



# DESIGN AND PERFORMANCE ANALYSIS OF HELICAL GEAR FOR AL AND STEEL MATERIAL BY USING ANSYS

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## Abstract

Marine engines are among heavy-duty machineries, which need to be taken care of in the best way during prototype development stages. These engines are operated at very high speeds which induce large stresses and deflections in the gears as well as in other rotating components. For the safe functioning of the engine, these stresses and deflections have to be minimized.

In this project, we have performed static-structural analysis on a high speed helical gear used in marine engines, using different materials. The results obtained in the static analysis are compared with those obtained in theoretical and a conclusion has been drawn on the material to be used for the gear. To estimate bending stress used to the 3-D solid model of helical gear. Ansys software package is used to analyze the twisting stress. Contact stresses are calculated by using modified AGMA contact stress method.

**Index Terms:** Helical gear, marine engines, 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.

### A. 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.

### B. 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 Parallel, (b) Intersecting, and (c) Non-Intersecting and Non-parallel

### C. 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.

**D. 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.

**E. 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.

**F. According to the position of axes of the shafts:**

1) *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 axes. 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.

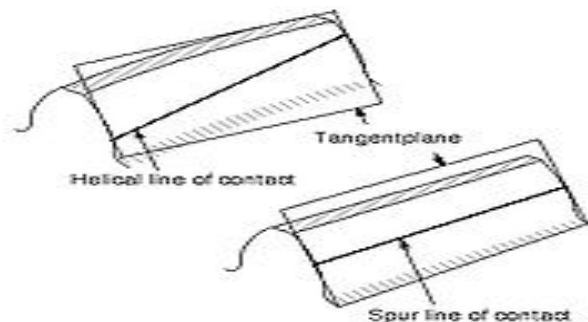


Fig: 1 Figure showing different lines of contact

2) *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.

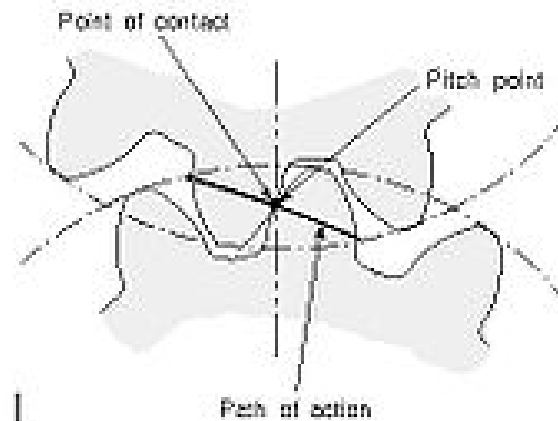


Fig: 2 Pitch point

**3) 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

**4) 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.

5) *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. 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.

A. *Helical gear nomenclature*

Helix angle,  $\psi$

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

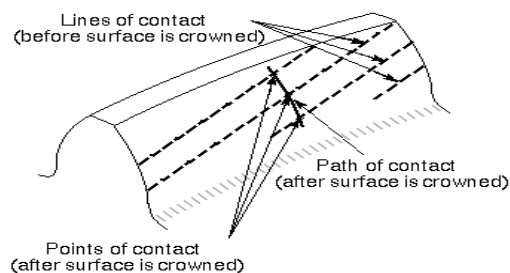


Fig.4 helical gear nomenclature

B. *Helical Gear geometrical proportions*

$p = \text{Circular pitch} = \frac{d_g}{z_g} = \frac{d_p}{z_p}$

$p_n = \text{Normal circular pitch} = p \cdot \cos\beta$

$P_n = \text{Normal diametrical pitch} = \frac{P}{\cos\beta}$

$p_x = \text{Axial pitch} = p_c / \tan\beta$

$m_n = \text{Normal module} = m / \cos\beta$

$\alpha_n = \text{Normal pressure angle} = \tan^{-1}(\tan\alpha \cdot \cos\beta)$

$\beta = \text{Helix angle}$

$d_g = \text{Pitch diameter gear} = z_g \cdot m$

$d_p = \text{Pitch diameter pinion} = z_p \cdot m$

$a = \text{Center distance} = \frac{(z_p + z_g) \cdot m_n}{2 \cos\beta}$

$a_a = \text{Addendum} = m$

$a_f = \text{Dedendum} = 1.25 \cdot m$

**III. MARINE ENGINES**

A. *Reciprocating diesel engines:*

The engine used in 99% of modern ships is diesel reciprocating engines. The rotating crankshaft can power the propeller directly for slow speed engines, via a gearbox for medium and high speed engines, or via an alternator and electric motor in diesel-electric vessels. The reciprocating marine diesel engine first came into use in 1903 when the diesel electric river tanker Vandal was put in service by Branobel. Diesel engines soon offered greater efficiency than the steam turbine, but for many years had an inferior power-to-space ratio.

