Design Analysis of High Speed Helical Gear Used In Marine Engines

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Abstract- *Marine engines are used for heavy duties so they must take a great care at prototype development stages. As these engines are works at very higher speeds which may also 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, Gears are one of the most critical components in mechanical power transmission systems. Today's competitive business in the global market has brought increasing awareness to optimize the gear design to transmit the power and torque gears are used and the transmission efficiency is more in this kind than any other type of transmission. The helical gear offers high contact and more friction which avoids slippage when compared to spur gear. The project involves in estimating the bending stress on the teeth of helical gear so, for this paper Catia software is used to design a 3d model of helical gear teeth and the numerical solution is done by ANSYS, which is a finite element analysis package. The analytical investigation is based on Lewis stress formula. The aim of the present study is to focus on reduction of weight and thereby reducing the unbalance forces setup in the system.*

Keywords- Material, Marine application, helical gear

I. INTRODUCTION

Gears are used in many fields and under a wide range of conditions such as in smaller watches and instruments to the heaviest and most powerful machinery like lifting cranes. 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 two stages (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. Helical gears are the modified forms of spur gears, in which all the teeth are cut at a constant angle, known as helix angle, to the axis of the gear, where as in spur gear, teeth are cut parallel to the axis. Helical gears are also employed to transmit power between two shafts parallel to the axis. The following are the requirements that must be met in the design of gear drive. The gear teeth should have sufficient strength, so that they will not fail under static and dynamic loading during normal running conditions. The gear teeth should have clear characteristics so that their life is satisfactory, the use of space and material should be economical. The alignment of the gears and deflections of the Shafts must be considered, because they affect the Performance of the gears. The lubrications of the gears must be satisfactory. Currently the popular standards are ISO and AGMA.

II. METHODOLOGY

Gears are one of the most critical components in mechanical power transmission systems. Today's competitive business in the global market has brought increasing awareness to optimize the gear design to study of the connecting rod and its design.

The objective of the project is to estimate the bending stress of the helical gear using the analytical investigation based on Lewis stress formula and validate the same using finite element analysis, and find the natural frequencies of the gear and understand its vibration characteristics.

Three dimensional solid model of the gear is generated using CATIA that is powerful and modern modeling software and the analysis is done by ANSYS, which is a finite element tool. The aim of the present study is to focus on reduction of weight and thereby reducing the unbalance forces setup in the system.

III. MODELING OF HELICAL GEAR

The 3D model of the helical gear was developed using NX cad software. The Siemens is the parent company for NX software and NX -CAD is invades broad industrial sectors, and has been explained in the previous post position of NX cad between 3d modeling software programs.

NX cad classified under the following software packages: CAD, CAM & CAE.

Calculation of the net head (H):

$\mathbf{H = H_g - H_t\ m}$
Where, assume H_g = 45m
$H_t = 0.06 * H_g = 0.06*45 = 2.7$ m
$\mathbf{H = H_g - H_t} = 45 - 2.7$
= 42.3 m
Net head (H) **= 43m.**

1. Calculation of the turbine speed (N) :

The turbine Speed Can be Calculated as:

$$N = N_s * \frac{H^{\frac{5}{4}}}{\sqrt{P}}$$

Where, assume N_s= 1900 rpm,
Power (P) = 45 kW

$$N = 1900 * \frac{43^{\frac{5}{4}}}{\sqrt{45000}}$$

N = 990 rpm
The Speed of the turbine = 990 rpm.

2. Calculation of the jet velocity (V_j) =

$$V_j = 0.98 * \sqrt{2 * g * H}$$

Where g =**9.8 m/sec**
H **= 43 m**
$V_j = 0.98 * \sqrt{2 * 9.81 * 43}$
V_j = 28.46 m/sec
The velocity of jet (V_j) = **28.46 m/sec.**

4. Calculation of the Bucket Speed (U1) =

$\mathbf{U_1 = 0.46 * V_j}$
Where $\mathbf{V_j}$ **=** 28.46 m/sec
U_1 = 0.46 * 28.46
U_1 = 13.09 m/sec.

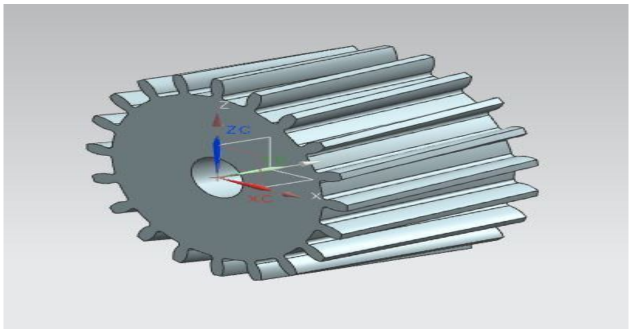

Figure 1. shows the isometric view of Helical Gear.

