Acoustic Signal Analysis of Spur Gear with Pitting Defect

Vijay Kumar Karma[1] Govind Maheshwari[2]
[1,2]Institute of Engineering & Technology, Devi Ahilya Vishwavidhyalaya, Indore, MP, India

Abstract— The aim of this research paper is to identify and find out the energy dissipated by spur gear with defects in single stage spur gear box using experimental setup. The Acoustic signals are captured from the experimental setup for different loading conditions and pitting defects and the sudden change in the acoustic signals is then analyzed. MATLAB code is used for the identification of faults using wavelet technique. A number of defects i.e. single pit on single tooth, single pits on multiple teeth, multi pits on single tooth, single and multi-pits on multiple teeth, multi pits on multiple teeth, are created on driver gear and signals are captured for healthy and defected gears. On comparing the signature of healthy and defected gears at different rpm and load the energy dissipated is analyzed.

Key words: Spur Gear, Acoustic Signal Analysis

I. INTRODUCTION

The work in the paper deals with the capturing of acoustic signals with the help of microphone of a single stage spur gear box at different conditions of working. Spur gear are the most commonly used type of transmitting members in rotating machinery in various industries. To transmit power it is necessary that the machinery should be in good working conditions. Any deviation from this condition will results in the variation of its performance, and may leads to the costly break down in some cases. Therefore, conducting effective condition monitoring and fault diagnosis is desirable and imperative in industry. [1] Condition monitoring is defined as the detection and collection of information that indicate the state of machine. Condition monitoring provides information, which helps to maximize machine life. In this paper, Acoustic signal is used for condition monitoring. It is the new approach for condition monitoring in rotating machinery. It offers some advantages over other techniques. It is highly sensitive and offers opportunities for detect the defects in moving elements. Acoustic signal mainly detect high frequency sound and it is not affected by mechanical background noise. [2]

In the present work the faults considered are pitting on single and multiple teeth. The fault is created artificially. The Acoustic signal data is collected from the experimental setup at different pitting defects and then the energy dissipated is found out. Wavelet technique is used in order to evaluate the acoustic signal and to determine how the energy dissipated varies with increasing pitting.

II. LITERATURE REVIEW

Shipley [3] presented a brief review of every type and major stages of gear failures with detailed explanation. He has demonstrated the defects using photographs of actual failures, along with probable cause and most effective remedies. Saxena et al [4] provided a brief discussion on current practices of predictive maintenance (PDM) methodologies such as vibration analysis and acoustic analysis. These techniques are widely used since they offers a complimentary tool for health monitoring or assessment of gears in rotating machineries. The importance of wavelet transformation has also been mentioned in their work. Loutas et al [5] introduced a different nondestructive inspection methodologies and the processing of the acquired waveforms with advanced signal processing techniques for condition monitoring using acoustic emission and vibration measurements with the help of experimental setup whose details are provide in their research paper. Maynard & Kenneth [6] introduced a new signal processing approach based on acoustic emission (AE) in a very slowly rotating machine that can be supplement by or supplement to other signal processing methods. Singh et al [7] presented a brief review of some current AE based techniques used for condition monitoring in geared transmission systems. Michael et al [8] discussed various methods used for the diagnosis of the gear box. Their main objectives was focused towards the features that are used for the detection of gear faults. They provided an overview of the preprocessing flow of categorization of features and calculation of the processing scheme. Yang et al [9] explained various vibration feature extraction techniques for fault diagnosis of rotating machinery in time domain, frequency domain and time-frequency domain. They concluded and investigated that the frequency domain features are generally more consistent in the detection of damage then time domain parameters. Qingbo and Xiang [10] proposed a new wavelet method which employs the TFM base to demodulate the periodic impulses from original faulty signals. Gao et al [11] proposed the method of enveloping that provides the theoretical basis for preventing and monitoring turbine's faults. Zhang et al [12] proposed a rolling bearing fault diagnosis method based on the combination of envelope analysis and wavelet analysis. Their developed method can pick up the fault frequencies effectively and enhance the capabilities of fault diagnosis under strong noise. Wen-Chang et al [13] developed a new method to overcome the traditional envelope method for the selection of the resonant frequency band. The proposed method combined the empirical mode decomposition (EMD) and the envelope analysis to detect the fault of the rolling bearing. Eric et al [14] used "Envelope Analysis" a well-known signal processing technique for bearing fault detection. Hui et al [15] proposed a new approach based on the fusion of the Laplace wavelet transform and envelope spectrum for detection and diagnosis of defects in rolling element bearings. Randall et al [16] in rolling bearing envelope analysis shows that better results can be obtained by analyzing the squared envelope of the corresponding analytic signal, which avoids the interference of sum frequencies which result from two-sided spectra.

