GEARBOX VIBRATION ANALYSIS ON SPALLING GEAR TOOTH

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Abstract-

In this paper, the vibration of gearbox is investigated by gear tooth spalling fault. Spalling on gear teeth is one of the most common defects in gear transmission. The tooth spalling may be any shape and in this paper a rectangular spalling is created at the centre of gear teeth. In Modal analysis natural frequency and deformation mode shape of the model is calculated with the help of finite element analysis in Ansys software. In Harmonic response analysis a dynamics load is applied on the spalling and frequency response of deformation and total deformation of the gearbox is calculated with the help of frequency response curve resonance frequency of gearbox is calculated.

Keywords: - *Gearbox, mess stiffness, vibration, spalling etc.*

1. INTRODUCTION

Gearbox vibration analysis has been widely used in fault detection of rotation machinery. The vibration of a gearbox carries the signature of the faults in the gear and early fault detection of the gearbox is possible by analyzing the vibration through condition monitoring. Tooth fracture, spalling, cracks are the common defects in gear transmission system. Spalling is the most common type of surface fatigue failure. Spalling is a defect which is produced by high stresses and high sliding velocities between in teeth contact. Gearbox vibration are often caused by damaged or spalling gear teeth. When gear tooth engagement involve a spalled tooth, the force cannot be transferred as with the other gear tooth engagements. If the gear is broken less force can be transferred at this point of the cycle. Vibrations occur as a result. By considering excitation in vibration of the gearbox are calculated with the help of finite element method and mechanic vibration theory by this resonance frequency, natural frequency and various modes of deformation are obtained. In this study, a procedure is produced to predict the vibration of gearbox due to spalling effect are mainly coming out from gearbox. In various deformation, modes are also calculated by that resonant frequency can be calculated. Ganesha.B et.al deals with the software to calculate the Dynamic Vibration Analysis of Gearbox Using ANSYS software. International Journal of Innovative Reasearch in Science Engineering and Technology[1].Ankur Saksena et.al deals with the dynamic behaviour of the multi mesh geared-rotor system in which finite element method is used to locate the natural frequencies and force harmonic reaction of system[2].Rishav Ranjan et.al has been analysed the harmonic reaction of gearbox and analysis has been executed to discover the strain and secure running frequencies for special substance to keep away from resonance[3].Omar D mohammad et.al is proposed the making use of vibration primarily based tracking tools structure is discover to initiation and improvement of deterioration earlier than incident of failure its used to find the crack modelling and gear mesh stiffness calculation, dynamics modelling and simulation method for fault detection and vibration analysis[4].Akhilesh lodwal et.al has been analysed the time varying mesh stiffness determined the health of gearbox and used in fault finding of gear analytically in which spalling evolved on tooth profile reasons extrude in time varying tools mesh stiffness behaviour of system[5].

2. METHODOLOGY

Gearbox under high speed and heavy load spalling is one of the main failure mechanisms of gear teeth. During gear meshing, gear excitation is caused due to fluctuation and gear error in mesh stiffness. This excitation occurs due to spalling on gear tooth in dynamics condition after some interval of time spalling width and depth are increased due to vibration frequency were change.

The procedure consists of three steps gearbox model development, model analysis and harmonic analysis. With thehelp of this analysis finite element method calculate the relation between frequency and deformation it also known as finite element harmonic response analysis.

1. **Model development: -** Model is mainly designed and drafted on Creo Parametric 5.0 and after making or assembled all the parts of gearbox then analysis on Ansys Workbench R18.

Specification of Gearbox: -

TABLE 1:- PARAMETERS OF GEAR-PAIR

Modules (mm)	Gear Ratio (T1/T2)	Pressure angle (˚)	Widthof spalling (mm)
3.0	84/21	20˚	5

1.1 Lower Casing:- Lower Casing is a outer cell of gearbox which protect to gear and pinion assembly. Lower casing of gearbox as shown in fig 1.

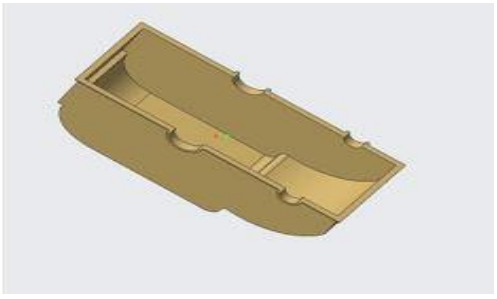

Figure 1 :- Lower Casing

1.2 Upper Casing: - Upper casing is the uppermost cell of gearbox which is jointed with lower casing through nuts and bolts. Upper Casing of gearbox as shown in fig 2.

