Research Paper Engineering

Modal Analysis of Helical Gear

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ABSTRACT

A modal analysis is a technique used to determine the vibration characteristics of structures. Natural vibration characteristics of the helical gears have an important influence on the normal use of the helical gear in any kind of machinery or machine structure. In order to improve the quietness and reliability of the driven system and improve the transmission efficiency of helical gear, it is very necessary to check the natural frequency of gear by modal analysis. In this paper, the model of helical gear shown; is established by using modeling software Solid work. Through data exchange interface, the same model was converted into ANSYS for the further vibration analysis at the low natural frequencies to obtain the vibration modes. This is the basis for the further investigation to improve the design and optimize the gear transmission system.

Keywords : helical gear, modal analysis, natural frequency

1. Introduction

A gear is a rotating machine part having cut teeth, or cogs, which meshes with another toothed part in order to transmit torque. Gear used in transmission is analogous to wheel in a pulley but gear is positive drive as it offers no slip during the rotation and gives smooth drive. Gear is used to change the power or speed between input and output stage. In present era of sophisticated technology, gear design has evolved to a high degree of perfection. Design and manufacture of precision cut gears made from material of high strength have made it possible to produce gear that are able to transmit extremely large loads at extremely high circumferential speeds with very little noise, vibration and other undesirable aspects of gear devices. The complexity of the design of multi-stage gear lies in the strong and often intractable connections between the design variables defining its sub-systems. The impact of a certain choice of gear width and centre distance may yield a minimum mass gearing, but the selection of such gears may cascade through sub-sequent steps of the design process which leads to a heavier gear than if a slight compromise had been made on the choice of that first gearing.

Helical gears have the advantage of transmitting power between axes that make a certain angle. When a pair of parallel helical gears meshes, the following conditions must be satisfied for proper running of the test:

(i) The gears must have helix angle of equal values;
(ii) The gear teeth of each member must have the same module;
(iii) The gear teeth of each member must have opposite helices, that is, one gear must have right-handed helical teeth while the other must have left-handed ones. One of the fundamental difference between spur and helical gear as far as the course of a action is concerned is that the contact of the two spur gears in mesh takes place always in a line extending all along the surface of the tooth, this line being always parallel to the axis of the gear. It has been estimated that one consequence of the sloping contact line in a meshing pair of helical gears is that the maximum bending moment on a helical gear tooth is only a little greater than half that on the same size of spur gear tooth, assuming the load to be the same in each case.

- Natural frequencies: - at what frequencies the structure would tends to vibrate naturally.
- Mode shapes: - in what shape the structure would tends to vibrate at each frequency.
- Mode participation factors: - the amount of mass that participates in a given direction for each mode for most fundamental of all the dynamic analysis types.

2. FINITE ELEMENT MODELLING FOR MODAL ANALYSIS [2, 3, 6]

Start with the linear general equation of motion:-

$$[M]\{\ddot{u}\}+[C]\{\dot{u}\}+[K]\{u\}=\{F\}$$

Assume free vibrations, and ignoring damping:-

$$[M]\{\ddot{u}\}+\overbrace{[C]}^{0}\{\dot{u}\}+[K]\{u\}=\overbrace{\{F\}}^{0}$$

$$[M]\{\ddot{u}\}+[K]\{u\}=\{0\}$$

Assume harmonic motion:-

$$\{u\}=\{\phi\}_i\sin(\omega_i t+\theta_i)$$

$$\{\dot{u}\}=\omega_i\{\phi\}_i\cos(\omega_i t+\theta_i)$$

$$\{\ddot{u}\}=-\omega_i^{\,2}\{\phi\}_i\sin(\omega_i t+\theta_i)$$

Substituting and simplifying:-

$$[M]\{\ddot{u}\}+[K]\{u\}=\{0\}$$

$$-\omega_i^{\,2}[M]\{\phi\}_i\sin(\omega_i t+\theta_i)+[K]\{\phi\}_i\sin(\omega_i t+\theta_i)=\{0\}$$

$$\left(-\omega_i^{\,2}[M]+[K]\{\phi\}_i=\{0\}\right)$$

This equality is satisfied if $\{\phi\}_i=0$ (trivial, implies no vibration) or if

$$\det\left([K]-\omega_i^2[M]\right)=\{0\}$$

This is an Eigen value problem which may be solved for up to n Eigen values ωi2 and n Eigen vectors, {φ} i, where n is the numbers of DOF. Note that the equation

$$\det\left(\left[K\right]-\omega_i^2\left[M\right]\right)=\{0\}$$

has one more unknown than equations; therefore, an additional equation is needed to find a solution. The addition equation is provided by mode shape normalization.

• Mode shapes can be normalized either to the mass matrix

$$\{\phi\}_i^T\left[M\right]\{\phi\}_i = 1$$

or to unity, where the largest component of the vector {φ}i is set to 1.

