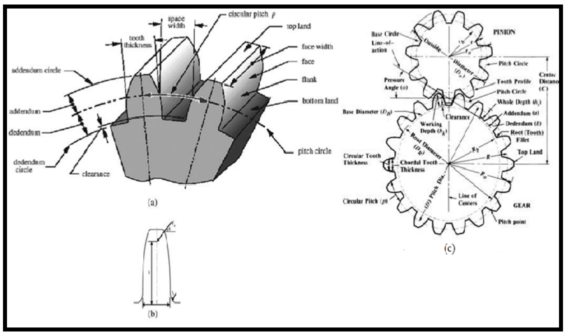

Fig: 2 Tool used in gear geometry

III. MODELING OF HELICAL GEAR USING CATIA

It was developed by Dassault Systèmes in 1981 and it is located in French. Versions of CATIA are V1, V2, V3, V4, V5 and V6 more companies are using from V4 only. Now in the market many companies are using V5R16 and in V5 we have many versions from V5R1 to V5R21.It is a tool based software these tools we call as features, so it is a feature based software .It is a parametric software, parametric mean while designing or after completing the design we can change the parameters of the component. CATIA stand for Computer Aided Three Dimensional Interactive Application. It is a product modeling software can be custom-made via Application Programming Interfaces (API). CATIA V5 features are parametric solid/surface-based wrap up which uses NURBS as the interior surface representation and has quite a lot of workbenches that make available KBE support(1).

Before creating helical gear we should know the specifications of helical gear based on the data and formulas we can design the helical gear.

Specification of Helical gear

rb - base cylinder radius

r - pitch circle radius

rk - outside circle radius

rf - root radius

a - pressure angle (20deg)

m – Modulo (in our example 20) m=p/3.14159 where p is circular pitch 2r=m*z

z - Number of teeth (in our example 30)

The following figure shows complete helical gear model which is generated by using CATIA and then it is retrieved into ANSYS using IGES files.

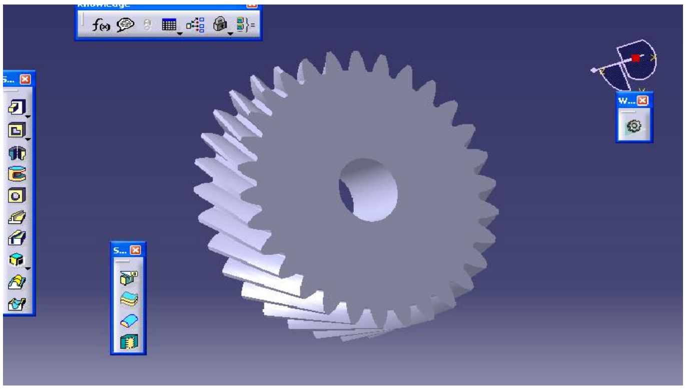

Fig: 3 shows Designed helical gear

IV. ANSYS

The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multi physics analyses with drag-and-drop simplicity. With bi-directional CAD connectivity, powerful highly-automated meshing, a project-level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench platform delivers unprecedented productivity, enabling Simulation Driven Product Development. In this project ANSYS 13.0 played a major role, all the analysis was done with the implementation of ANSYS. Mainly Modal ANSYS and Static Structural ANALYSIS were done in this Project.

Modal Analysis

In this Modal ANSYS, only the deformation of the component was calculated with applying forces and boundary conditions. The deformation will be calculated at different natural frequencies and it was mentioned as different modes. Applying of the boundary conditions will give you the specified directional deformation along with the total deformation.In this section modal analysis is done by using ANSYS and which is shown in result table.

Structural Analysis

After the preprocessing, the solution has to be done. From solution phase, choose the new analysis as static. Then solve the current load step option. The solution will be done. A model is generated using CATIA software and then it is retrieved into ANSYS using IGES files.

In this section the Structural analysis is to be done .The following Figure shows total deformation of gear, the structural analysis of helical gear for aluminum and steel at load 100Mpa, 200Mpa, 300Mpa, 400 Mpa, 500 Mpa.