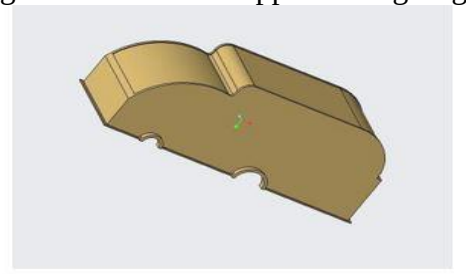

Figure 2:- Upper Casing

1.3 Gear Pair Assembly: - Gear Pair Assembly is the combination of gear and pinion which are connected with each other in dynamic condition. Gear Pair assembly of gearbox as shown in fig 3.

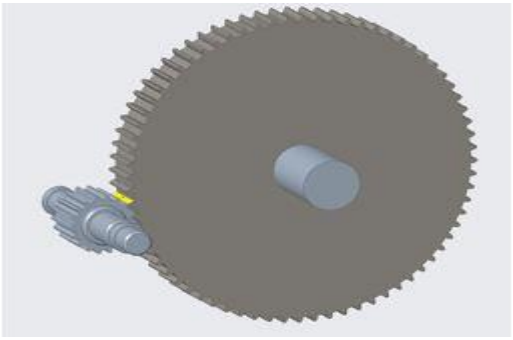

Figure 3:- Gear Pair Assembly

1.4 Spalling on Gear Teeth: - Spalling is created on the center of gear teeth with 5 mm of width and depth. Spalling as shown in fig 4.

Figure 4:- Spalling on gear teeth

1.5 Gearbox Full Assembly:- Gearbox are designed by the assembly of upper casing, lower casing and gear pair. Gearbox Assembly as shown in fig 5.

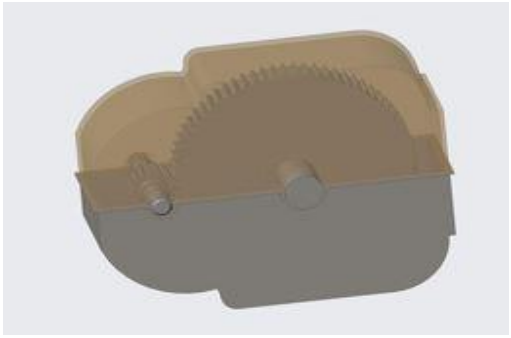

Figure 5:- Assembly of Gearbox

In Model development, numerous data is required to designed a model. Properties of material, Parameters of material and specification of material is play a very significant role to developed a model. To reached final outcome of any model firstly overview the design , sufficient parameter, proper material selection are required. After all this, using design software to make a prototype of gearbox on Creo Paramertic 5.0. reassemble all the part in a systematic view to make proper gearbox. Then analysis the prototype under boundary condition in Ansys Workbench R18 for getting final results.

2. MODEL ANALYSIS:-

The modal analysis deals with the dynamics behavior of mechanical structures under the dynamics excitation. The modal analysis is used to determine the dynamic characteristics of a system such as natural frequency, mode shapes etc. The natural frequencies and modes shapes play a vital role in the design of a structure for dynamic loading vibration. The modal analysis helps to reduce the noise emitted from the system to the environment. It helps to point out the reasons of vibrations that cause damage of the integrity of system components. Using it, we can improve the overall performance of the system in certain operating conditions.

2.1 Gearbox vibration Analysis:-

Gearbox vibration analysis with the help of modal analysis natural frequency in various modes of deformation is calculated . Various deformation is found with the different natural frequencies. Without considering any damping condition limit within 0 Hz to 1200 Hz and taking 8 modes of deformation as shown in fig 6.

