ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Contact Analysis of a Helical Gear with Involute Profile

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ABSTRACT

Gears are toothed wheels designed to transmit torque to another gear. The teeth of gears are shaped to minimize wear, vibration, and noise, and to maximize the efficiency of power transmission. One of the main reason of the failure in the gear is bending stresses and vibrations. But the stresses are occurred due to the contact between two gears when power transmission process is started. Due to contact between two gears stresses are evolved, which are determined by using analyzing software called ANSYS. Finding stresses has become most popular in research on gears to minimize the vibrations, bending stresses and reducing the mass percentage in gears. A two-wheeler gear component is considered for design and analysis where improvements are made to get maximized efficiency. Also, stresses are used to find the optimum design in the gears which reduces the chances of failure. In this project, two-wheeler gear model is generated by using CATIAV5 and ANSYS is used for numerical analysis. The analytical study is based on Hertz's equation. Study is conducted by varying the materials of the teeth and to find the change in Contact stresses between gears.

1. 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 can transmit 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.

2.1 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". $p_n = p\cos(\psi)$

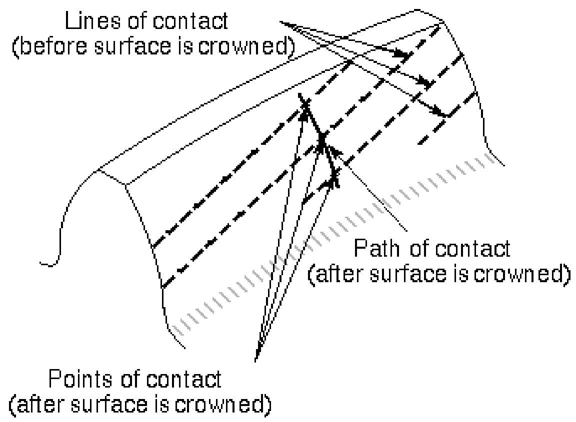

Figure 1: GEAR TEETH CONTACT PATH

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2.2 Helical Gear geometrical proportions

- 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 = $1.25 * m$

2.3 Addendum

The addendum is the height by which a tooth of a gear projects beyond (outside for external, or inside for internal) the standard pitch circle or pitch line; also, the radial distance between the pitch diameter and the outside diameter.

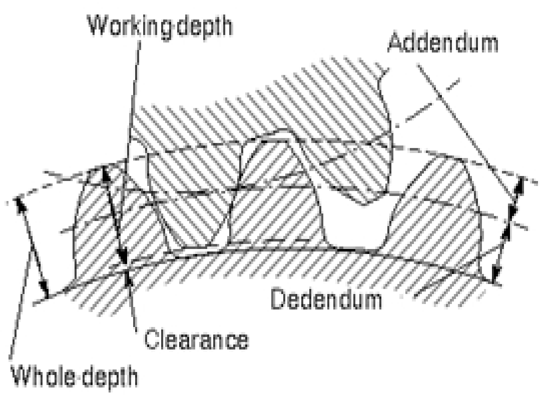

Figure 2: Addendum angle figure

2.3.1 Addendum angle

Addendum angle in a bevel gear, is the angle between elements of the face cone and pitch cone.

2.3.2 Addendum circle

The addendum circle coincides with the tops of the teeth of a gear and is concentric with the standard (reference) pitch circle and radially distant from it by the amount of the addendum. For external gears, the addendum circle lies on the outside cylinder while on internal gears the addendum circle lies on the internal cylinder

2.4 Dedendum angle

Dedendum angle in a bevel gear, is the angle between elements of the root cone and pitch cone.

2.4.1 Equivalent pitch radius

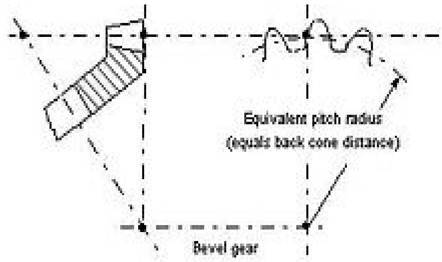

Figure 3: Equivalent Pitch radius

Equivalent pitch radius is the radius of the pitch circle in a cross section of gear teeth in any plane other than a plane of rotation. It is properly the radius of curvature of the pitch surface in the given cross section. Examples of such sections are the transverse section of bevel gear teeth and the normal section of helical teeth.

