International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 14
November 2017

Design And Analysis Of Helical Gear Tooth

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ABSTRACT: Gears are mainly used to transmit the power in mechanical power transmission systems. These gears play a most predominant role in many automobile and micro electro mechanical systems. One of the main reason of the failure in the gear is bending stresses and vibrations also to be taken into account. But the stresses are occurred due to the contact between two gears while power transmission process is started. Due to meshing between two gears contact 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 also reducing the mass percentage in gears. These stresses are used to find the optimum design in the gears which reduces the chances of failure. The model is generated by using CATIAV5 and ANSYS is used for numerical analysis. The analytical study is based on Hertz's equation.

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.

1.1 Advantages of Gear Drives:

The following are the advantages of the gear drives compared to other drives.

- Gear drives are more compact in construction due to relatively small centre distance.
- Gears are used where the constant velocity ratio is desired.
- Gears can be operated at higher speeds.
- It has higher efficiency.
- Reliability in service.
- It has wide transmitted power range due to gear shifting facility.
- Gear offers lighter loads on the shafts and bearings.
- Gear can change the direction of axis of rotation.

1.2 DISADVANTAGES OF GEAR DRIVES:

- Not suitable for the shafts which are at longer center distance.
- Manufacturing is complex. It needs special tools and equipment.
- Require perfect alignment of shafts.
- Requires more attention to lubrication.
- The error in cutting teeth may cause vibration and noise during operation.

1.3 General Classification of gears:

Although the types and the modalities of gear design vary widely for mechanical power transmission, gears are generally categorized into the following types.

1.3.1 According to the position of axes of the shafts:

The axes of the two shafts between which the motion is to be transmitted, may be

(a) Parallel, (b) Intersecting, and (c) Non-Intersecting and Non-parallel

1.3.2 According to the peripheral velocity of the gears:

The gears, according to the peripheral velocity of the gears, may be classified as: (a) Low Velocity, (b) Medium Velocity and (c) High Velocity.

1.3.3 According to type of gearing:

The gears, according to the type of gearing may be classified as (a) External Gearing, (b) Internal Gearing, (c) Rack and Pinion.

1.3.4 According to the position of the teeth on the gear surface:

The teeth on the gear surface may be (a) Straight (b) Inclined (c) Curved.

1.3.5 According to the position of axes of the shafts:

Spur Gears: Spur gears are the simplest and most common type of gear. Their general form is a cylinder or disk. The teeth project radially, and with these "straight-cut gears", the leading edges of the teeth are aligned parallel to the axis of rotation. These gears can only mesh correctly if they are fitted to parallel axles. Spur gears on non-parallel shafts can mesh, but only point contact will be achieved, not line contact across the full width of the tooth; also the length of the path of contact may be too short. This causes impact stress and noise. Spur gears make a characteristic whine at high speeds and can not take as much torque as helical gears because their teeth are receiving impact blows.

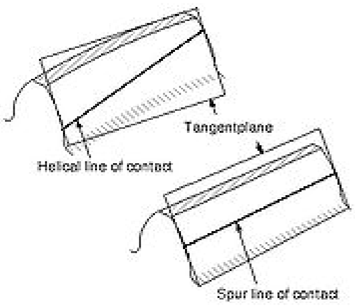

Fig: 1.Figure showing different lines of contact

Helical Gears: 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. The angled teeth engage more gradually than do spur gear teeth. This causes helical gears to run more smoothly and quietly than spur gears. Helical gears also offer the possibility of using non-parallel shafts.

With parallel helical gears, each pair of teeth first makes contact at a single point at one side of the gear wheel; a moving curve of contact then grows gradually across the tooth face. It may span the entire width of the tooth for a time. Finally, it recedes until the teeth break contact at a single point on the opposite side of the wheel. Thus force is taken up and released gradually.

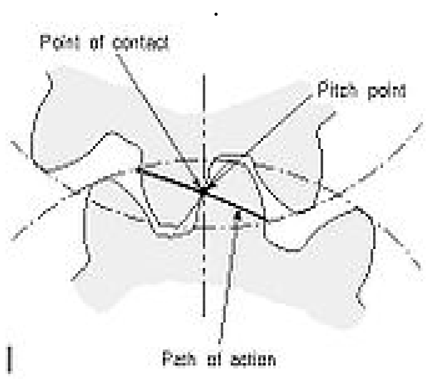

Fig: 2.Pitch point

Double Helical Gears:
Double helical gears, also known as herringbone gears, overcome the problem of axial thrust presented by 'single' helical gears by having teeth that set in a 'V' shape. Each gear in a double helical gear can be thought of as two standards, but mirror image, helical gears stacked. This cancels out the thrust since each half of the gear thrusts in the opposite direction. They can be directly interchanged with spur gears without any need for different bearings.