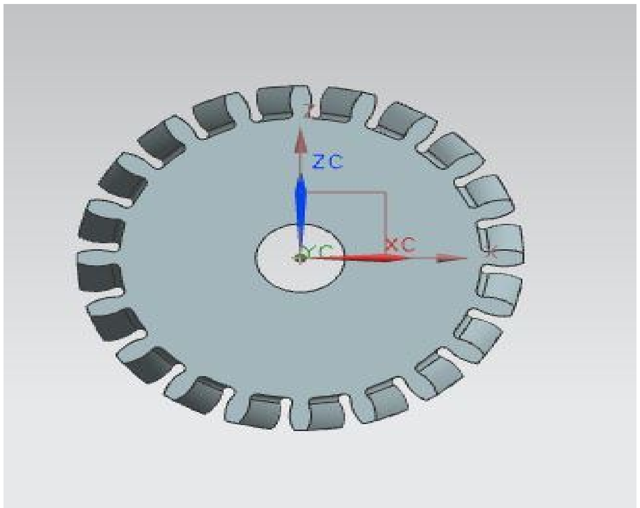

Figure 2. shows front view of Helical Gear.

IV. FEM THEORY

Finite Element Modeling (FEM) and Finite Element Analysis (FEA) are two most well known mechanical building applications offered by existing CAE frameworks. This is ascribed to the way that the FEM is maybe the most prominent numerical strategy for tackling building issues. The strategy is sufficiently general to deal with any intricate state of geometry (issue space), any material properties, any limit conditions and any stacking conditions.

The sweeping statement of the FEM fits the investigation prerequisites of the present complex building frameworks and outlines where shut shape arrangements are representing balance conditions are not accessible. In addition it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

1. FINITE ELEMENT ANALYSIS OF HELICAL GEAR

Solid Modeling is geometrical representation of a real object without losing information the real object would have. It has volume and therefore, if someone provides a value for density of the material, it will have mass and inertia. Unlike the surface model, if one makes a hole or cut in a solid model, a new surface is automatically created and the model recognizes which side of the surface is solid material. The most useful thing about solid modeling is that it is impossible to create a computer model that is ambiguous or physically non realizable. A model is created using CATIA software and then it is retrieved into ANSYS using PARASOLID files.

2. FEM Package:

ANSYS mechanical is a self contained analysis tool incorporating pre-processing such as creation of geometry and meshing, solver and post processing modules in a unified graphical user interface. ANSYS is a general-purpose finite element-modeling package for numerically solving a wide variety of mechanical and other engineering problems. These problems include linear structural and contact analysis that is non-linear. Among the various FEM packages, in this work ANSYS is used to perform the analysis.

V. ANALYSIS OF HELICAL GEAR

The 3d model of the HELICAL GEAR is created in CATIA and converted into parasolid. The parasolid file is imported into Ansys and finite element analysis is carried out using Ansys software.

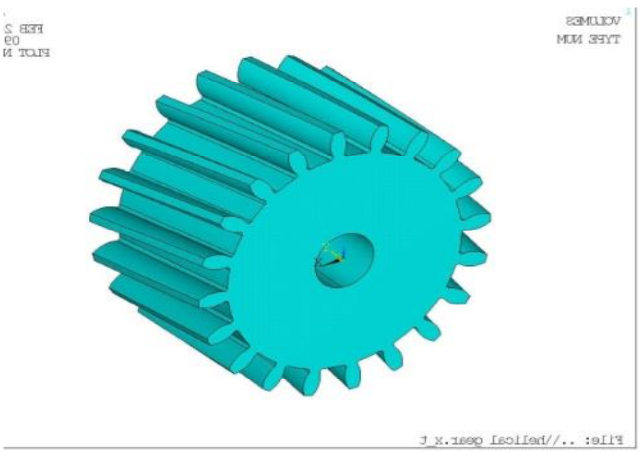

Figure 3. shows the 3D model of the Helical Gear

MATERIAL PROPERTIES:

Material used for control bay is Aluminium Alloy 24345.The physical properties are as mentioned below:
Young's Modulus: 0.7e5N/mm2
Poisson's Ratio: 0.3
Density: 2700kg/m3
Yield strength: 420Mpa

ELEMENT TYPE:

Name of the Element: SOLID 92
Number of Nodes: 10
DOF: UX, UY & UZ

SOLID 92 INPUT DATA:

The geometry, hub areas, and the arrange framework for this component are appeared in Figure "SOLID92 Geometry".