3. CONTACT STRESS

Contact stress causes deformation, plastic or elastic. The contact area will change depending on the magnitude of the contact stress. Therefore, it is very important to calculate the actual stress at the point of contact, the so-called contact stress.

3.1 CHARACTERISTICS OF CONTACT STRESSES

1. Represent compressive stresses developed from surface pressures between two curved bodies pressed together;

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2. Possess an area of contact. The initial point contact (spheres) or line contact (cylinders) become area contacts, as a result of the force pressing the bodies against each other;
3. Constitute the principal stresses of a triaxial (three dimensional) state of stress;
4. Cause the development of a critical section below the surface of the body;
5. Failure typically results in flaking or pitting on the bodies' surfaces.

3.1.1 TWO DESIGN CASES

Two design cases will be considered,
1. Sphere – Sphere Contact (Point Contact _ Circular Contact Area)
2. Cylinder – Cylinder Contact (Line Contact _ Rectangular Contact Area)

3.1.2 SPHERE – SPHERE CONTACT

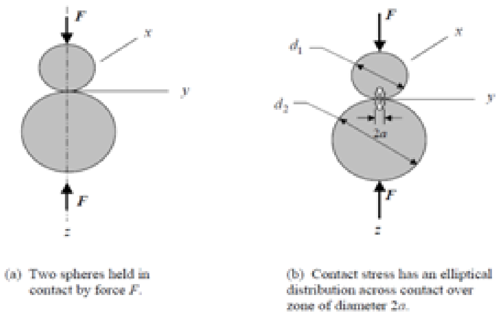

Figure 4: Sphere contact

3.1.3 CYLINDER–CYLINDER CONTACT

Consider two solid elastic cylinders held in contact by forces F uniformly distributed along the Cylinder length l.

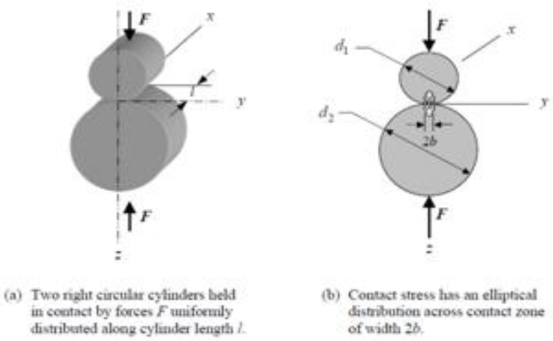

Figure 5: Cylinder Contact

4. Design of Helical gear and its dimensions:

There are Five General Procedures to Create an Involute Curve.

The sequence of procedures employed to generate the involute curve are illustrated as follows: -
1. Set up the geometric parameters Number of teeth
   - Diametric pitch
   - Pressure angle
   - Pitch diameter
   - Face width
   - Helix angle
2. Create the basic geometry such as addendum, dedendum and pitch circles in support of the gear tooth.
3. Define the involute tooth profile with datum curve by equation using cylindrical coordinate system.
4. Create the tooth solid feature with a cut and extrusion. Additional helical datum curves are also required in this step to sweep helical gear teeth.
5. Pattern the tooth around the center line axis.

The key specifications of geometrical parameters and the helical gear model developed by using the above procedures in CATIA V5 R20 are shown in and Table 1 respectively.

