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Detection of Gear Tooth Defects by Using MATLAB & FEA Technique

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Abstract -

Abstract— In gearboxes, load fluctuations on the gearbox and gear defects are two major sources of vibration. Further, at times, measurement of vibration in the gearbox is not easy because of the inaccessibility in mounting the vibration transducers. Vibration analysis techniques are used for detection of fault in gear system, fluctuation in gear load such as a method for monitoring the evolution of gear faults based on the newly developed time- frequency analysis through FEA, in which analysis is carried out with the decomposed current signal to trace the sidebands of the high frequencies of vibration,. It is also helpful tool for health monitoring of gears. Acoustic signal can be used effectively along vibration signal to detect the various local faults in gearboxes using the wavelet transform technique. Two commonly encountered local faults, tooth breakage and tooth crack were simulated. In fault simulating, two very similar models of worn gear have been considered with partial difference for evaluating the preciseness of the proposed algorithm. Moreover, the processing of vibration signals has become much more difficult because a full-of-oil complex gearbox system has been considered to record raw vibration signals. Raw vibration signals were segmented into the signals recorded during one complete revolution of the input shaft using tachometer information and then synchronized using piecewise cubic hermit interpolation to construct the sample signals with the same length.

Key words: Gear Defects, Vibration Analysis, Finite Element Analysis, Acoustic Signal, Tooth Breakage, Raw Vibration Signals.

1.INTRODUCTION

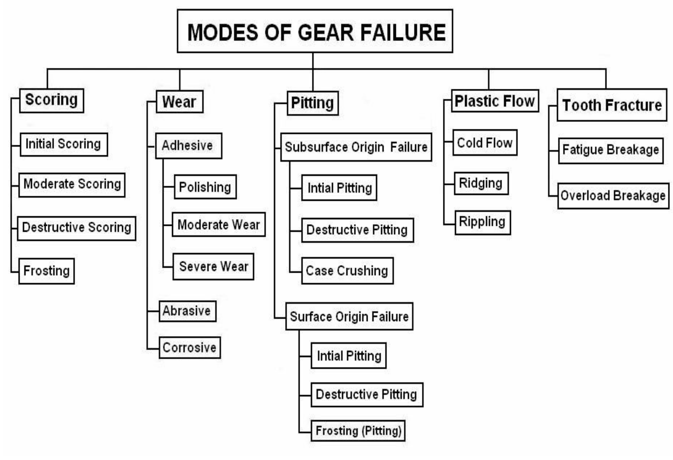
Gear Box Gear Box constitutes a very vital link in the transmission chain of a variety of equipment and machinery. The earliest drives used cylindrical rods inserted radically in one wheel meshing with similar rods mounted axially in another wheel. This type of drive performed satisfactory, though inefficiently, at low speeds and low loads but trouble was encountered as soon as load or speed was raised. The increasing trend towards predictive maintenance has led to the development of a vast number of machine condition monitoring techniques. Of these techniques, vibration analysis and oil analysis are the two distinct and most readily used methods in determining mechanical failures in common components of industrial machinery such as gears and bearings. Gear mechanisms are an important element in a variety of mechanical systems. For that reason, early fault detection in gears has been the subject of intensive investigation and many methods based on vibration signal analysis have been developed. Conventional methods include crest factor, kurtosis, power spectrum estimation, time-domain averaging and demodulation, which have proved to be effective in fault diagnosis and are now well established.

A large number of research papers on vibration-based fault detection and diagnosis have been published. When there is a force variation in a gearbox, the component will generate a vibration. This vibration is then transmitted to the surrounding structure, and therefore noise and vibration will be generated in the gearbox. Transmission error (TE) is generally considered to be the primary excitation mechanism for gear noise and vibration. According to, a transmission error is defined as —the difference between the actual position of the output gear and the position it would occupy if the gear drive were perfectly conjugate. Vibration signal analysis is an important tool to experimentally investigate gear vibration because gears generate vibrations at specific frequencies, which are related to the number of gear teeth and the rotational speed of the gear shaft. AE is defined as transient elastic waves within a material caused by deformation and the release of localized stress energy. Even though AE has been studied as a potential tool for machine fault diagnosis for a long time, the source and characteristics of AE signals, especially in machine fault detection, are still not fully understood. Initially, burst type AE signals were used for fault detection in structural health monitoring. The AE bursts are believed to be fault related. While this might hold a ground truth for static structural fault detection, it has never been proved for rotating machines. It is generally accepted that an increase in meshing stress would generate AE responses with larger amplitude. In this paper, AE signals are postulated to be mostly related to the interaction and impact of teeth during tooth meshing. The impact on the surface of the tooth causes material deformation and this is followed by the stress energy release, which will then cause transient elastic waves.

2. Body of Paper

Gear Tooth Defects Gear failure can occur in various modes. In this chapter details of failure are given. If care is taken during the design stage it to prevent each of these failures a sound gear design can be evolved.