Bevel Gears:
Bevel gears are essentially conically shaped, although the actual gear does not extend all the way to the vertex (tip) of the cone that bound it. With two bevel gears in mesh, the vertices of their two cones lie on a single point, and the shaft axes also intersect at that point. The angle between the shafts can be anything except zero or 180 degrees. Bevel gears with equal numbers of teeth and shaft axes at 90 degrees are called miter gears.

Fig:3 Bevel Gears

Worm Gears:

Worm gear is a special case of a spiral gear in which the larger wheel usually has hollowed or concave shape such that a portion of the pitch diameter of the other gear is enveloped on it. The smaller of the two wheels called the worm which also has a large spiral angle. The shafts may have any angle between them, but normally it is 90°.The system can be non-throated, single throated, double throated types.

Hypoid Gears:

These are similar to spiral bevel gears, but have non-intersecting axes i.e. the axes of pinion is offset relative to the gear axis. However the plane containing the two axes is usually at right angles to each other.

II. GEOMETRY OF HELICAL GEARS

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 can not 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.

III. CATIA V5 R20 (Computer Aided Three Dimensional Interactive Application)

As the world’s one of the supplier of software, specifically intended to support a totally Integrated product development process. Dassault Systems (DDS) in recognized as a strategic partner which can help a manufacturer to the turn a process into competitive advance, greater market share and higher profits and industrial and mechanical design to functional simulation manufacturing and information management.

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 virually unlimited range of the product.

“ Feature based” means that we create parts and assemblies by defining feature like extrusion sweeps, cuts, holes, round and so on instead of specifying low level geometry like lines, areas circles. This means that the designer can think of the computer model at a very high level and leave all low geometry detail for Catia to figure out.

“Parametric” means that the physical shape of the part as assembly is driven by the value assigned to the attributes of its features. We may define or modify a feature dimension or other attributes at any times. Any changes will automatically propagate through the model.

“Solid Modeling “ means that the computer model we create is able to contain all the information that a real solid object would have. It has volumes and therefore, if you provide a value for the density of the material it has mass and inertia.

3.1 Benefits of CATIA:

1. It is much faster and more accurate than any CAD system.

2. Once design is complete, 2-D and 3-D views are readily obtainable.

3. The ability to change in late design process is possible.

4. It provides a very accurate representation of model specifying all the other dimensions hidden geometry etc.

5. It provides a greater flexibility for change, for example, if we like to change the dimensions in design assembly, manufacturing etc. will automatically change.

6. It provides clear 3-D Model which are easy to visualize or model created and & it Also decrease the time required for the assembly to a large extent.

3.2 CATIA Applications

Feature and Capabilities

Commonly referred as a 3D product lifecycle management software suite. CATA support multiple stages of product development (CAx). The stages range from conceptualization, through design (CAD) and manufacturing (CAM) until analysis (CAE), as of 2007 the latest release is V5 release 18(V5R 18)

3.2.1 Industries using CATIA:

CATIA is widely used through the engineering industry, especially in the automotive and aerospace sectors, CATIA V4, VATIA V5 are the dominant systems.

3.2.2 AEROSPACE:

The Boeing Company used CATIA to develop its 777 airliner, and is currently using CATIA V5 for the 787 series aircraft. European aerospace giant airbus has been using CATIA since 2001. In 2006 airbus announced that the reduction of it airbus 380 using catia. Canadian aircraft maker bombardier aerospace has done all if its designing on catia

3.2.3 AUTOMOTIVE

Automotive Companies that use CATOA to varying degrees are BMW. Porsche, Daimler, Chrysler, Audi, Volvo, fiat, Gestamp Automaocian, benteler AG PSA, Pevgcot Citroen, Penault, Toyota, Honda, ford Scania, Hyundai proton (company), TATA motors and Mahindra Goodyear uses it in making tires for automotive and aerospace and also uses a customized CATIA for its design and development. All automotive companies sue CATIA for car structures door beams IP supports, bumber beams root rails, side rails, body components because CATIA is very good in surface creation and computer representation of surfaces.