Diesel engines today are broadly classified according to:

- (i) Their operating cycle (a) two-stroke (b) four-stroke
- (ii) Their construction (a) Crosshead (b) trunk (c) opposed piston
- (iii) Their speed

1. *Slow speed:* any engine with a maximum operating speed up to 300 revs/minute, although most large 2-stroke slow speed diesel engines operate below 120 revs/minute. Some very long stroke engines have a maximum speed of around

80 revs/minute. The largest, most powerful engines in the world are slow speed, two stroke, and crosshead diesels.

2. *Medium speed*: any engine with a maximum operating speed in the range 300-900 revs/minute. Many modern 4-stroke medium speed diesel engines have a maximum operating speed of around 500 rpm.

3. *High speed*: any engine with a maximum operating speed above 900 revs/minute. Most modern larger merchant ships use either slow speed, two stroke, crosshead engines, or medium speed, four stroke, trunk engines. Some smaller vessels may use high speed diesel engines. The size of the different types of engines is an important factor in selecting what will be installed in a new ship. Slow speed two-stroke engines are much taller, but the area needed, length and width, is smaller than that needed for four-stroke medium speed diesel engines. As space higher up in passenger ships and ferries is at a premium, these ships tend to use multiple medium speed engines resulting in a longer, lower engine room than that needed for two-stroke diesel engines. Multiple engine installations also give redundancy in the event of mechanical failure of one or more engines and greater efficiency over a wider range of operating conditions. As modern ships' propellers are at their most efficient at the operating speed of most slow speed diesel engines, ships with these engines do not generally need gearboxes. Usually such propulsion systems consist of either one or two propeller shafts each with its own direct drive engine. Ships propelled by medium or high speed diesel engines may have one or two (sometimes more) propellers, commonly with one or more engines driving each propeller shaft through a gearbox.

#### IV. 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.

#### V. FEA SOFTWARE – ANSYS

##### A. ANSYS Stands for Analysis System Product.

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 inc. supports the ongoing development of innovative technology and delivers flexible, enterprise wide engineering systems that enable companies to solve the full range of analysis problem, maximizing their existing investments in software and hardware.

##### B. Evolution of ANSYS:

ANSYS has evolved into multipurpose design analysis software program, recognized around the world for its many capabilities.

Today the program is extremely powerful and easy to use.

Each release hosts new and enhanced capabilities that make the program more flexible, more usable and faster. In this way ANSYS helps engineers meet the pressures and demands modern product development environment.

#### *C. Overview of the program*

The ANSYS program is flexible, robust design analysis and optimization package. The software operates on major computers and operating systems, from PCs to workstations and to super computers. ANSYS features file compatibility throughout the family of products and across all platforms. ANSYS design data access enables user to import computer aided design models in to ANSYS, eliminating repeated work. This ensures enterprise wide, flexible engineering solution for all ANSYS user.

#### *D. User Interface:*

Although the ANSYS program has extensive and complex capabilities, its organization and user-friendly graphical user interface makes it easy to learn and use.

There are four graphical methods to instruct the ANSYS program:

Menus.

Dialog Boxes

Tool bar.

Direct input of commands.

#### *Menus:*

Menus are groupings of related functions or operating the analysis program located in individual windows. These include:

- Utility menu
- Main menu
- Input window
- Graphics window
- Tool bar
- Dialog boxes

#### *Dialog boxes:*

Windows present the users with choices for completing operations or specifying settings. These boxes prompt the user to input data or make decisions for a particular function.

#### *Tool bar:*

The tool bar represents a very efficient means for executing commands for the ANSYS

program because of its wide range of configurability. Regardless of how they are specified, commands are ultimately used to supply all the data and control all program functions.

#### *Output window:*

It records the ANSYS response to commands and functions.

#### *Graphics window:*

Represents the area for graphic displays such as model or graphically represented results of an analysis. The user can adjust the size of the graphics window, reducing or enlarging it to fit to personal preferences.

#### *Input window:*

Provides an input area for typing ANSYS commands and displays program prompt messages.

#### *Main menu:*

Comprise the primary ANSYS functions, which are organized in pop-up side menus, based on the progression of the program.

