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Design And Analysis Of High Speed Helical Gear 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. The present thesis deals with static-structural and dynamic analysis on a high speed helical gear used in marine engines, have been performed. The dimensions of the model have been arrived at by theoretical methods. The stresses generated, deflections and mode shapes of the tooth have been analyzed for different materials. Finally the results obtained by theoreticalanalysis and Finite Element Analysis are compared to check the correctness. A conclusion has been arrived on the material which is best suited for the marine engines based on the results.

Catia V-5 is used to model the gear, Hyper mesh is used to meshed the modal and finally meshed modal is analyze using FEA software ANSYS

Keywords: "Helical Gear, Static Analysis, Modal Analysis, Harmonic Analysis"

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.

LITERATURE REVIEW

There has been a great deal of research on gear analysis, and a large body of literature on gear modeling has been published. The gear stress analysis, the transmission errors, and the prediction of gear dynamic loads, gear noise, and the optimal design for gear sets are always major concerns in gear design. ErrichelloandOzguvenand Houser survey a great deal of literature on the development of a variety of simulation models for both static and dynamic analysis of different types of gears.

The first study of transmission error was done by Harris. He showed that the behaviour of spur gears at low speeds can be summarized in a set of static transmission error curves. In later years, Mark and analyzed the vibratory excitation of gear systems theoretically. He derived an expression for static transmission error and used it to predict the various components of the static transmission error spectrum from a set of measurements made on mating pair of spur gears. Kohler and Regan discussed the derivation of gear transmission error from pitch error transformed to the frequency domain. Kubo et al estimated the transmission error of cylindrical gears using a tooth contact pattern.

The best way of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. The design of gear is a complex process. Generally it needs large number of iterations and data sets. In many cases gear design is traditional and specified by different types of standards. B.Venkatesh etc. [1] presented that the stresses were calculated for helical gear by using different materials. Pushpendra Kumar etc. [2] explained about the bending stress for different face width of helical gear calculated by using MATLAB Simulink.

Prashanthpatil, etc. [3] investigated the 3D photo elastic and finite element analysis of helical gear. Khalish.C [4] focused on Lewis beam strength equation was used to finding out bending strength of a helical gear. Yi-Cheng Chen et al. [5] in their study stress analysis of a helical gear set with localized bearing contact have investigated the contact and the bending stresses of helical gear set with localized bearing contact by using finite element analysis. S.Vijayaragan and N.Ganesan [6] carried out a static analysis of composite helical gears using three dimensional finite element methods to study the displacements and stresses at various points on a helical gear tooth. For determining the stresses at any stage during the design of gears helix angle and face width are important. Rao and Muthuveerappan [7] have explained the geometry of helical gears by simple mathematical equations. A parametric study was made by varying the face width and the helix angle to study their effect on the root stresses of helical gears.

MATERIALS USED

MATERIALS	YOUNGS MODULES (N/mm^2)	DENSITY (Kg/m^3)	POISSIONS RATIO
40 Ni2 Cr1 Mo28 steel	$215*10^3$	7850	0.30
Ceramic	$340*10^3$	3900	0.220

BOUNDARY CONDITIONS:

Modified Lewis beam strength method is used to find Bending stress and modified AGMA contact stress method is used to find compressive stress theoretically.

Geometry boundary conditions:

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

Loads applied:

F_T=274767.21 N

F_r=100007.08 N

TYPES OF ANALYSIS CARRIED OUT

Static analysis

Modal analysis

Harmonic Analysis

Experimental Results

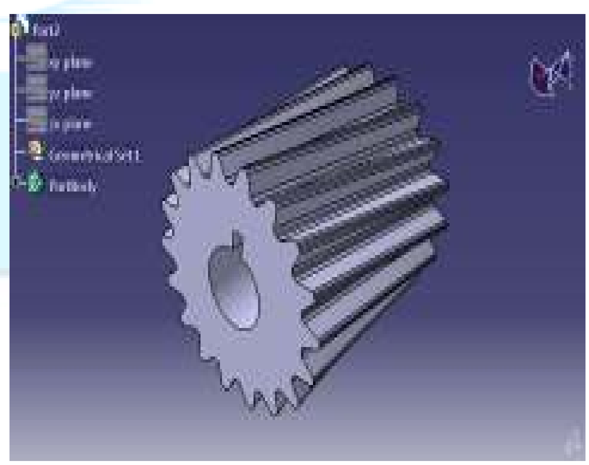

Fig: Catia model of helical gear

Fig: Meshed model of helical gear

Static Analysis For Steel Gear

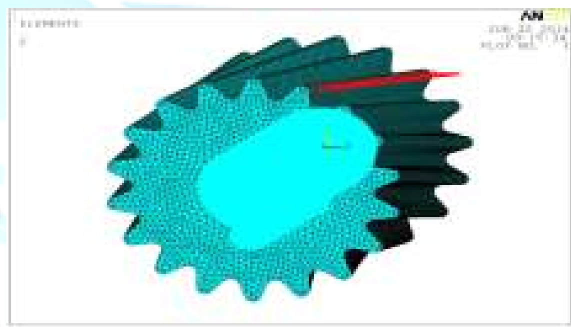

Fig: All applied boundary conditions

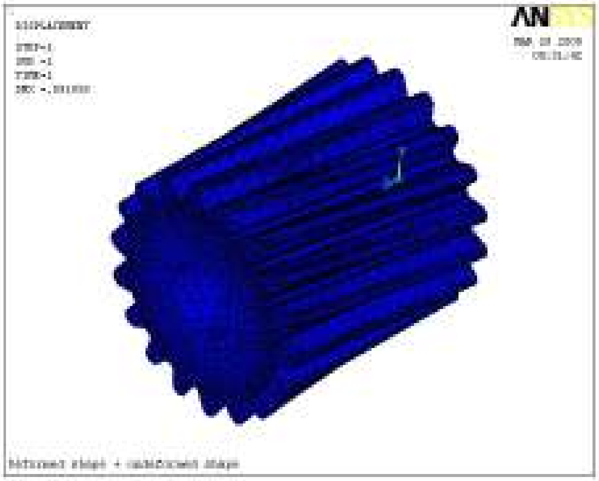

Fig: Deflection of Helical Gear with steel as material

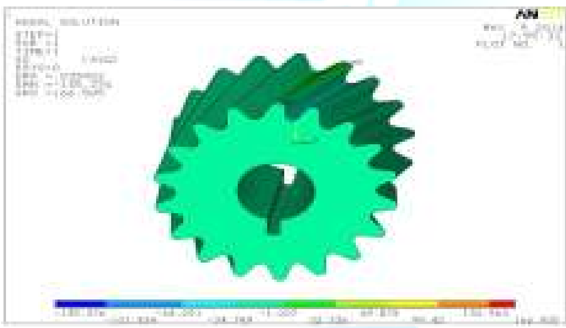

Fig: Bending stress of Helical Gear with steel as material

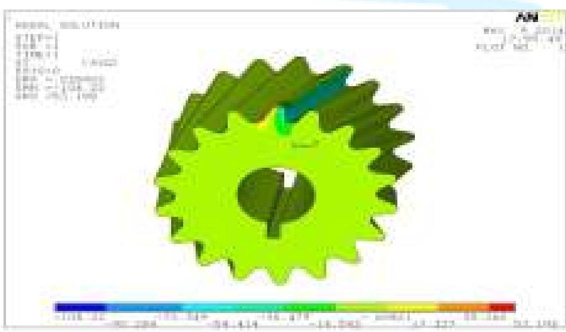

Fig: Compressive stress of Helical Gear with steel as material

Fig: Z Component of stress of Helical Gear with steel as material

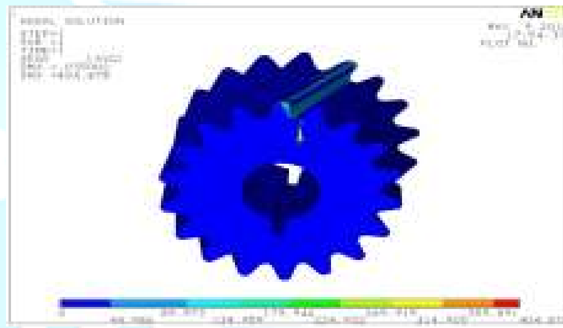

Fig: Von mises stress of Helical Gear with steel as material

Static Analysis ForCeramic Gear

Fig: Deflection of Helical Gear with ceramic as material

Fig 7.10: Bending stress of Helical Gear with ceramic as material

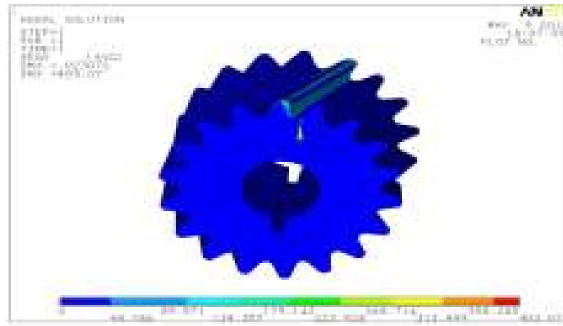

Fig: Von mises stress of Helical Gear with ceramic as material

Fig 7.11: Compressive stress of Helical Gear with ceramic as material

Fig: Z Component of stress of Helical Gear with ceramic as material

MODAL ANALYSIS

Steel Gear

Fig: Natural Frequency at mode 1 =3774

.