3.2.4. SHIPBULIDING:

Dassault system has begun serving shipbuilders with CATIA V5 release 8. which includes special features useful to shipbuilders, GD Electric boat used CATIA to design the latest fast attack submarine class for the united states Navy, the virgina class, Northrop Grumman Newport news also used CATIA to design the Gerald R.Ford class of supper carries for us navy.

3.5 MODULES IN CATIA

- **Sketch module:**

Sketcher module enables us to create sections. Sketcher technique is used in many areas of Catia. Using Sketcher mode, we can create geometry without regard to the exact relationships between parts of sketch or the cxact value of dimensions, when we generate the sections, Catia makes explicit assumptions. For example if we draw nearly horizontal line, it becomes exactly horizontal and all these assumptions are displayed graphically.

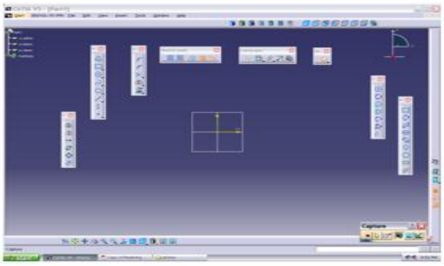

Fig.3.5.1

IV.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

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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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
6. The key specifications of geometrical parameters and the helical gear model developed by using the above procedures in Pro/Engineer are shown in and Table 4.1 and Figure 4.1 respectively.

Number of teeth	25
Diametral pitch (p) [mm]	60
Pressure angle	20 degree
Addendum [mm]	1/p
Dedendum [mm]	1.25/p
Helix angle	12 degree

4.1 HELICAL GEAR RELATIONS AND DIMENSIONS

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=20^0, 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

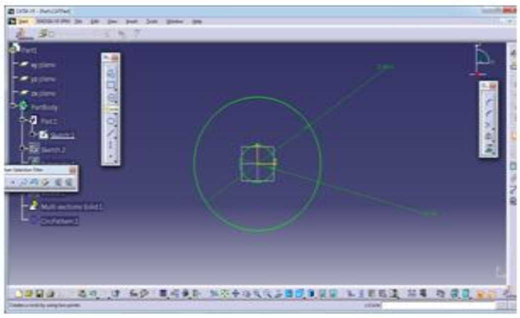
=5.18mm

Deddendum b=ht-a=5.18-2.4=2.78mm,

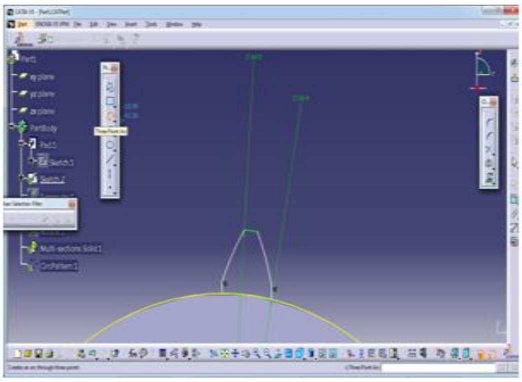
Root dia Dr=D-2b=60-2(2.78),

54.4mm.