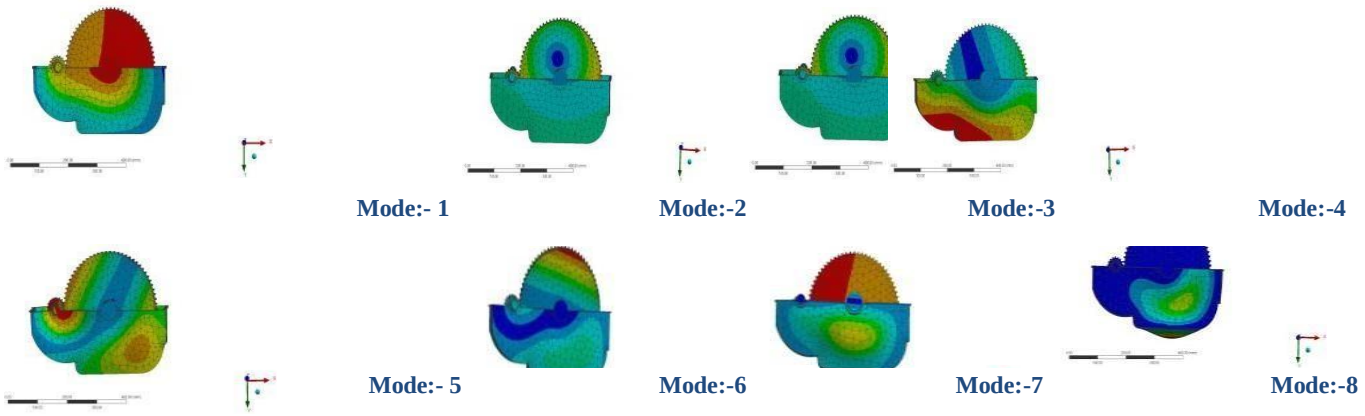

Figure 6:- Various Modes of deformation

Mode 1: -Frequency 144.84 Hz
Mode 2: - Frequency 370.5 Hz
Mode 3: - Frequency 496.3 Hz
Mode 4: - Frequency 522.12 Hz
Mode 5: - Frequency 695.18 Hz
Mode 6: - Frequency 855.38 Hz
Mode 7: - Frequency 800.45 Hz
Mode 8: - Frequency 907.4 Hz

2.2 Modes Analysis:-

In model analysis, natural frequencies are obtained. These natural frequencies are of paramount importance in various engineering fields. Due to this frequencies various modes of deformation are getting. For getting total deformation , fixed the lower case of gearbox and obtaining total deformation of vibration.

Table 2:- Modes and Frequencies of deformation

MODES	FREQUENCIES
1	144.84
2	370.5
3	496.3
4	522.12
5	695.18
6	773
7	800.45
8	907.42
9	996.08
10	1045.8

3. **Harmonic Analysis:-** Harmonic Analysis is a linear dynamic analysis used to determine the response of a system to excitation at specific frequencies. It is a branch of mathematical concerned with the representation of functions or signals as the superposition of basic waves, and the study of generalization of the notions of Fourier series and Fourier transforms. It is also referred to as Frequency Analysis. In a Harmonic Analysis, the load applied to the linear model is a steady state sinusoidal load at a given frequency.

In harmonic analysis, load is specific on this model 1000kN load is applied in downward direction on y direction. Due to which on spalling consist gear teeth having high deformation obtained while on non spalling gear teeth less amount of deformation is obtained. In total deformation, by observing resonance condition arrived earlier in spalling gear teeth as compare to non spalling gear teeth.

Taking some engineering data to analysis the spalling gearbox are as below:-

Properties and Material Selection: -

Table 3:- Part and Material of Gearbox

S.No	Parts	Material
1	Upper Housing	Stainless steel
2	Lower Housing	Stainless steel
3	Spalling of gear	Grey cast iron
4	Gear Pair	Grey cast iron
5	Roller bearing	Crominum steel
6	Shaft	Grey cast iron

Various properties are taking to analyse the material such as Density, Poission's ratio, Modulus of Elasticity are as given below:-

Material Properties of Gearbox:-

Table 4:- Gearbox Material Properties

S.no	Material	Properties	Properties	Properties
		Density , ρ (kg/m^3)	Poisson'sRatio, μ	Modulus of Elasticity E(GPa)

1.	Grey cast iron	7200	0.28	110
2.	Stainless steel	7750	0.31	193
3.	Crominiun steel	7150	0.20	245

Harmonic response of the spalling gear teeth for the excitation in the range of 0-1200 Hz has been studied. The maximum amplitude (0.014659-00 mm) at the frequency of 500Hz for non-spalling gear teeth. While the maximum amplitude (0.0003568-00mm) atthe frequency of 330 Hz for spalling gear teeth. At the frequency 330 Hz, the amplitude and stress are maximum, as the frequency increases the amplitude and stress decreases. To avoid the resonant condition, the safe working frequency range is 0-300Hz. These characteristics are helpful for proper design of the system.

4. RESULTS:-

Frequency response curve for spalling and non spalling gear teeth:-

- In this analysis for the dynamic response, aload is specified is known as harmonic response analysis, by the help of this total deformation of gearbox and frequency response for amplitude this is deformation can be calculated. For this within a frequency range 0 Hz to 1200 Hz for 100 intervals are calculated. Frequency response with deformation as shown in fig.7.