Project Methodology: To collect vibration signature of good



gears and defective gear (missing tooth) from Fast Fourier Transform (FFT) Unit. Real time vibration signatures of good and defective gears are to be acquired with the help of accelerometers using Data Acquisition System (DAS). Modeling of gear box containing good and defective gears would be carried out using CATIA DS R15. The same model will then exported MATLAB & FEA for simulation and further analysis. Transient analysis would be carried out initially with only two spur gears, gearbox housing and the two shafts to get feel of simulation and analysis in FEM environment.

The experimental rig consists of two electrical machines, a pair of spur gears, a power supply unit with the necessary speed control electronics and the data acquisition system. Referring to Figure No.4.2, a DC machine of 1.5 KW rotates the pinion. The load is provided by an AC asynchronous machine, which is configured as a brake. The transmission ratio is 35/19=1:59, which means that an increase in rotational speed is achieved. The vibration signal generated by the gearbox was picked up by an accelerometer bolted to the pinion body and the electrical signal was transferred to an external charge amplifier through slip rings. No form of signal averaging was used as the signal to noise ratio has been considered high enough.

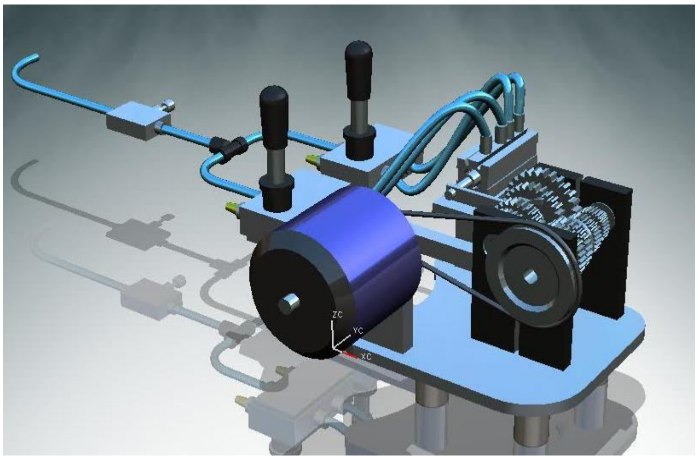


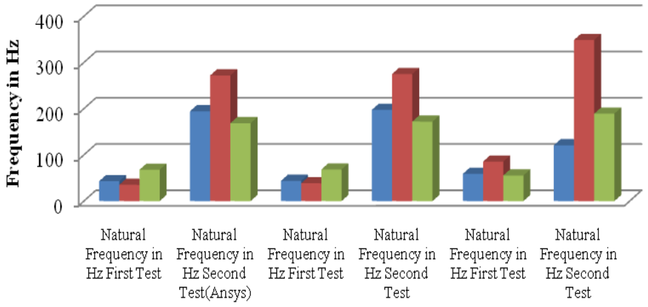
Fig -1: Experimental Test Rig (Graphical Representation)

Table -1: Experimental Results on FFT Analyzer Accelerometer

Sr. No.	Gear Defect	Direction of Probe Position	Natural Frequency (Hz) Before Defect (Healthy Gear)	Natural Frequency (Hz) After Defect (Faulty Gear)
1	Scoring	H	42.9	197.5
2		V	35.2	275.4
3		A	67.7	172.8
1	Pitting	H	43.7	197.5
2		V	38.5	275.0
3		A	68.4	172.0
1	Tooth Fracture	H	58.9	120.7
2		V	85.4	348.6
3		A	55.4	189.2

H: Horizontal, V: Vertical, A: Axial

Chart -1: Experimental Results Comparison of Scoring, Pitting & Tooth Failure.



ANSYS-Gear Profile

The Fig -2 below show the imported file (IGES) of Gear pair in the ANSYS simulator, for performing structural evaluation of all parameters