Ceramic Gear

Fig: Natural Frequency at mode=6935

NATURAL FREQUENCIES OF STEEL AND CERAMIC

SET	Frequency in Hz	
	For steel	For ceramic
1	3774	6935
2	4801	8826
3	5307	9693
4	5565	10164
5	5593	10209
6	5782	10566

HARMONIC ANALYSIS

For Steel Gear

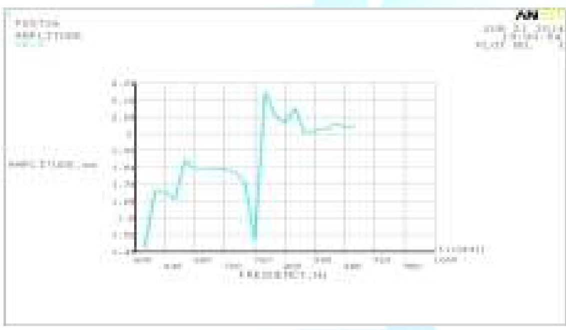

Fig: amp-freq graph in Ux direction

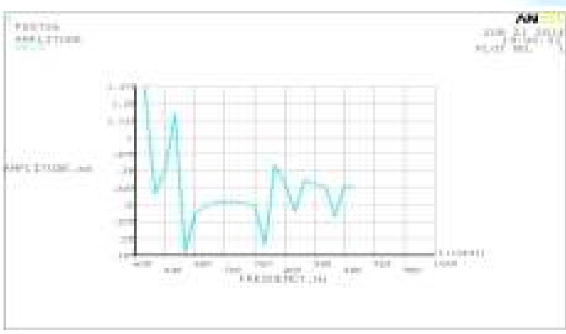

Fig: amp-freq graph in Uy direction

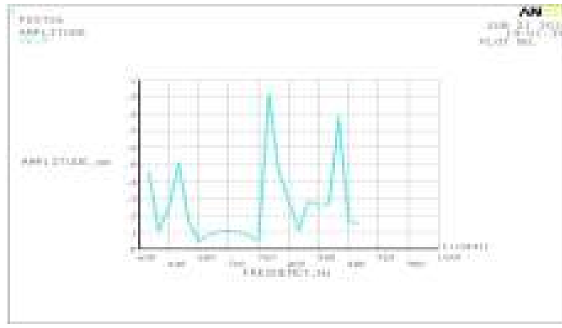

Fig: amp-freq graph in Uz direction

For Ceramic Gear

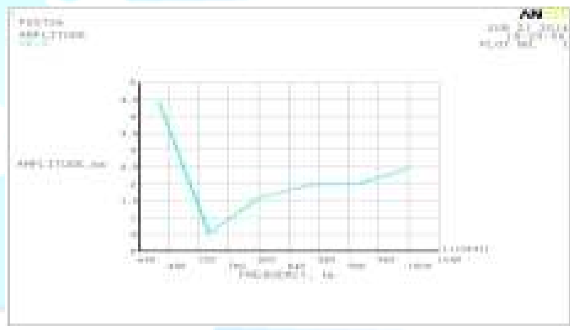

Fig: amp-freq graph in Ux direction

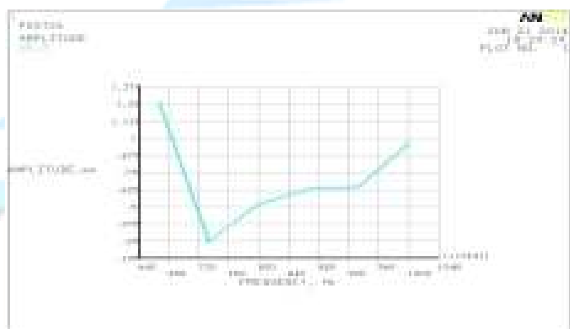

Fig amp-freq graph in Uy direction

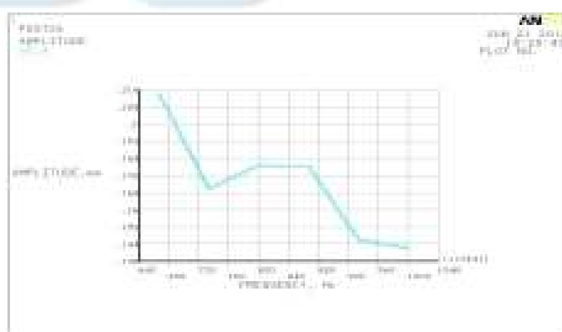

Fig: amp-freq graph in Uz direction

DISCUSSION OF RESULTS

Results for Steel As Material

The following table shows the comparison between theoretical results & experimental results.