#### *Utility menu:*

It contains ANSYS utility functions that are mapped here for access at any time during an ANSYS session. These functions are executed through smooth, cascading pull down menus that lead directly to an action or dialog box.

#### *Processors:*

ANSYS functions are organized into two groups called processors. The ANSYS program has one pre-processor, one solution processor; two post processors and several auxiliary processors such as the design optimizer. The ANSYS pre-processor allows the user to create a finite element model to specify options needed for a subsequent solution. The solution processor is used to apply the loads and the boundary conditions and then determine the response of the model to them. With the ANSYS post processors, the user retrieves and examines the solutions results to evaluate how the model responded and to perform additional calculations of interest.

#### *Database:*

The ANSYS program uses a single, centralized database for all model data and solution results. Model data (including solid

model and finite element model geometry, materials etc) are written to the database using the processor. Loads and solution results data are written using the solutions processor. Post processing results data are written using the post processors. Data written to the database while using one processor are therefore available as necessary in the other processors.

*File format:*

Files are used, when necessary, to pass the data from part of the program to another, to store the program to the database, and to store the program output. These files include database files, the results file, and the graphics file and so on.

#### VI. REDUCING THE DESIGN AND MANUFACTURING COSTS USING ANSYS (FEA):

The ANSYS program allows engineers to construct computer models or transfer CAD models of structures, products, components, or systems, apply loads or other design performance conditions and study physical responses such as stress levels, temperature distribution or the impact of vector magnetic fields.

In some environments, prototype testing is undesirable or impossible. The ANSYS program has been used in several cases of this type including biomechanical applications such as high replacement intraocular lenses. Other representative applications range from heavy equipment components, to an integrated circuit chip, to the bit-holding system of a continuous coal-mining machine.

ANSYS design optimization enables the engineers to reduce the number of costly prototypes, tailor rigidity and flexibility to meet objectives and find the proper balancing geometric modifications.

Competitive companies look for ways to produce the highest quality product at the lowest cost. ANSYS (FEA) can help significantly by reducing the design and manufacturing costs and by giving engineers added confidence in the products they design. FEA is most effective when used at the conceptual design stage. It is also useful when used later in manufacturing process to verify the final design before prototyping.

Analysis types available:

Structural static analysis.

Structural dynamic analysis.

Structural buckling analysis.

Linear buckling

Non linear buckling

Structural non linearities

Static and dynamic kinematics analysis.

Thermal analysis.

Electromagnetic field analysis.

Electric field analysis

Fluid flow analysis

Computational fluid dynamics

Pipe flow

Coupled-field analysis

Piezoelectric analysis.

#### VII. TYPES OF STRUCTURAL ANALYSIS:

Structural analysis is the most common application of the finite element method. The term structural (or structure) implies civil engineering structures such as bridges and buildings, but also naval, aeronautical and mechanical structures such as ship hulls, aircraft bodies and machines housings as well as mechanical components such as pistons, machine parts and tools.

There are seven types of structural analyses available in ANSYS. One can perform the following types of structural analyses. Each of these analysis types are discussed in detail as follows.

Static analysis

Modal analysis

Harmonic analysis

Transient dynamic analysis

Spectrum analysis

Buckling analysis

Explicit dynamic analysis

##### A. *Structural static analysis:*

A static analysis calculates the effects of steady loading condition on a structure, while ignoring inertia and damping effects such as those caused by time varying loads. A static analysis can, however include steady inertia loads (such as gravity and rotational velocity), and time varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes.)

##### B. *Procedure for ANSYS analysis:*

Static analysis is used to determine the displacements, stresses, strains and forces in

structures or components due to loads that do not induce significant inertia and damping effects. Steady loading in response conditions are assumed. The kinds of loading that can be applied in a static analysis include externally applied forces and pressures, steady state inertial forces such as gravity or rotational velocity imposed (non-zero) displacements, temperatures (for thermal strain).

A static analysis can be either linear or non linear. In our present work we consider linear static analysis.

The procedure for static analysis consists of these main steps:

- Building the model.
- Obtaining the solution.
- Reviewing the results.
- Direct generation.
- Solid modeling

With solid modeling we can describe we can describe the geometric boundaries of the model, establish controls over the size and desired shape of the elements and then instruct ANSYS program to generate all the nodes and elements automatically. By contrast, with the direct generation method, we determine the location of every node and size, shape and connectivity of every element prior to defining these entities in the ANSYS model. Although, some automatic data generation is possible (by using commands such as FILL, NGEN, EGEN etc) the direct generation method essentially a hands on numerical method that requires us to keep track of all the node numbers as we develop the finite element mesh. This detailed book keeping can become difficult for large models, giving scope for modeling errors. Solid modeling is usually more powerful and versatile than direct generation and is commonly preferred method of generating a model.