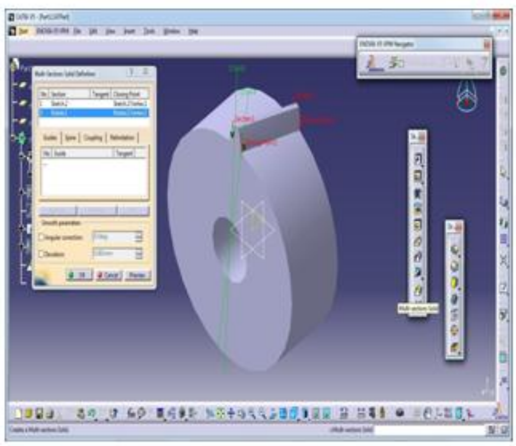
4.2 THE FOLLOWING ARE THE PICS OF SEQUENCIAL DESIGN PROCEDURE IN CATIA



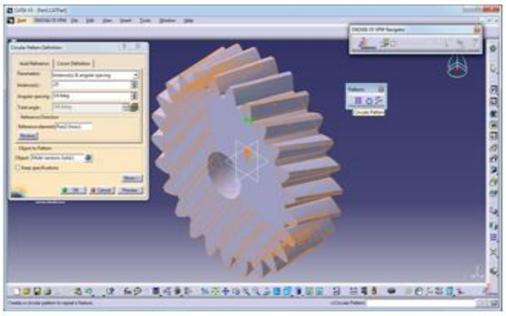
4.2.1 helical gear base diagram



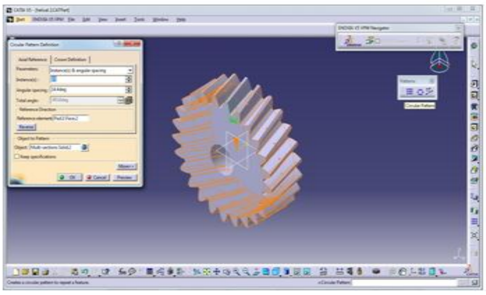
4.2.2 helical gear involute



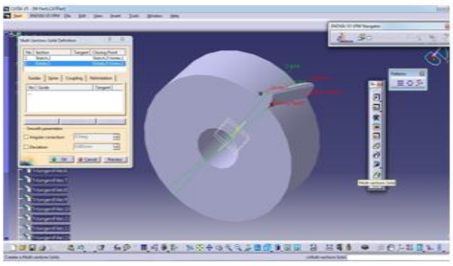
4.2.3 helical gear teeth



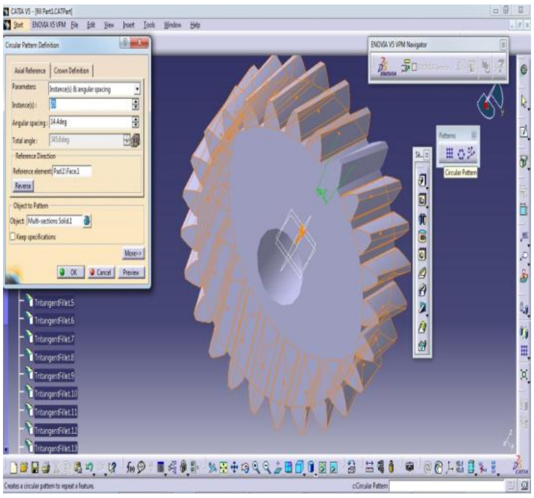
4.2.4 helical gear teeth generation



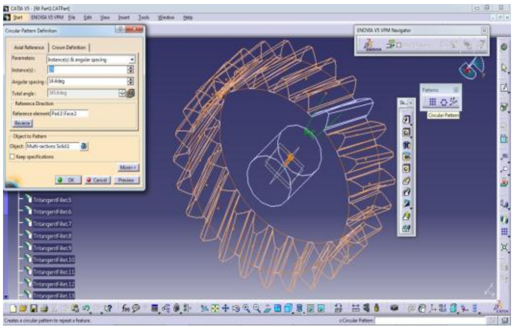
4.2.5 driven helical gear teeth generation



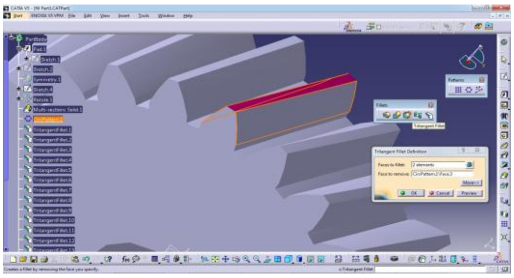
4.2.6 driving helical gear with fillet...teeth generation



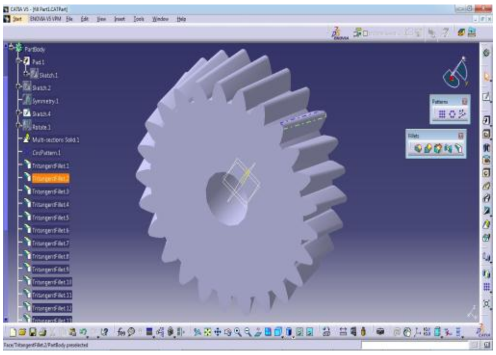
4.2.7 driving helical gear with fillet...teeth generation using circular pattern



4.2.8 driving helical gear with fillet...teeth generation using circular pattern (wireframe)



4.2.9 driving helical gear with fillet



4.2.10 driving helical gear with fillet complete

V. FINITE ELEMENT METHODS

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and industries. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problems rather than exact closed form solution.

It is not possible to obtain analytical mathematical solutions for many engineering problems. An analytical solutions is a mathematical expression that gives the values of the desired unknown quantity at any location in the body, as consequence it is valid for infinite number of location in the body. For problems involving complex material properties and boundary conditions, the engineer resorts to numerical methods that provides approximate, but acceptable solutions.