No. of teeth	25
Diametric pitch	60mm
Pressure angle	20 degree
Addendum	1/p mm
Dedendum	1.25/p mm
Helix angle	12 degree

Table 1: Gear dimensions

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Pitch dia D= 60 mm,
No. of teeth N=25,
Diametric pitch p=N/D=25/60
=0.416 mm,
Base circle dia Db=D*cos (pi),

(where pi=20°, pressure angle)
=60*cos (20)
=56.38mm
Addendum a=1/p =1/o.416 =2.4mm
Outside Dia Do=D+2a=60+2(2.4)
=64.8mm,
Circular pitch p =3.1416/p =3.1416/0.416
=7.55 mm,
Whole depth ht=2.157/p=2.157/0.416
=5.18mm
Deddendum b=ht-a=5.18-2.4=2.78mm,
Root dia Dr=D-2b=60-2(2.78),
54.4mm.

5. CATIA

Catia Mechanical design solution will improve our design productivity. Catia is a suit of programs that are used in design, analysis, and manufacturing of a virtually unlimited range of the product.

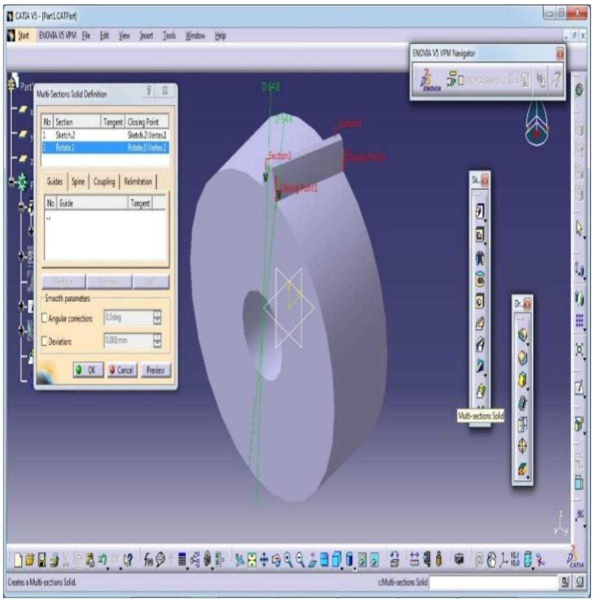

Figure 6: helical gear teeth

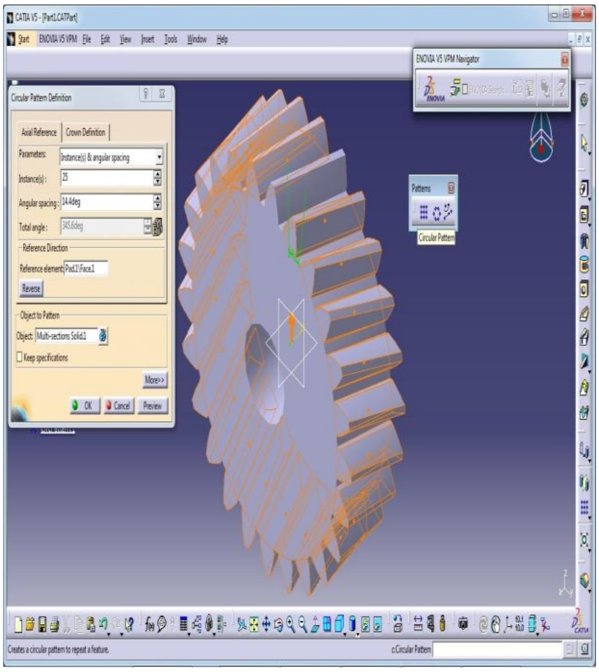

Figure 7: helical gear teeth generation

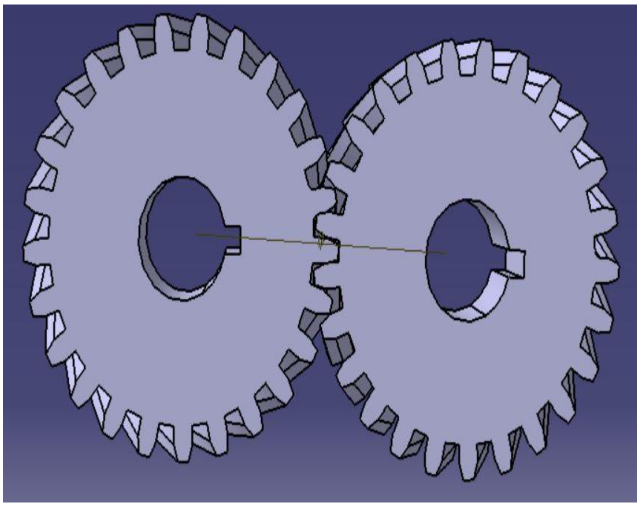

Figure 8: Helical gear assembly with driving and driven gears

6. ANSYS

Dr. John Swanson founded ANSYS. Inc in 1970 with a vision to commercialize the concept of computer simulated engineering, establishing himself as one of the pioneers of Finite Element Analysis (FEA).ANSYS analysis and simulation tools give customers ease-of-use, data compatibility, multi-platform support and coupled field multi-physics capabilities.

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6.1 MESHING:

