CONTACT STRESS ANALYSIS OF HELICAL GEAR PAIRS OF DIFFERENT HELIX ANGLE

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Abstract: *The gear contact stress problem has been great point of interest for many years, but still an extensive research is required to understand the various parameters affecting this stress. Among such parameters, helix angle is one which has played a crucial role in variation of contact stress. Numerous studies have been carried out on spur gear for contact stress variation. Hence, the present work is an attempt to study the contact stresses among the helical gear pairs, of different materials such as Steel, Cast iron, Aluminum under static conditions, by using a 3D finite element method. The helical gear pairs on which the analysis is carried are 10, 15, 20, 25 degree helical gear sets. The helical gear contact stress is evaluated using FEA. The FEA results have been further compared with the analytical calculations. The analytical calculations are based upon AGMA equations, which are modified to include helix angle. This approach can be applied to gear design efficiently.*

***Keywords**: Helical gear helix angle contact stress AGMA equation*

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I. INTRODUCTION

One of the best methods of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. The rapid development of industries such as vehicle, shipbuilding and aircraft require advanced application of gear technology. Customers prefer cars with highly efficient engine. This needed up a demand for quite power transmission. Automobile sectors are one of the largest manufacturers of gears. Higher reliability and lighter weight gears are necessary to make automobile light in weight as lighter automobiles continue to be in demand. The success in engine noise reduction promotes the production of quieter gear pairs for further noise reduction. The best way of gear noise reduction is attained by decreasing the vibration related with them. The gear contact stress problem has been a great point of interest for many years, but still an extensive research is required to understand the various parameters affecting this stress. Among such parameters, helix angle is one which has played a crucial role in variation of contact stress.

Gears are one of the oldest of humanity's inventions. Nearly all the devices we think of as machines utilize gearing of one type or another. Gear technology has been developed and expanded throughout the centuries. In many cases, gear design is considered as a specialty. Nevertheless, the design or specification of a gear is only part of the overall system design picture. From industry's standpoint, gear transmission systems are considered one of the critical aspects of Contact Stress Analysis. The understanding of the behaviour when gears are in mesh is extremely important if one wants to perform system monitoring and control of the gear transmission system. Although there are large amount of research studies about various topics of gear transmission, the basic understanding of gears in mesh still needs to be confirmed. Pitting is a surface fatigue resulting from repetitions of high contact stress. The surface fatigue mechanism is not definitively understood. The contact affected zone, in the absence of surface shearing traction's, entertains compressive principal stresses. When a pair of gears mesh, localized Hertzian contact stress are produced along with tooth bending and shearing. This is a non-linear problem, and it can be solved by applying different types of contact elements and algorithms in finite element codes. However, due to the complicated contact conditions, acquiring results in the meshing cycle can be challenging since some solutions may not converge. In any case, using quadrilateral elements seem to be useful in solving gear contact problems with finite element analysis. Furthermore, meshing stiffness is often being discussed when a pair of gears are in mesh. Meshing stiffness can be separated into Torsional Mesh Stiffness and Linear Tooth Mesh Stiffness.

II. DESIGN MODEL OF HELICAL GEAR PAIRS

2.1 Fundamentals of Cad

CATIA V5 employs two operating modes for part modeling, model made for modeling 3Dparametric parts and drawing mode for creating 2D drawings of them. These modes operate independently but share the same design data. Part modeling requires beginning the design work in model mode where a model of the part is immediately built. Then the drawing mode can be used at any point to document the design. In traditional Computer Aided Design, a 2D drawing is created at the beginning and then 3D model is built to analyses, and verify the initial concept.

2.2 Modeling Software

There are different software available for modeling assembly and detailing purposes. Some of the notable software includes Solid works, Creo, Ideas NX, Mechanical desktop, Unigraphics and CATIA.

CATIA V5 (computer aided three dimensional interactive application) is a multi-platform CAD/CAM/CAE software used as the modeling tool as well as assembly and detailing in this project.

2 .3 Part Modeling

Many technical designs consist of complex assemblies made from angular shaped parts. The CATIA V5 is a 3-D parametric solid modeler with both part and assembly modeling capabilities. You can see the CATIA V5 to model piece parts and then combine them into more complex assemblies. With CATIA V5 a part is designed by sketching its components shapes and defining their size shape and inters relationships. By successfully creating these features you construct the part in a building block fashion. Since CATIA V5 has parametric features, you can change one feature and all related features are automatically updated to reflect the change and its effects throughout the part. It can be used to create angular shaped part, to which 3D surface can be applied to create hybrid parts consisting of mixture of angular and curved shapes.

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The figure shows CATIA gear pairs model of different helix angle. The helix angle such as 10^{o}, 15^{o}, 20^{o}, 25^{o}.This CATIA model to be used in analysis.

III. FINITE ELEMENT ANALYSIS

3.1 Fundamentals of CAE

Computer Aided Engineering (CAE) is defined as the use of computer system to find the analytical solution for various engineering problems using different numerical methods. There are three numerical methods available to obtain analytical solution for engineering problems.

1. Functional approximation
2. Functional difference method
3. Finite Element Method (FEM) / Finite Element Analysis (FEA).