### **VIII. THEORETICAL DESIGN CALCULATIONS**

#### *A. Calculations for Steel [40 Ni2 Cr1 Mo28 steel]:*

Input parameters:

Power = P=9000 KW

Speed of Pinion: N= 3500 r.p.m

Gear Ratio, i=7

Helix Angle,  $\beta=25^\circ$

Material Selection:

The material for pinion & Gear is 40 Ni2 Cr1 Mo28 steel.

Its design compressive stress & bending stresses are

$[\sigma_c=11000\text{kgf/cm}^2]$ ,  $[\sigma_b=4000\text{kgf/cm}^2]$  [Table 7,PSG 8.5]

Properties for 40 Ni2 Cr1 Mo28 Steel:

Density of 40 Ni2 Cr1 Mo28 Steel ( $\rho$ ) = 7860 kg / m<sup>3</sup>

Young's Modulus =  $215 \times 10^5$  N / m<sup>2</sup>

Poisson's ratio ( $\nu$ ) = 0.30

i= 7

$\psi=0.3$

[Table 9,10 PSG 8.14]

[MT]= MTkd k

MT=97420 KW/N

kd k=1.3

[MT]= MT kD k

= $(97420 \times 9000 \times 1.8)/3500$

= 325661.14 kgf-cm

Now, minimum centre distance based on the surface compressive strength is given by

$a \geq (i+1) \sqrt[3]{[0.7/\sigma_c]^2 \times E[MT]/(i\psi)}$

$a \geq 88.41$  cm

#### *B. Calculations for Al [98%Al2O3 , 0.4-0.7% Mn, 0.4-0.7%Mg ]:*

Input parameters:

Power = P=9000 KW

Speed of Pinion: N= 3500 r.p.m

Gear Ratio, i=7

Helix Angle,  $\beta=25^\circ$

Material Selection:

Let the material for pinion & Gear is Aluminum Alloy.

Its design compressive stress & bending stresses are

$[\sigma_c=25000\text{kgf/cm}^2]$ ,  $[\sigma_b=3500\text{kgf/cm}^2]$  [Table 7,PSG 8.5]

Properties for Aluminum Alloy:

Density of Aluminum Alloy ( $\rho$ ) =

3900 kg / m<sup>3</sup>

Young's Modulus =  $340 \times 10^3$  N / m<sup>2</sup>

Poisson's ratio ( $\nu$ ) = 0.220

i= 7

$\psi=0.3$

[Table 9,10 PSG 8.14]

[MT]= MTkd k

MT=97420 KW/N

kd k=1.3

[MT]= MT kD k

= $(97420 \times 9000 \times 1.8)/3500$

= 325661.14 kgf-cm



**IX. ELEMENT CONSIDERED FOR STATIC ANALYSIS:**

According to the given specifications the element type chosen is SOLID 45. SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

The element is defined by eight nodes and the orthotropic material properties. Orthotropic material directions correspond to the element coordinate directions. The element coordinate system orientation is as described in Coordinate Systems.

The following Figure shows the schematic diagram of the 8-noded static solid element.