III. ANALYSIS OF FAULTS

To perform the analysis the experiment is carried out in two phases without loading and with loading. The acoustic signals are recorded for the following cases of pitting defects:

- Gear with single pit on single tooth designated as defect 1

- Gear with single pit on multiple teeth designated as defect 2
- Gear with multi pits on single tooth designated as defect 3
- Gear with multi pits on multiple teeth designated as defect 4
- Gear with multi pits and single pit on multiple teeth designated as defect5

All this pits were produced manually on gear using a drill.

The healthy gears are mounted and the corresponding acoustic signals are captured. The time domain acoustic signals for healthy gear at different speed without loading and with loading are taken. The experimental setup used for the work is shown in the Fig. 1. The time domain signal is then converted into frequency domain with the help of FFT of the signal. After filtering the acoustic signal and analyzed using wave menu tool of MATLAB toolbox and the energy dissipated by the healthy gear are taken for different rpm. After analyzing the signals, energy dissipated by the healthy gear at different rpm is determined. The energy dissipated by the healthy gear is ranges from 4.006dBJ -15.34dBJ for different rpm. This procedure is repeated for all kind of defects considered for analysis by replacing the driver gear with the respective defective gears. Fig. 2 represents the energy dissipated by healthy gear at different rpm.

The procedure to determine the energy dissipated by the defective gears is mentioned for one of the case of defect1. The same procedure is adapted for determining the energies dissipated by the gear with defect2, defect3, defect4 and defect5 and hence a sample case for defect1 is described here.

A. *Analysis of Defect 1*

In the experimental setup the driver gear was replaced with gear of defect1 and the acoustic signal is captured for one second. This step is repeated five times for next five different pitting defective gears at different speed. It is observed that the acoustic signals are changed as compared to the healthy gear. The amplitude is higher at the frequency nearly 4.5 kHz and that the acoustic bursts due to the defect in the gear tooth generate high frequency components (in the range of 4.3–5.3 kHz). Therefore a frequency band range between 4.3 kHz to 5.3 kHz is selected by applying the filtering of the signal. After filtering the signal, at different rpm, the energy dissipated by the defect1 gear is analyzed using wave menu tool of MATLAB toolbox. After analyzing the signals the energy dissipated by gear with defect1 at different rpm is obtained. The energy dissipated varies and ranges between 5.244dBJ -22.34 dBJ. Fig. 3 represent the energy dissipated by gear of defect1 at different rpm.