3.2 Static Analysis

Static analysis is used to determine the displacements stresses, stains 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. A static analysis calculates the effects of steady loading conditions 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 static equivalent wind and seismic loads).

The procedure for static analysis consists of these main steps;

- Building the model
- Obtaining the solution
- Reviewing the results.

3.3 Finite Element Generation/ Meshing

ANSYS simulation provides two forms of automated meshing. Fully automatic and manually directed automatic.. Pre-processor allows the user to generate nodes and elements automatically at the same time allowing control over size and number of elements. There are various types of elements that can be mapped or generated on various geometric entities. The elements developed by various automatic element generation capabilities of Pre-processor can be checked element characteristics that may need to be verified before the finite element analysis for connectivity, distortion-index etc.

The requirements of good mesh are as follows;

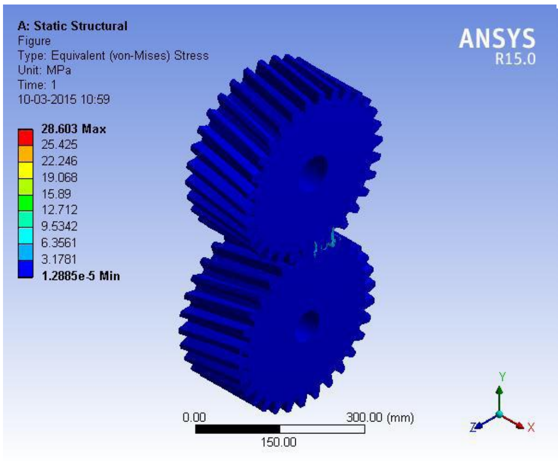
- ✓ Nodal locations should be precise and should not go beyond the boundary.
- ✓ Various element types and shapes should be available to provide the user with more flexibility to meet the compatibility and requirements.
- ✓ Mesh gradation or mesh smoothing should be possible for users to control the mesh size.
- ✓ To convert from one element type to another should be possible.
- ✓ Element aspect ratio should be close to one for better results.
- ✓ Mesh geometry and topology or mesh orientation should be uniform.

The time taken to generate mesh and to perform FEA should be less.

IV. RESULT AND DISCUSSION

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally displacements or deformation values are given as output. Computer Aided Engineering (CAE) plays a vital role in validating the design and optimizing the process conditions. Software such as ANSYS is well known for structural and thermal analyses. It helps to improve the part quality, service life and to reduce the part cost by optimizing the part size. This software uses various computer simulation techniques to analyze and execute the results. The result interpretation requires sound knowledge of the material, process, design and machining. Even though the results are not 100% accurate, it is acceptable one. The accuracy varies because of various factors such as, selection of unsuitable elements, deficiencies in individual elements, poor assessment of output data, masking of important features, lack of standardization between system codes, etc.

The below figure shows the von-mises stress (contact stress) for different helix angle of steel material. They are 10deg, 15deg, 20deg, 25deg, helical gear pairs.



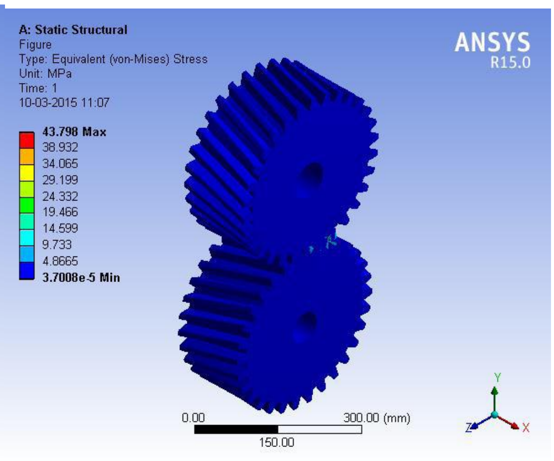
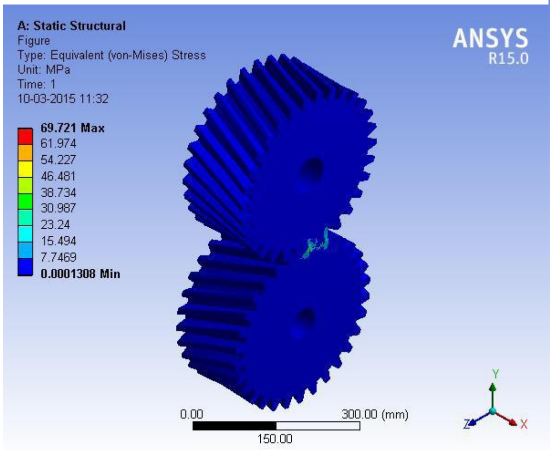


Fig 4.1 Gear pair of helix angle 10^{O} **Fig 4.2** Gear pair of helix angle15^{O}