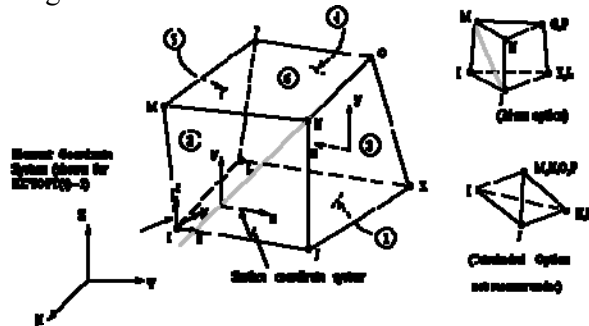


Fig: 5. SOLID-45, 8-NODE STATIC ELEMENT

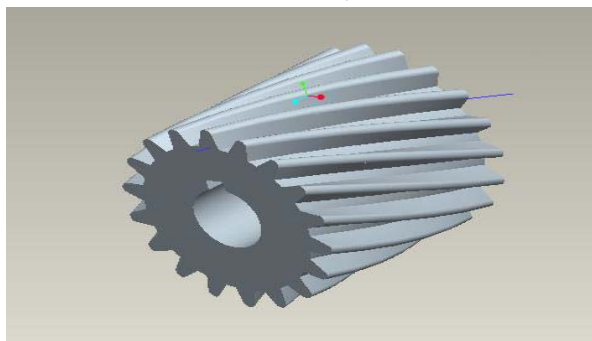


Fig:6. SOLID MODEL OF HELICAL GEAR GENERATED BY PRO/ENGINEER

MATERIALS	YOUNGSMODULS (N/mm2)	DENSITY (Kg/mt3)	POISSONRATIO
Steel	215*105	7850	0.30
Aluminium	340*105	3900	0.220

Table 1 The following Materials used

**X. LITERATURE REVIEW**

**Mr. P. B. G. S. N. Murthy(1)** et al 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 speak to stresses are calculated by using analytical method as well as Finite element analysis. To estimate bending stress modified Lewis beam strength method is used.

**Sanmala Rajasekhar et al (4)** Marine motors are among substantial obligation hardware, which should be dealt with in themost ideal path amid model improvement stages. These motors are worked at high speeds which incite substantial anxieties and diversions in the riggings and in other turning parts. A conclusion has been landed on the material which is most appropriate for the marine motors in viewof the outcomes

**K.Bicha et al (2)**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. 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 .

**XI. ANSYS RESULTS**

**RESULTS FOR STEEL:**

Before building the model, it is important to think about whether a free mesh or a mapped mesh is appropriate for the analysis. A free mesh has no restrictions in terms of element shapes and has no specified pattern applied to it.



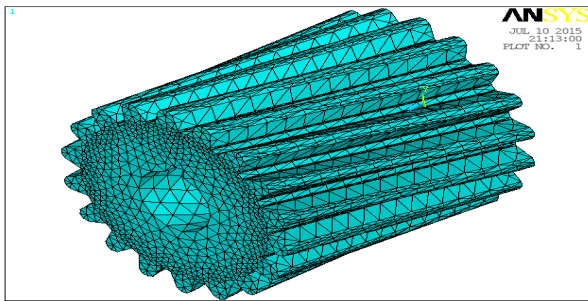


Fig: 7 meshed gear model

For mapped mesh, we must build the geometry as a series of fairly regular volumes and/or areas that can accept a mapped mesh. The type of mesh generation considered here is a free mesh since the 3D figure is not a regular shape. Solid 45 is used to model in ANSYS.

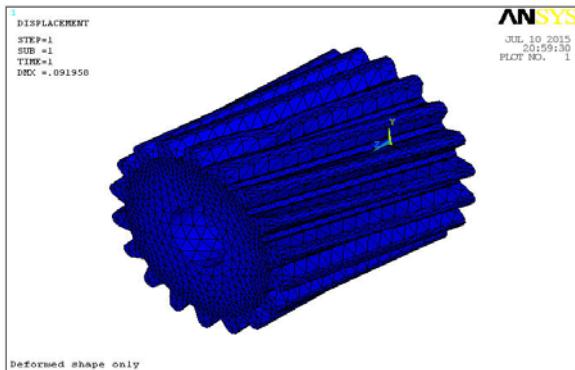


Fig: 8 deformed model of helical gear with steel as a material

**XII. BOUNDARY CONDITIONS:**

*A. Geometry boundary conditions:*

The shaft is fixed at the centre along with its key.

*B) Loads applied:*

FT=137572.60 N

FR =55248.70 N

Finally the boundary conditions are verified before going for a solution.