Fig. 1: Experimental Setup

Fig. 2: Energy dissipated by Healthy Gear at different rpm

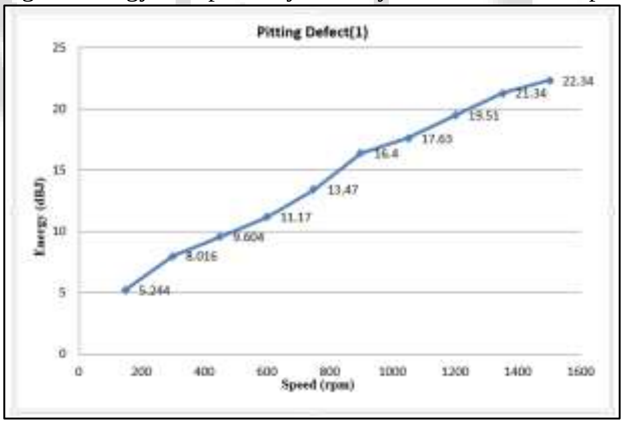

Fig. 3: Energy dissipated by Gear of defect1 at different rpm

IV. RESULT AND DISCUSSIONS

After capturing and filtering the signals a graph is plotted between the energy of defective gear and speed (rpm) without loading. It is clear from the figure 4 that the energy range of defective gears is higher in case of multi pits on multiple teeth 13.36dBJ-47.13dBJ and lowest in case of single pit on single tooth 5.244dBJ-22.34dBJ. The energy dissipated by the gear of single pits on multi teeth and multi pits on single tooth was found to be 6.997dBJ-29.42dBJ and 9.8dBJ-38.93dBJ respectively. In case of multi pits with single pit on multiple teeth defect the energy dissipated are 12.6dBJ-39.66dBJ. It was observed that when the severity level of the pitting defect is increased then the energy dissipation is also increased.

A graph is also plotted between the energy dissipated by the gear of defects and load at various speeds. It is clear from the figure 5 that the energy range of defective gear is higher in case of multi pits on multiple teeth (12.42dBJ-19.51dBJ) and lowest in case of single pit on single tooth (5.236dBJ-11.36dBJ).The energy dissipated by gear of single pits on multi teeth and multi pits on single tooth was found to be (6.26dBJ-13.13dBJ) and (7.062dBJ-15.34dBJ) respectively. In case of multi pits with single pit on multiple teeth defect the energy dissipated are (8.01dBJ-16.4dBJ). It was observed that when the severity level of the pitting defect is increased then the energy dissipation is also increased.

V. CONCLUSIONS

It is observed that the defect5 is most severe as the energy of defect is highest i.e. 13.36dBJ-47.13dBJ.

It is observed that the effect of single pit defect without loading and single pit defect with loading (1kg) is minor as their energies were found low.

It can be seen from the figure that energy dissipated was increased with increased rpm and load, max energy dissipated was at 1500 rpm and minimum at 150 rpm.

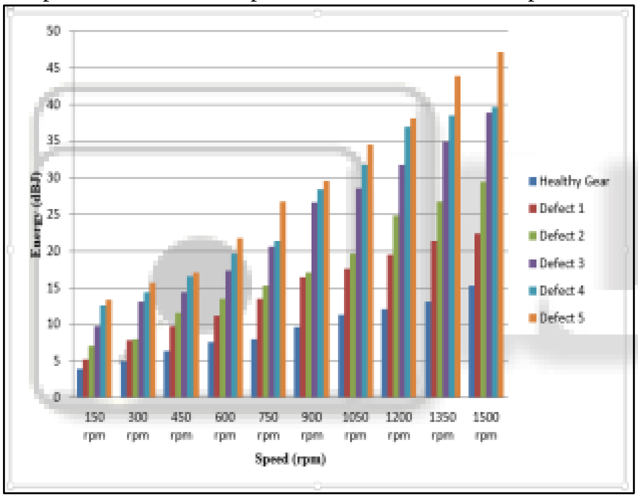

Fig. 4: Comparison of the Energy dissipated by healthy and defective gears at different rpm without load

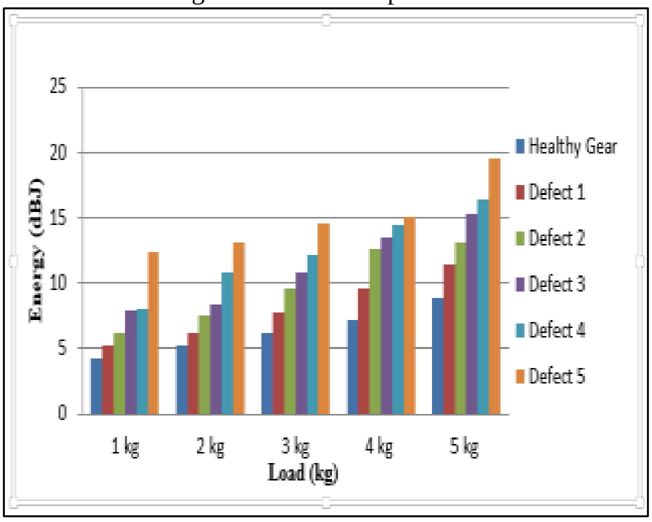

Fig. 5: Comparison of the Energy dissipated by healthy and defective gears at different load.

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