Structural Analysis for Aluminum

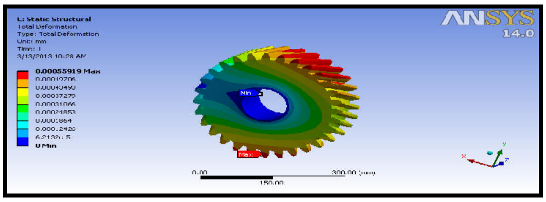

Fig: 4.1 Total deformations at 100 Mpa

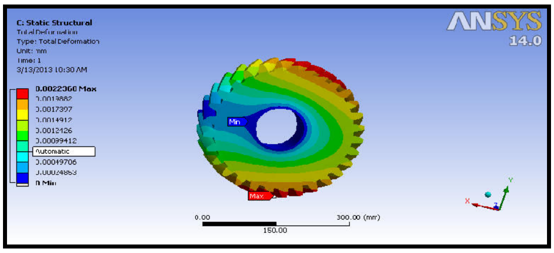

Fig: 4.2 Total deformations at 200 Mpa

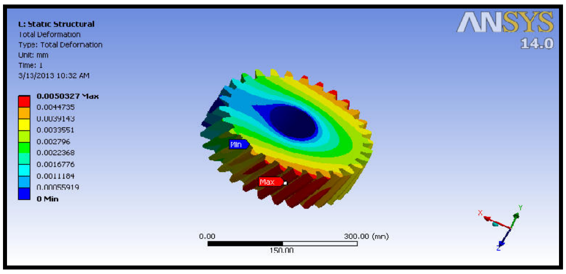

Fig: 4.3 Total deformations at 300 Mpa

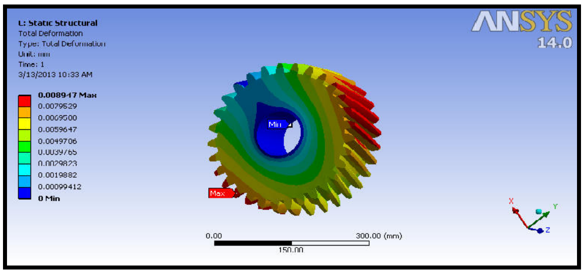

Fig: 4.4 Total deformations at 400 Mpa

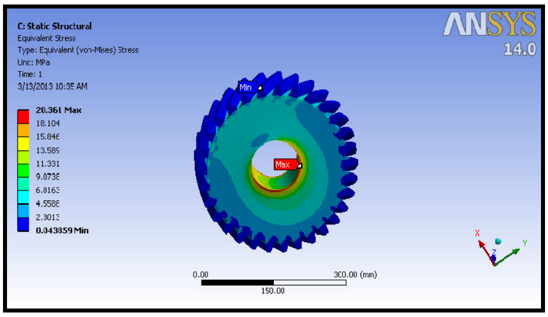

Fig: 4.5 Total deformations at 500 Mpa

Structural Analysis for Structural Steel

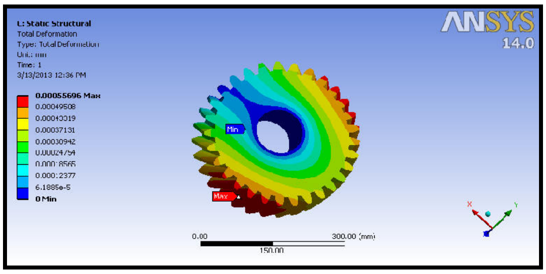

Fig: 4.6 Total deformations at 100 Mpa

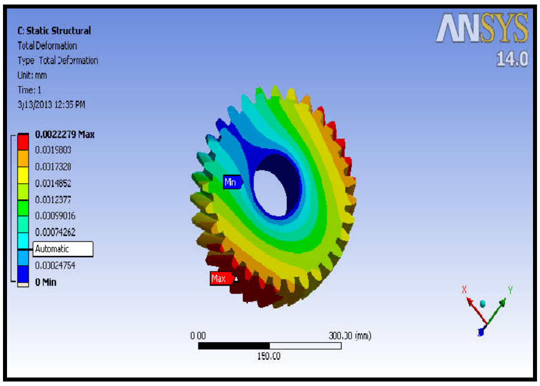

Fig: 4.7 Total deformations at 200 Mpa

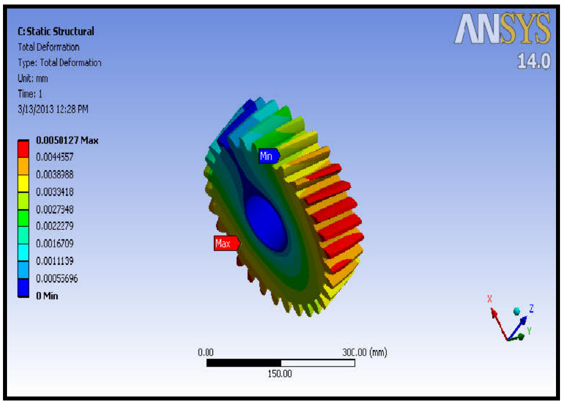

Fig: 4.8 Total deformations at 300 Mpa

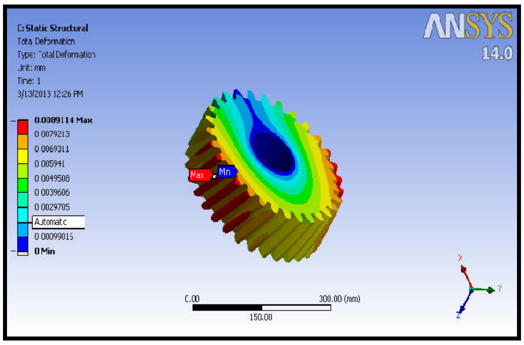

Fig: 4.9 Total deformations at 400 Mpa

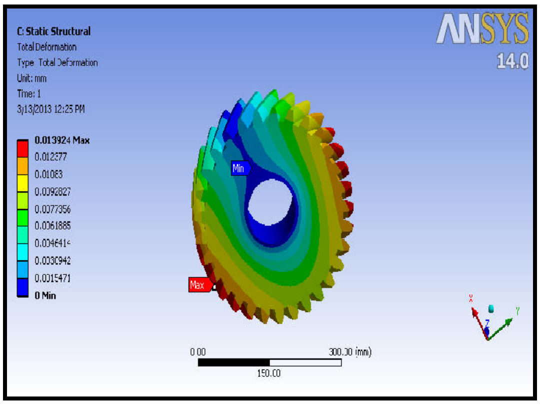

Fig: 4.10 Total deformations at 500 Mpa

V. RESULTS

The analysis is carried out by ANSYS. The following First table shows the modal analysis and second table shows the comparison of equivalent stresses & Total deformation for aluminum and Structural steel.

Table: 1 Modal Analysis

S.No	Equivalent Stresses (Mpa)	Total Deformation (mm)
1	3609.7	7.0487
2	4346.2	10.334
3	4346.7	10.338
4	4668.9	7.1834
5	5243.8	11.19
6	5244	11.189

Table-2 Comparison of equivalent stresses & Total deformation between aluminum and structural steel

S. NO	LOAD	Equivalent stress (Mpa)		Total Deformation (mm)	
		Aluminum	Structural Steel	Aluminum	Structural Steel
1	100	0.81445	2.2572	.00055919	0.000556
2	200	3.2578	9.0288	.0022368	0.002229
3	300	7.3301	20.315	.0050327	0.050127
4	400	13.031	30.115	.008947	0.008911
5	500	20.361	56.43	0.01398	0.013924

VI. CONCLUSION

1. From the tables, it is observed that bending and compressive stresses of ceramics are less than that of the steel.
2. Bending and compressive stresses were obtained theoretically & by using ansys software for both ceramic& steel.
3. Weight reduction is a very important criterion in the helical gears.
4. Hence aluminum material is preferred.

VII. FUTURE SCOPE OF THE WORK

In the present investigation of static analysis, a high speed helical gear is analyzed by fem package ansys. As a future work, modal analysis and harmonic analysis of the gear can be performed to find out the mode

VIII. ACKNOWLEDGMENT

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