The fundamental areas that have to be learned for working capability of finite element method include:

- **MATRIX ALGEBRA.**
- **SOLID MECHANICS.**
- **VARIATION METHODS.**
- **COMPUTER SKILLS.**

Matrix techniques are definitely most efficient and systematic way to handle algebra of finite element method. Basically matrix algebra provides a scheme by which a large number of equations can be stored and manipulated. Since vast majority of literature on the finite element method treats problems in structural and continuum mechanics, including soil and rock mechanics, the knowledge of these fields became necessary. It is useful to consider the finite element procedure basically as a Variation approach. This conception has contributed significantly to the convenience of formulating the method and to its generality.

VI. ANSYS RESULTS

MILD STEEL FOR 10N FORCE:

Project

First Saved	Saturday, February 25, 2017
Last Saved	Saturday, February 25, 2017
Product Version	16.0 Release
Save Project Before Solution	No
Save Project After Solution	No

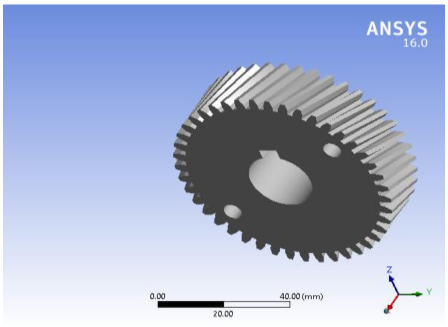


TABLE 8
Model (A4) > Static Structural (A5) > Loads

Object Name	*Displacement*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	6 Faces	2 Faces
Definition		
Type	Displacement	Force
Define By	Components	
Coordinate System	Global Coordinate System	
X Component	Free	0. N (ramped)
Y Component	0. mm (ramped)	10. N (ramped)
Z Component	0. mm (ramped)	0. N (ramped)
Suppressed	No	

FIGURE 3
Model (A4) > Static Structural (A5) > Displacement

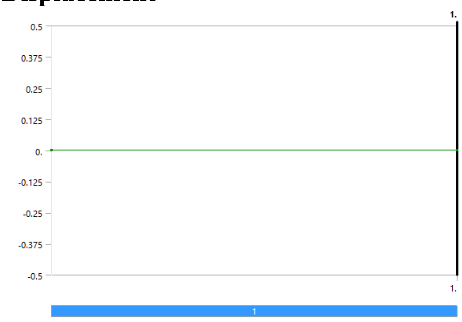
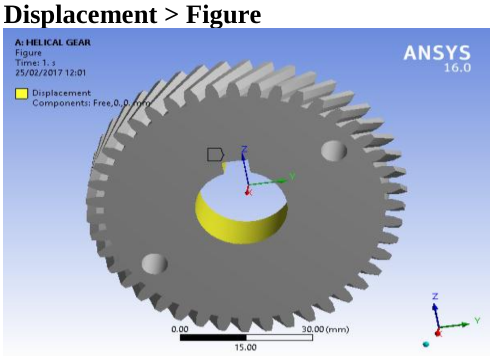


FIGURE 4
Model (A4) > Static Structural (A5) > Displacement > Figure



e-ISSN: 2348-6848
p-ISSN: 2348-795X
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FIGURE 5
Model (A4) > Static Structural (A5) > Force

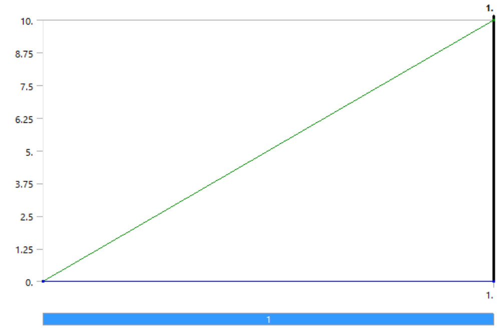
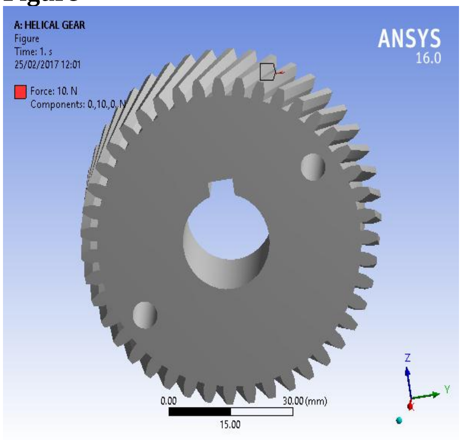