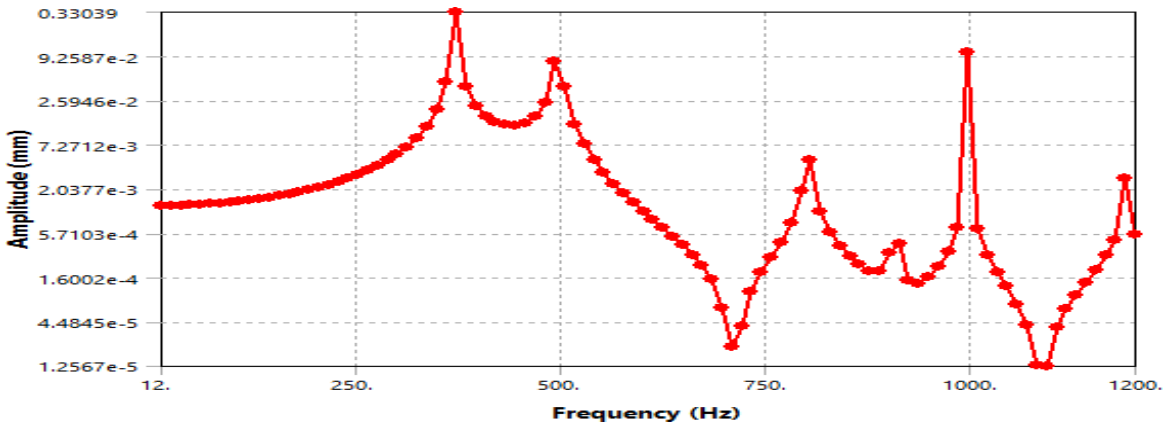

Figure 7:- :- Graph plot b/w frequency and amplitude in spalling gear tooth

From the above figure at around 330 Hz deformation is maximum. i.e nearly 0.33039 mm, so if gearbox frequency matches this frequency, then the condition of resonance occurs**.**

- In this analysis for the dynamic's response, total deformation of gearbox and frequency response for amplitude this can be calculated. For within the frequency range 0 Hz to 1200 Hz for 100 intervals are calculated for non- spalling gear tooth. Frequency response with deformation as shown in fig.8.

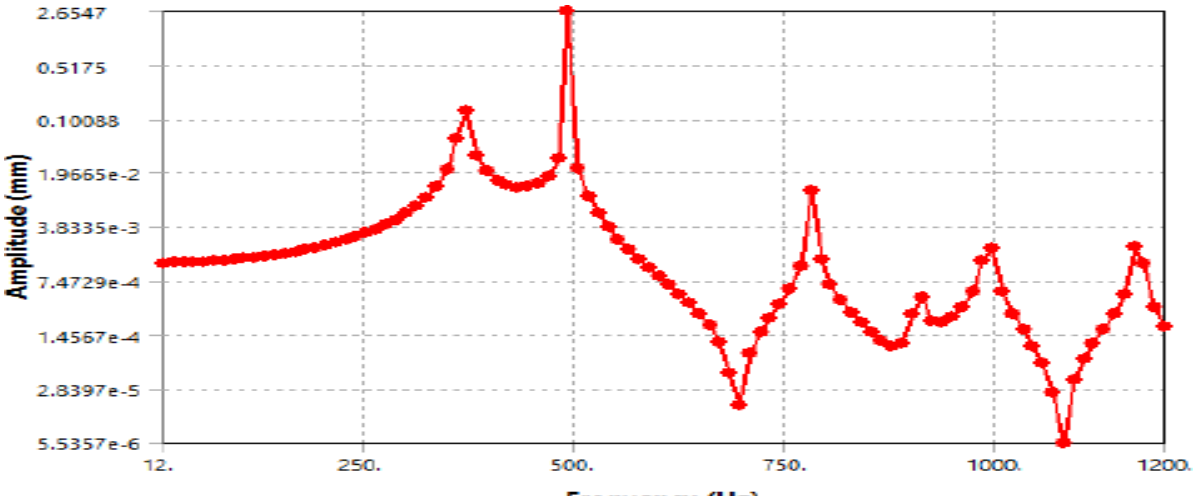

Figure 8:- Graph plot b/w frequency and amplitude in non- spalling gear tooth

5. CONCLUSION:-

- Natural vibrations modes of the gearbox are being calculated with the help of modal analysis and various modes of deformation.
- With the help of harmonic response, by applying a dynamic load frequency response of deformation are obtained.
- With the help of frequency response, resonance frequency for spalling and non-spalling of gear obtained. Resonance frequency response of spalling gear in 350 Hz with the deformation of 0.33039 mm while resonance frequency of non-spalling gear in 500 Hz with the deformation of 2.6547mm.
- By observing the resonance frequency resonance condition arrived earlier in spalling gear as compare to non-spalling gear.
- To find the vibration of any dynamics body this procedure is helpful to extract the vibration in frequency domain.
- In future research over on random vibration of gearbox in directional deformation and total deformation of any dynamic body is helpful to find the randomness of vibration of any body.

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