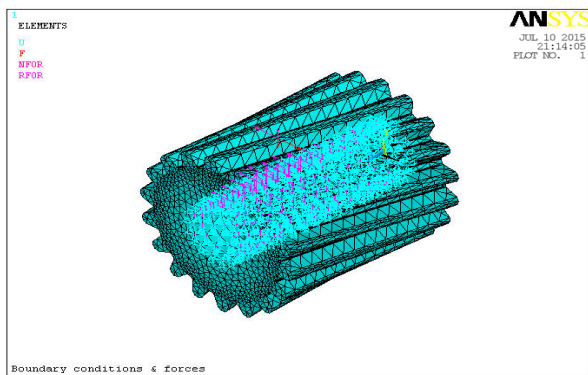


Fig: 9 boundary conditions & Forces

*Bending Stress calculation by using Ansys*

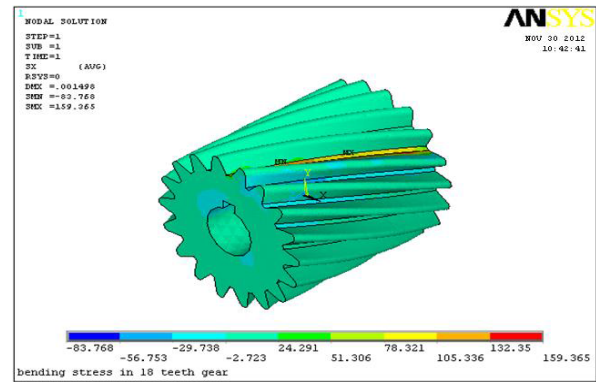


Fig .10 Bending stress of 15 number teeth modeled gear

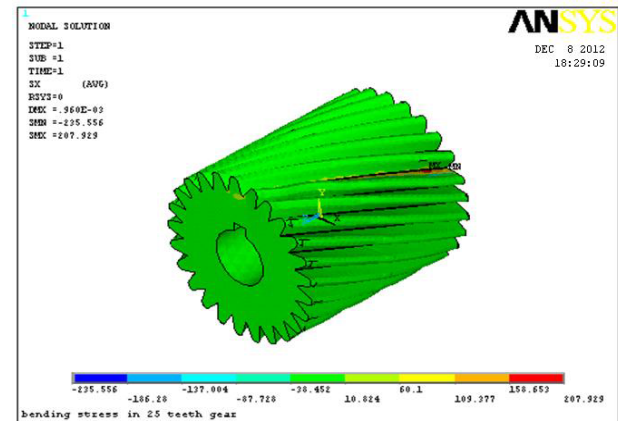


Fig .11 Bending stress of 25 number teeth modeled gear

*Contact Stress calculation by using Ansys*

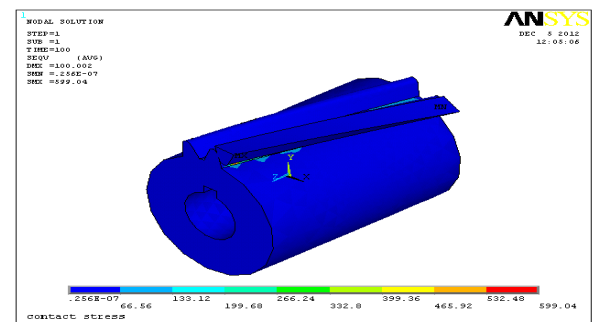


Fig 12. Stress in 15 helical gear contact

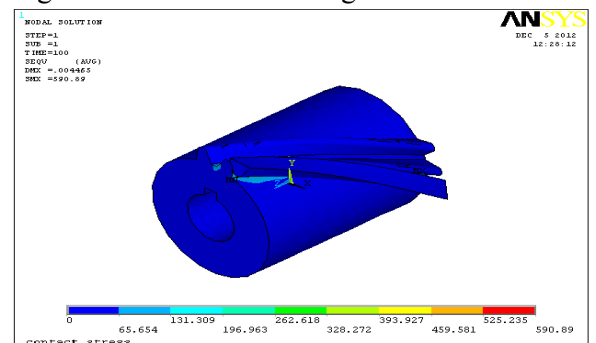


Fig 13. Stress in 25helical gear contact pair

**XIII. Conclusion**

In this work systematic and Finite component Analysis methods were previous to predicting the twisting and speak to stresses of involute helical stuff. Bending stresses are calculated by using modified Lewis beam strong point equation and Ansys software package. Contact stresses are calculated by by means of AGMA contact stress equation and Ansys software package.

Table 2 Comparison of Bending stress results

Number of Teeth	$\sigma_{(AGMA)}[MPa]$	$\sigma_{(ANSYS)}[MPa]$	Differences[%]
15	150.63	157.63	4.017
20	162.73	170.69	5.244
25	191.35	200.92	6.521

Table 3 Comparison of Contact stress results

Helix angle ( $\square$ ) [Degree]	Calculated AGMA contact stress [MPa]	ANSYS value [MPa]	Differences [%]
15	592.73	591.04	0.64
20	590.09	590.24	1.00
25	583.28	586.89	0.57

Error percentage is around 5 % in twisting stresses and around 1 % in contact stress analysis. Induced bending stress is a major function of number of teeth and helix angle influence is less on contact stresses. As a result, based on this finding if the material strength value is principle then a gear with minimum digit of teeth with any greatest coil angle of more look width is preferred.

**XIV. REFERANCES**

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