Adjacent to the hubs, the component input information incorporates the orthotropic material properties. Orthotropic materials bearings compare to the component organize headings. The components arrange framework introduction is as portrayed in Coordinate Systems. Component loads are depicted in Node and Element Loads. Weights might be contribution as surface loads on the component faces as appeared by the hovered numbers on Figure "SOLID92 Geometry". Positive weights act into the component.

Temperatures and fluencies might be contribution as component body loads at the hubs. The hub I temperature T (I) defaults to TUNIF. In the event that every other temperature are unspecified, they default to T (I). In the event that all corner hub temperatures are indicated, each midsize hub temperature defaults to the normal temperature of its contiguous corner hubs. For some other info temperature design, unspecified temperatures default to TUNIF.

BOUNDARY CONDITIONS:

The circumference of the shaft diameter is constrained in all DOF

Tangential load of 274750N applied on the teeth.

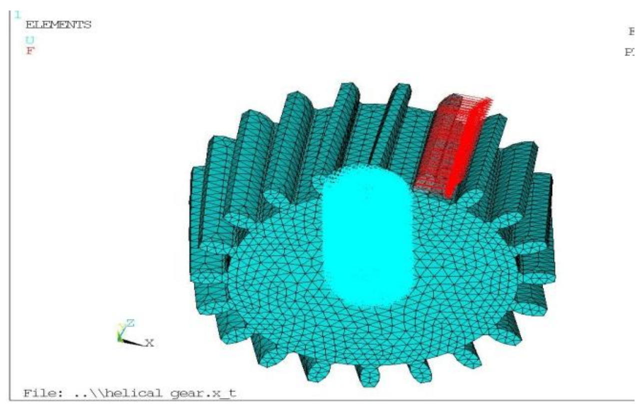

Figure 4. shows the boundary conditions and load applied on the Helical Gear.

TOTAL DEFLECTION:

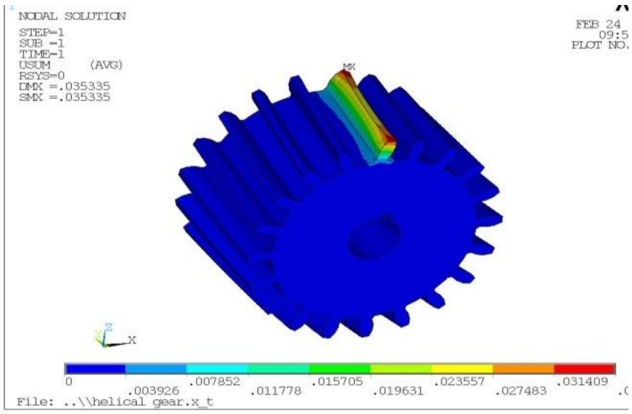

Figure 5. shows the total deflection on the Helical Gear.

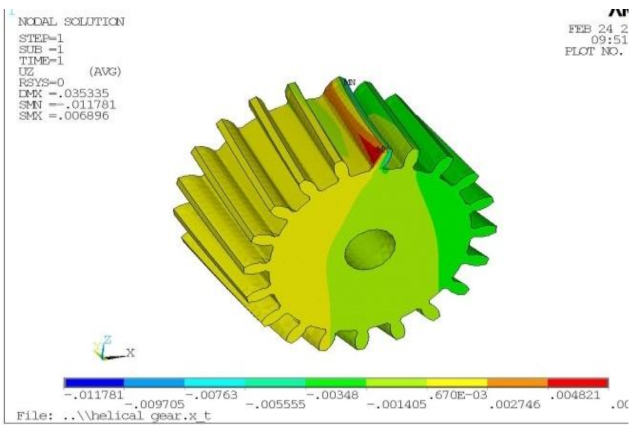

Figure 6. Total deflection of 0.035 mm is observed on the teeth of the helical gear.

STRESSES:

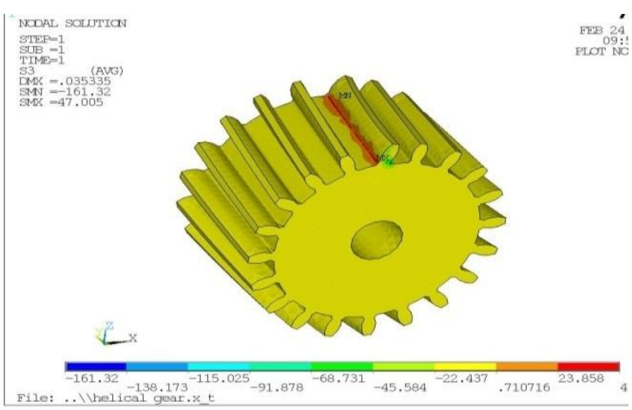

Figure 7. shows the 3rd principal Stress on the Helical Gear.