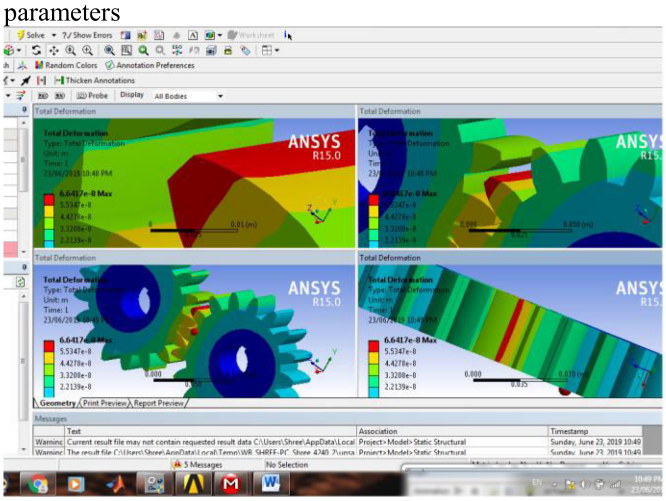


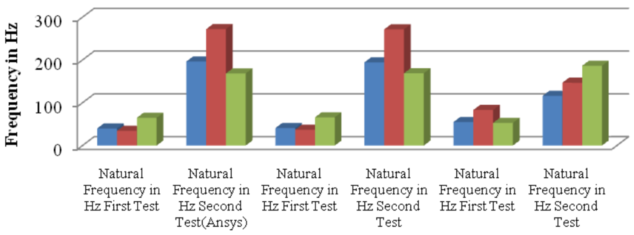
Fig -2: Gear Analysis in Workbench

Table -2: Test Reading on ANSYS

Sr. No.	Gear Defect	Direction of Probe Position	Natural Frequency (Hz) Before Defect (Healthy Gear)	Natural Frequency (Hz) After Defect (Faulty Gear)
1	Scoring	H	40.186	196.378
2		V	34.601	272.005
3		A	64.958	168.582
1	Pitting	H	40.861	194.501
2		V	36.982	271.642
3		A	66.005	169.153
1	Tooth Fracture	H	55.012	116.135
2		V	83.164	146.867
3		A	52.964	186.551

H: Horizontal, V: Vertical, A: Axial

Charts-2: Experimental Results Comparison of Scoring, Pitting & Tooth Failure by ANSYS.



MATLAB is a high performance numeric computation and visualization software product developed by The Math Works Inc, Massachusetts USA. It involves the use of an interactive environment containing numeric computation, matrix computation, and signal processing and graphics capabilities. The features which are particularly important in as far as vibration signal processing is concerned include its interactive nature, extensibility, multi platform capability, ability to link in existing code, standardized data format, range of built in functions and graphics capability.

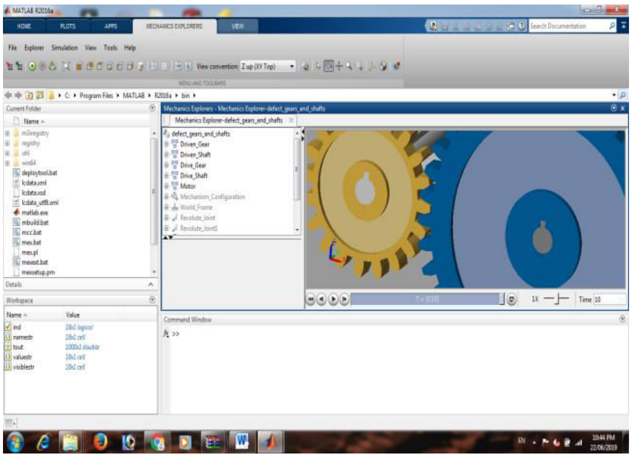


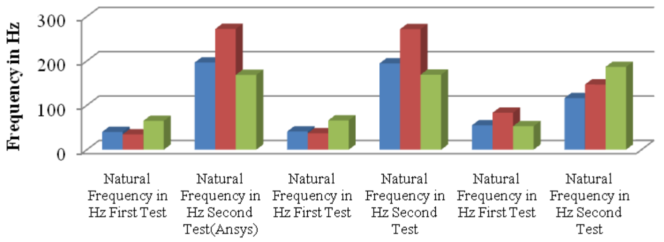
Fig -3: Meshing of CAD Model

Table -3: Test Reading on ANSYS

Sr. No.	Gear Defect	Direction of Probe Position	Natural Frequency (Hz) Before Defect (Healthy Gear)	Natural Frequency (Hz) After Defect (Faulty Gear)
1	Scoring	H	41.25	196.998
2		V	35.687	273.546
3		A	66.023	170.223
1	Pitting	H	40.861	194.501
2		V	36.982	271.642
3		A	66.005	169.153
1	Tooth Fracture	H	56.379	118.098
2		V	84.057	325.257
3		A	53.681	187.439

H: Horizontal, V: Vertical, A: Axial

Charts-3: Experimental Results Comparison of Scoring, Pitting & Tooth Failure by MATLAB



3. CONCLUSIONS

It is observed that vibration analysis is better compared to other monitoring techniques. To reduce costs and facilitate diagnosis, vibration analysis is a very popular technique. When the meshing characteristics are disturbed by a defective tooth, this will change the noise content of the acoustic signal when compared with the sound of healthy operation. The objective of this project is to identify the defects in gearbox in embryonic stages to minimize the damage by the method of early detection of gearbox faults. For that we have assembled a prototype of Two-Wheeler Gearbox and conducted experimental testing using FFT Analyzer.

The results obtained from FFT are then compared with the overall evaluation results obtained from ANSYS and MATLAB. The Validation of the results prove that there is sharp increase in vibration level in meshing gears in vertical loading conditions for three major defects namely Scoring, Pitting and Tooth Fracture Defect. Hence, the validation and vibration analysis technique shows that the defects in the gear box can be detected at very early (embryonic stages), which reduces the cost of detection and diagnosis.

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BIOGRAPHIES

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