3. HELICAL GEARBOX CALCULATION [9]
Technical Specification and Dimensions:

Input torque = 1464.2 Nm
Gear Teeth: - 17,
Helix Angle: - 13,
Normal Module: - 3.5
Pressure Angle: - 20,
Internal diameter = 25 mm
Face width = 100mm
\ D = 61.065 mm
\ D (addendum) = 69.031 mm;
\ D (dedendum) = 53.295 mm;
\ D (base) = 57.204 mm
\ Tooth thickness = 10.99557429 mm
\ Tooth height = 7.868 mm
\ Natural frequency = 578.8685 Hz

4. MODELLING AND MODAL ANALYSIS OF HELICAL GEAR

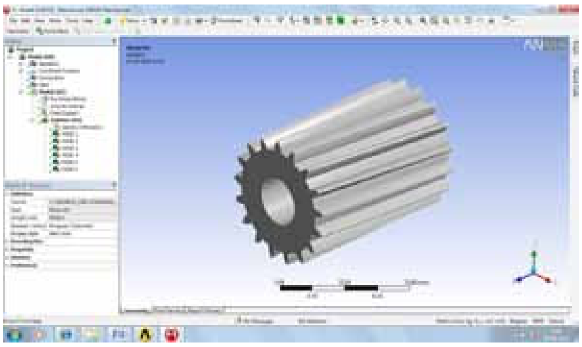

Figure 4.1 3D Model of Helical Gear

1) Create 3D Model on Helical Gear using above calculated parameter.
2) Apply Material as " 20 MnCr 5 ".
3) Generate Mesh for Helical Gear by using

Number of Nodes: - 10176 and Number of Elements: - 1785

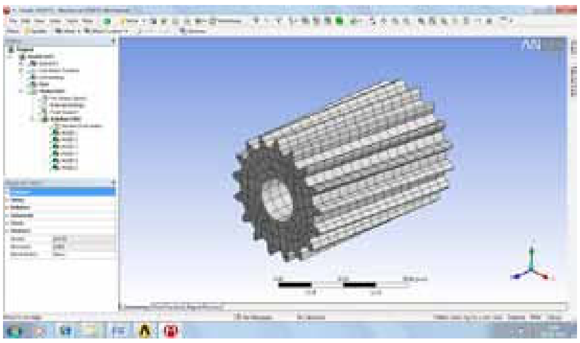

Figure 4.3 Meshed Model of Helical Gear

4) Apply Boundary Condition as a Remote Displacement where 5 D.O.F (3 Translation and 2 Rotation) Constrained and 1 D.O.F (Rotation about Z) is Free.

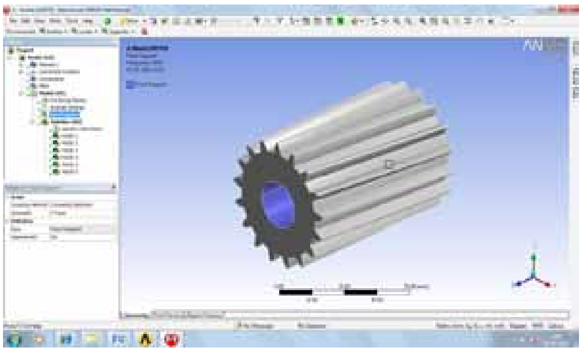

Figure 4.4 Remote Displacement

5) Run Analysis and Get Results.

5. RESULTS AND DISCUSSION

The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions, which are found safe from the aforesaid analysis.