From the above results, maximum Von-Mises stress of 111N is observed on the teeth of the helical gear. The Von-Mises stress is less than the yield strength of the material. So the helical gear is safe for the above said boundary conditions and loading.

DYNAMIC ANALYSIS:

The objective of analysis is to perform the model analysis of the helical gear and find the first 10 natural frequencies.

MODEL ANALYSIS OF THE EXISTING MODEL:

Modal analysis is performed on the helical gear to find the natural frequencies and mode shapes of the 1st ten natural frequencies. The mode number, frequencies and mode shapes are plotted below.

The 3D model Used for modal analysis

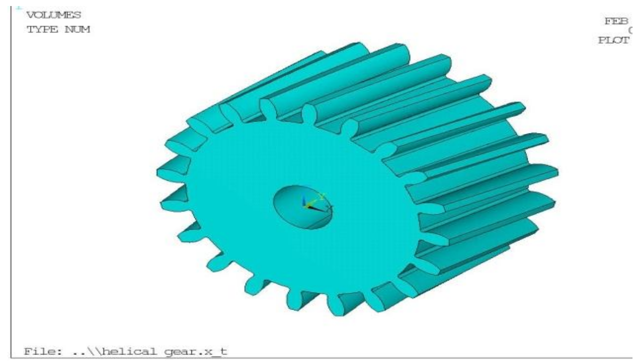

Figure 8. FE model Used for model analysis

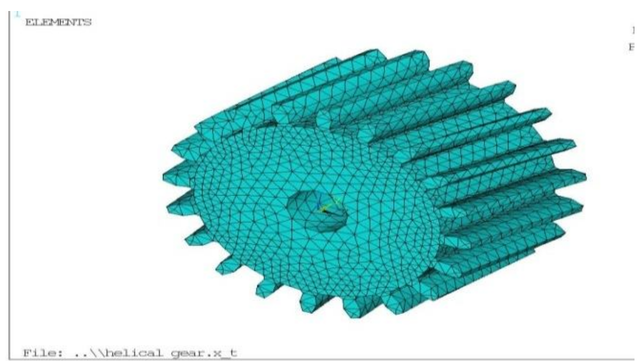

Figure 9.Boundary conditions used for model analysis

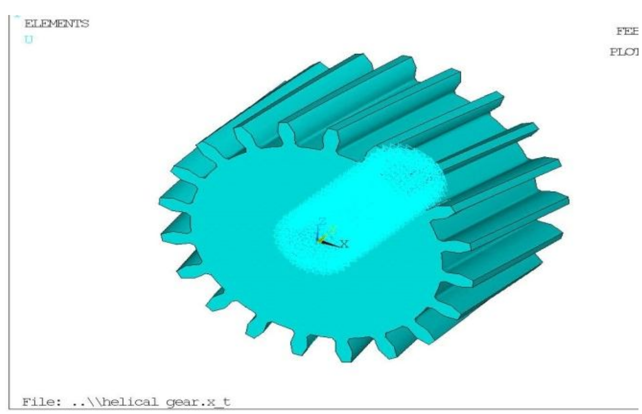

Figure 10. shows the boundary conditions applied on the helical gear for model analysis.

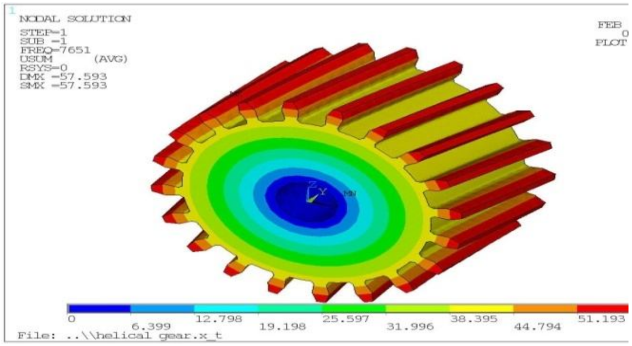

Figure 11. shows first mode shape of the Helical Gear.

VI. CONCLUSION

Von-Mises stress was obtained by theoretical and Ansys software for Aluminum alloy, values obtained from ANSYS are less than that of the theoretical calculations. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions, which are safe and less than the other materials like steel. Aluminum alloy reduces the weight up to 55-67% compared to the other materials. Aluminum is having unique property (i.e. corrosive resistance), good surface finishing, hence it permits excellent silent operation. Weight reduction is a very important criterion, in order to minimize the un balanced forces setup in the marine gear system, there by improves the system performance Hence aluminum alloy is best suited for marine gear in the high speed applications. As a future work, harmonic and transient analysis of the gear can be performed to find out the effect of various cyclic loading conditions along with temperature variations.

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