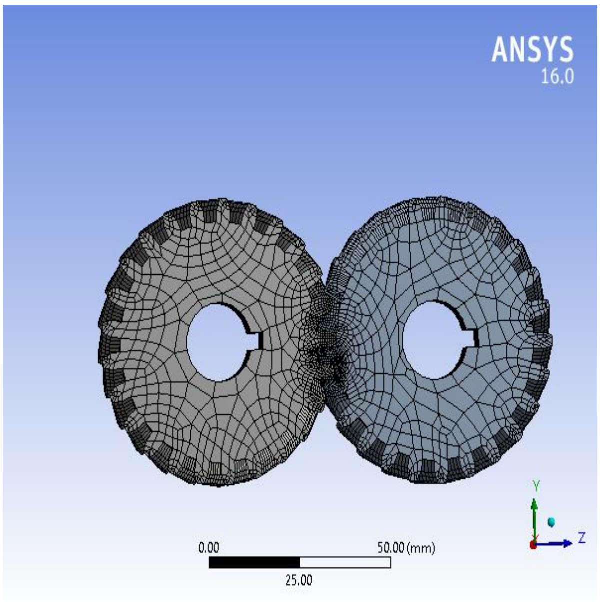


Figure 9: Meshing for Helical gears

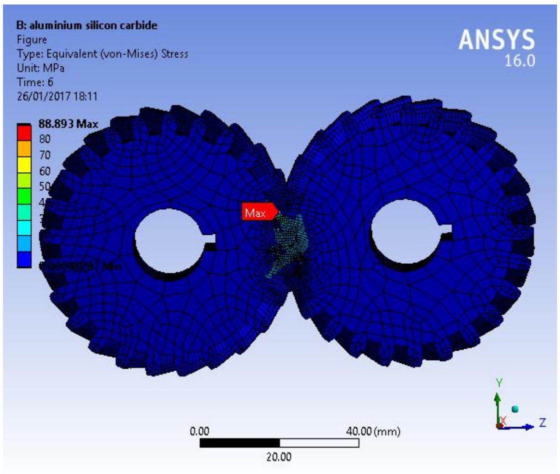


Figure 101: Stress results for Aluminium silicon carbide

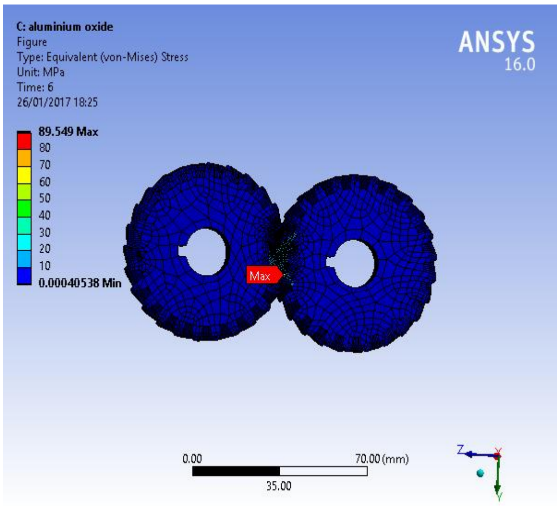


Figure 11: Equivalent stresses induced in Helical gear aluminium oxide material

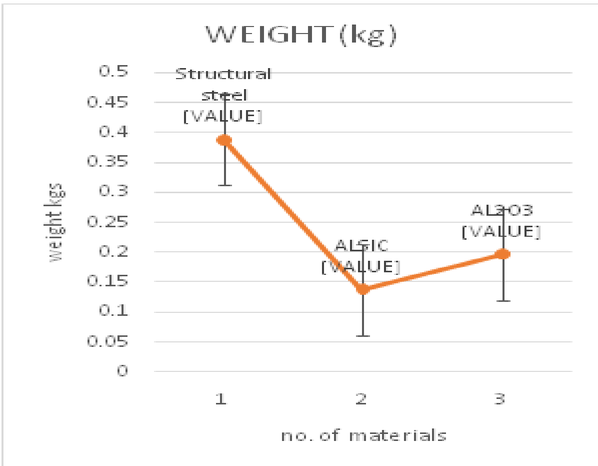
7. RESULTS:

MATERIAL	TOTAL DEFORMATION (mm)	WEIGHT (kg)	STRESS (MPa)
Structural steel	0.0051282	0.38937	88.852
Aluminium silicon carbide(ALSIC)	0.014568	0.1374	88.893
Aluminium oxide(AL203)	0.00027099	0.19633	89.549

Table 3: Results obtained for different materials of Helical Gear Contact analysis

ALSIC COMPOSITION:

Density	2.77e-006 kg mm^-3
Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat	8.75e+005 mJ kg^-1 C^-1
Tensile Ultimate Strength MPa	310
Tensile Yield Strength MPa	280



GRAPHS 1: Weight results obtained for all contact analysis of helical gears

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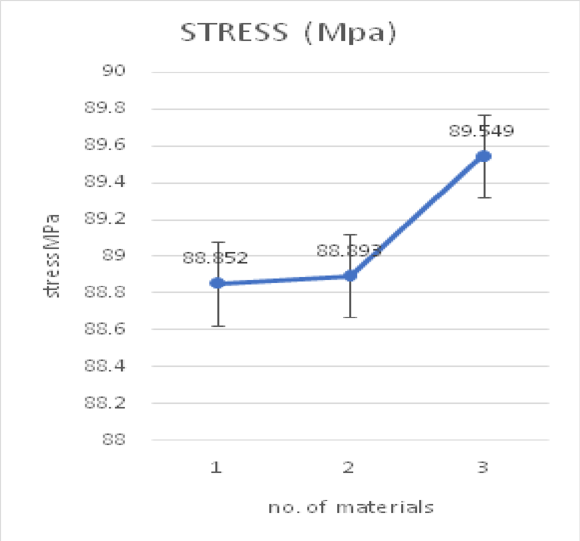

GRAPHS 2: Stresses induced in the analysis for various material types

8. CONCLUSION

In this paper, we optimized the weight of Helical gear assembly using different materials and simulated the contact stress analysis results. Analysis of the gear assembly is carried out by varying materials with structural steel, aluminium silicon carbide and aluminium oxide. As the strength of the gear tooth is important parameter to resist failure, we focus on the materials with maximum strength. Based on the result from the contact stress analysis the gear with least weight is selected. Optimization of the Helical gear assembly is done by reducing the weight with in allowable contact stresses.

Stainless steel cost = 0.25$ per kg
Aluminium silicon carbide = 1.80$ per kg
Alumina (Al_2O_3) = 1.90$ per kg

Comparing all the tabulated and graphed results, it can be concluded that using of Aluminium materials optimizes the weight and increases the performance of the gear components. Having analyzed the Helical gear with Aluminium silicon carbide and Aluminium oxide, a better weight reduction with minimum stresses and price can be obtained with the use of Aluminium Silicon Carbide (ALSiC).

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