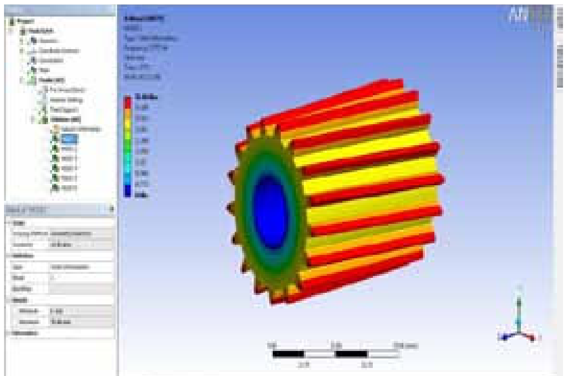

Figure 5.1 First Mode of Vibration

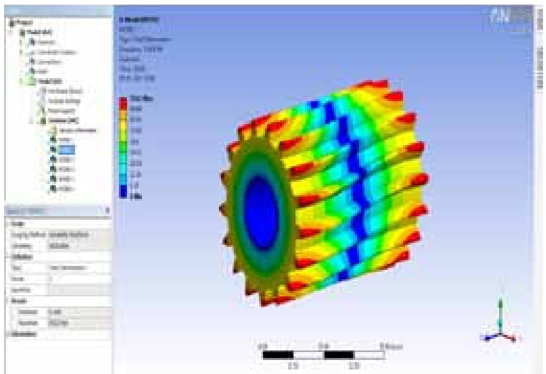

Figure 5.2 Second Mode of Vibration

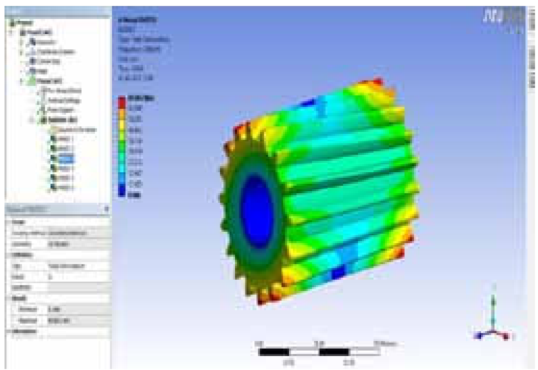

Figure 5.3 Third Mode of Vibration

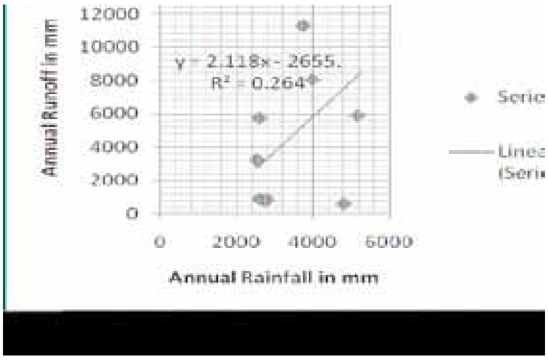

Figure 5.4 Forth Mode of Vibration

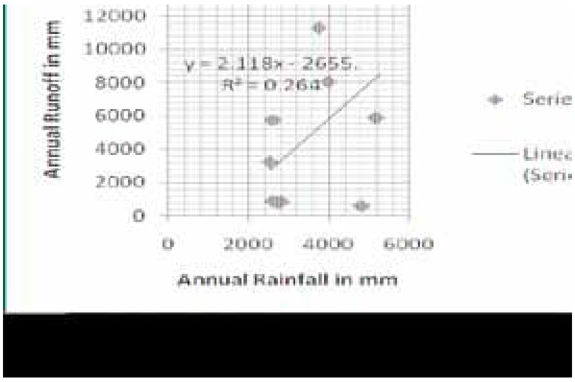

Figure 5.5 Fifth Mode of Vibration

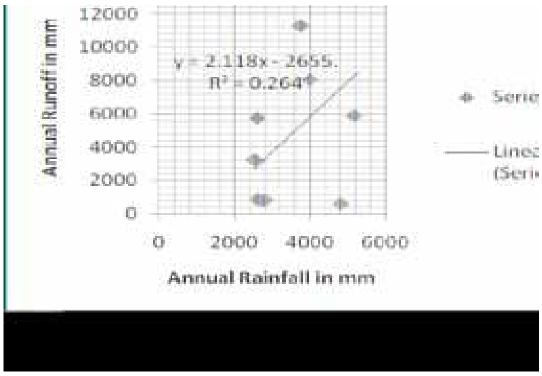

Figure 5.6 Sixth Mode of Vibration

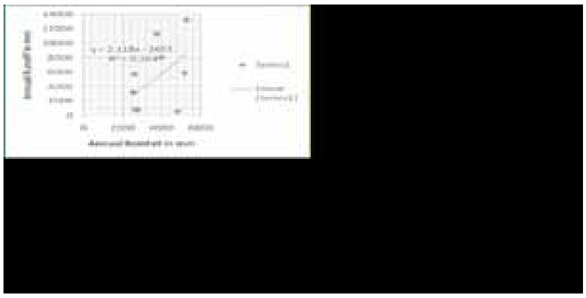

Figure 5.5 frequency response graphs

CONCLUSION

Modal frequency is within safe range. FEA analysis results perfectly match with theoretical results; hence FEA analysis seems to be a good tool to replace costly and time consuming experimental work.

REFERENCES

[1] Ramamurti V; Reddy K. R. K., "Dynamic analysis of spur gear tooth". The Institution of Engineering (India) Journal 82 (April 2001) 33-40. [2] Wilcox L., Coleman W.," Application of finite elements to the analysis of gear tooth stresses" Journal of Engineering for Industry 95 (4) (Dec. 1973) 1139-1148. [3] Ramamurti V., Gupta L. S.," Dynamic stress analysis on spur gear teeth. ASME Conference 38, 1979 DET. [4] Oda S., Nagamura K., Aoki K., "Stress analysis by thin rim spur gears by finite element method" . Bulletin of the Japanese Society of Mechanical Engineers 24 (193) (1981) 1273-1280. [5] Von Eiff H., Hirschmann K.H., Lechner G., "Influence of gear tooth geometry on tooth stress of external and internal gears ", ASME Journal of Mechanical Design 112 (4) (1990) 575-583. [6] Ramamurti V., Nayak H. Vijayendra , C. Sujatha," Static and dynamic analysis of spur and bevel gears using FEM, Mechanism and Machine Theory 33 (8) (1998) 1177-1193. [7] Hefeng M. Savage, R.J. Knott, " Computer modeling of rack generated spur gears. Mechanism and Machine Theory 20 (4) (1985) 351-360. (8) Khurmi R.S., Gupta J.K., " A Textbook of Machine Design, S Chand & Company LTD., New Delhi, pp 1035-1038, 2006. [9] " Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth ", ANSI/ AGMA 2001-B88, American Gear Manufacturers Association, Arlington, VA, 1988.