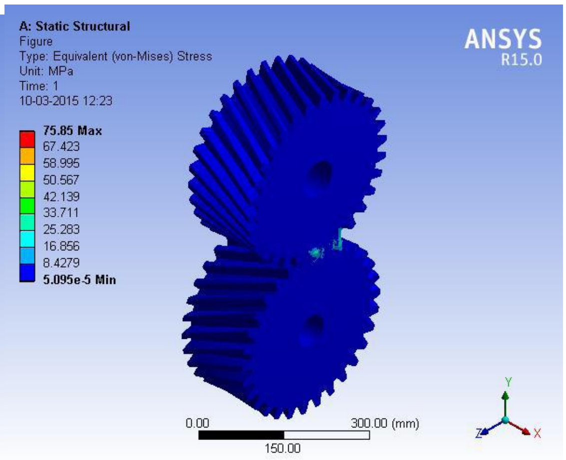


Fig 4.3 Gear pair of helix angle 20^{O} **Fig 4.4** Gear pair of helix angle 25^{O}

The below figure shows the von-mises stress (contact stress) for different helix angle of Cast Iron material. They are 10deg, 15deg, 20deg, 25deg. helical gear pairs.

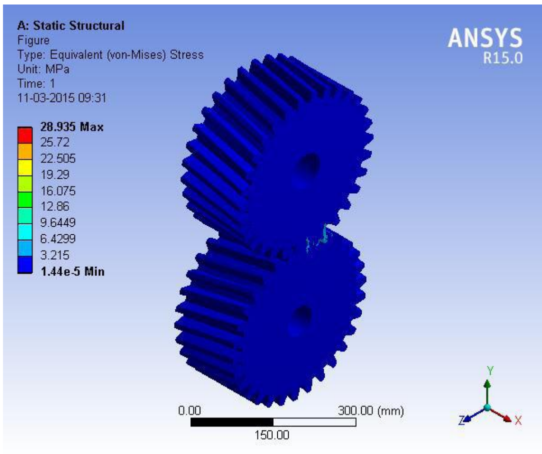


Fig 4.5 Gear pair of helix angle 10^{O}

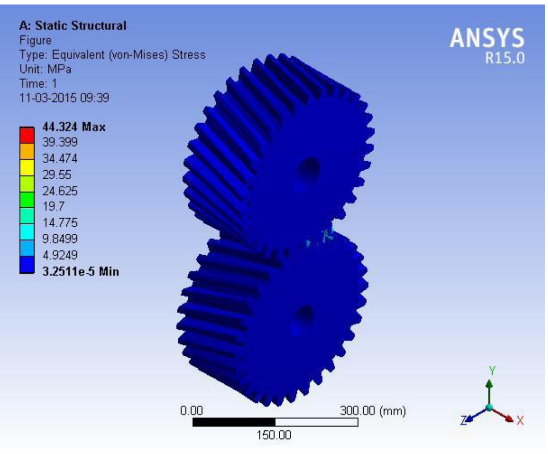


Fig 4.6 Gear pair of helix angle 15^{O}

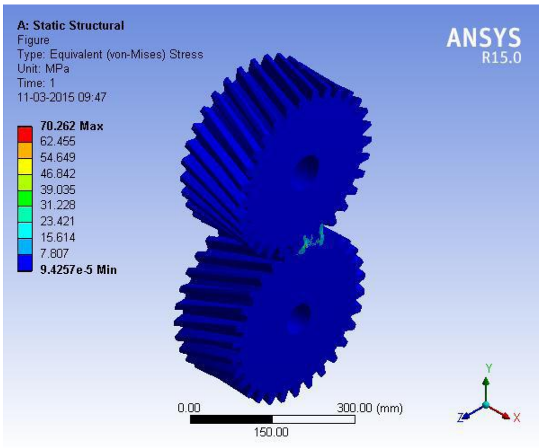


Fig 4.7 Gear pair of helix angle 20^{O}

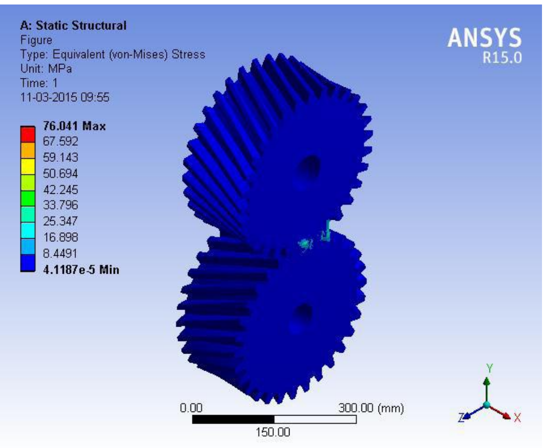


Fig 4.8 Gear pair of helix angle 25^{O}

CONTACT STRESS FOR DIFFERENT HELIX ANGLES OF DIFFERENT MATERIALS

The table shows contact stress for different helix angles of different materials which obtained from analysis (FEA) result. The helix angles are 10deg, 15deg, 20deg, 25deg. helical gear pairs.

contact stress for different helix angle

Helix Angle deg	Contact Stress (Steel) N/mm^2	Contact Stress (C.I) N/mm^2	Contact Stress (Al) N/mm^2
10°	28.603	28.935	28.430
15°	43.798	44.324	42.966
20°	69.721	70.262	68.857
25°	75.850	76.041	75.514

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