TABLE 1

PARAMETER	THEORETICAL RESULTS	ANSYS RESULTS
BENDING STRESS	543.966 N/mm^2	166.505 N/mm^2
COMPRESSIVE STRESS	5342.148 N/mm^2	53.198 N/mm^2
VON MISES STRESSES	σ_{yield}=1240 N/mm^2	404.818N/mm^2
DEFLECTION		0.091958 mm

TABLE 2

PARAMETER	DESIGN STRESSES	INDUCED STRESSES
BENDING STRESS	4000 N/mm^2	543.966 N/mm^2
COMPRESSIVE STRESS	11000 N/mm^2	5342.148mm^2

- From the table 1 we observe that the bending & compressive stresses obtained practically from the ANSYS are much lower than those of the results obtained theoretically. Thus the design is safe from the structural point of view.
- From the table 2 we observe that the induced bending & compressive stresses are much lower than the design stresses. Thus the design is safe from the structural point of view.
- The maximum deflection is found to be 0.091958mm which is well with in the permissible limits. Thus the design is safe based on rigidity point of view.
- The induced von mises stresses with magnitude of 404.818 N/mm^2 are much lower than the yield stress i.e. 1240 N/mm^2 according to the manufacturer's specifications.
- Thus the helical gear parameters that constitute the design are in turn safe based on the strength and rigidity.

RESULTS FOR CERAMIC [98% Al_2O_3] AS MATERIAL

The following table shows the comparison between theoretical results & experimental results.

TABLE 3

PARAMETER	THEORETICAL RESULTS	ANSYS RESULTS
BENDING STRESS	535.003 N/mm^2	155.994 N/mm^2
COMPRESSIVE STRESS	21245.47 N/mm^2	51.543 N/mm^2
VON MISES STRESSES	σ_{yield}=4800 N/mm^2	403.07 N/mm^2
DEFLECTION		0.035902 mm

TABLE 4

PARAMETER	DESIGN STRESSES	INDUCED STRESSES
BENDING STRESS	3500 N/mm^2	535.003 N/mm^2
COMPRESSIVE STRESS	25000 N/mm^2	21245.47 N/mm^2

- From the table 3 we observe that the bending & compressive stresses obtained practically from the ANSYS are much lower than those of the results obtained theoretically. Thus the design is safe from the structural point of view.
- From the table 4 we observe that the induced bending & compressive stresses obtained are much lower than those of the design stresses. Thus the design is safe from the structural point of view.
- The maximum deflection is found to be 0.035902mm which is well with in the permissible limits. Thus the design is safe based on rigidity point of view.
- The induced von mises stresses with magnitude of 403.07 N/mm^2 is far below the yield stress i.e. 4800 N/mm^2 according to the manufacturer's specifications.

- Thus the helical gear parameters that constitute the design are in turn safe based on the strength and rigidity.

Results Comparison Of Steel

Material used is Steel-40Ni2 Cr 1 Mo28

Power = 9000KW

Speed = 3500rpm

Centre Distance = 143cm

Face Width = 430mm

By Doing the Analysis to the Helical Gears the Results obtained are

Bending Stress = 166.505 N/mm^2

Compressive Stress = 53.198 N/mm^2

Maximum Deflection = 0.091958 mm

Results Comparison For Ceramics [98% Al_2o_3]

Material used is Ceramics-

Power = 9000KW

Speed = 3500rpm

Centre Distance = 143cm

Face Width = 430mm

By Doing the Analysis to the Helical Gears the Results obtained are

Bending Stress = 155.994 N/mm^2

Compressive Stress = 51.543 N/mm^2

Maximum Deflection = 0.035902 mm

TABLE 5

PARAMETERS	STEEL	CERAMICS
BENDING STRESS	166.505 N/mm^2	155.994 N/mm^2
Compressive stress	53.198 N/mm^2	51.543 N/mm^2
DEFLECTIONS	0.091958 mm	0.035902 mm

The results obtained above are less than material properties as mentioned before. Hence the design is safe and optimum.

CONCLUSION

- Bending and compressive stresses were obtained theoretically & by using Ansys software for both ceramic& steel.
- From the table 5, it is observed that bending and compressive stresses of ceramics are less than that of the steel.
- Deflections are also less for the ceramic helical gear from the table.5, Therefore ceramic material is best suited for the application.
- Weight reduction is a very important criterion in the marine gears.
- Modal analysis results shows that the natural frequencies are much higher for the ceramic Helical Gear than the steel.
- Harmonic analysis results shows that the resonant frequency range is higher for Ceramic Helical Gear than the steel
- Hence Ceramics material is selected.

FUTURE SCOPE OF THE WORK

- In the present investigation static, modal and harmonic analysis of a high speed helical gear, is analyzed by FEM package ANSYS
- As a future work transient and spectrum analysis of the gear can be performed to find out the mode shapes and natural frequencies of the gear.
- Steel and ceramic material analysis is carried out in this project Analysis can also be extended for different materials

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