FIGURE 6
Model (A4) > Static Structural (A5) > Force > Figure



Solution (A6)

TABLE 9
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
Post Processing	
Calculate Beam Section Results	No

TABLE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*	*Maximum Principal Stress*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent (von-Mises) Stress	Maximum Principal Stress	Total Deformation
By	Time		

Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	4.0299e-006 MPa	-0.16684 MPa	4.027e-011 mm
Maximum	0.50226 MPa	0.61948 MPa	3.5027e-005 mm
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

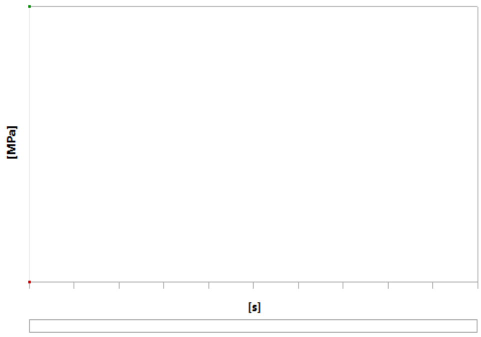


TABLE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	4.0299e-006	0.50226

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress > Figure

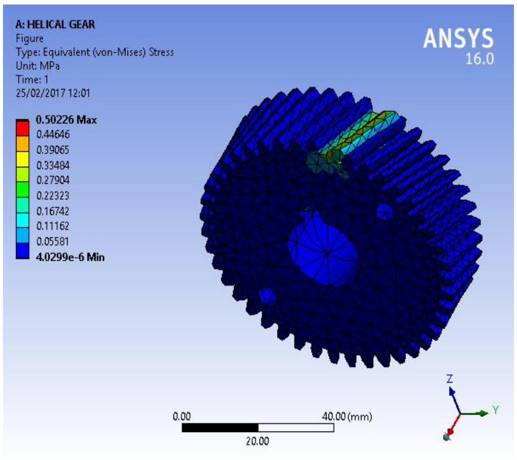


FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Principal Stress

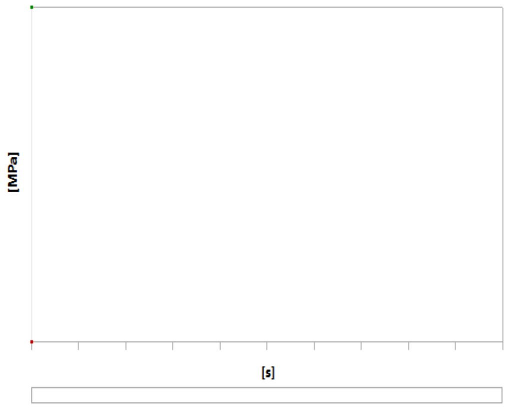


TABLE 13
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Principal Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	-0.16684	0.61948

FIGURE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Principal Stress > Figure

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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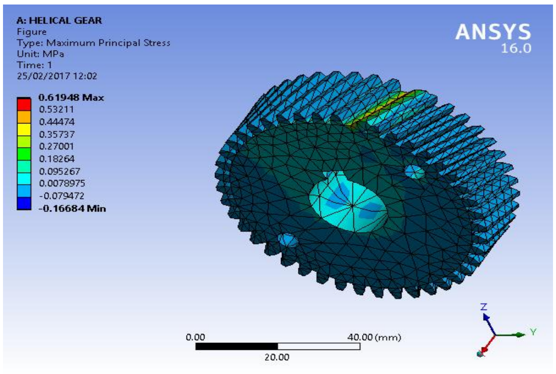

FIGURE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

VII.CONCLUSION

Gear analysis uses a number of assumptions, calculations and simplification which are intended to determine the maximum stress values in analytical method. In this paper, parametric study is also made by varying the geometry of the teeth to investigate their effect of contact stresses in helical gears. As the strength of the gear tooth is important parameter to resist failure. In this study, it is shown that the effective method to estimate the contact stresses using three-dimensional model 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: a phenomena in which a small particle are removed from the surface of the tooth that is because of the high contact stresses that are present between mating teeth, as of the obtained data the contact stresses which are acting on the modified helical gears are more when compared to the standard helical so these paper pretends to be failure theory by which the design aspects are to no changed to reduce the contact stresses.

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