Fault Diagnosis by Noise Measurement in Single Stage Gearbox

Vrushali D. Pawar[1], Prof. Pavankumar Sonawane[2]

[1]*Student, DYPIET, Mechanical Engineering, Pune, Maharashtra, India*
[2]*Asst. Professor, DYPIET, Mechanical Engineering, Pune, Maharashtra, India*

---***---

Abstract - *In automotive gearboxes, the gear damage detection is often very critical. Gearboxes are power transmission devices with the features of compact structure and high transmission efficiency. They have been widely used in many fields such as transportation, energy and chemical industry, etc. However, because of its complex structure and harsh working conditions, gears are prone to failure (e.g., abrasion, chipping, crack, etc. Noise measurement is one of the technologies for health monitoring and fault diagnosis in gearboxes. A specially built test rig was used to measure gearbox noise and vibration for the different test gear pairs. The assembly and disassembly of the different gears and pinions with defects give multiple noise measurement results. Different parameters can be diagnosed during the sound analysis.*

Key Words: Gearbox, vibration, sound pressure level, noise, pitting

1. INTRODUCTION

Gears are important elements for power transmission with its compact structure in a variety of industrial applications such as machine tool and gearboxes. Gear tooth failure is very common defect which leads to tremendous economic losses. For that reason, fault diagnosis in gears has been the subject of intensive research. The gearbox is a source of vibration and, consequently, noise. Except for bearing extreme structure resonance amplification, gears are the main sources of high frequency vibration and noise. Noise is a first sign for transmission problem. The gearbox's overall sound pressure level (SPL), compared to the SPL associated with the meshing gears, is only by some 5 dB higher at maximum. Condition monitoring is used to conduct preventive maintenance in order to prevent future development of faults. Machine condition monitoring can be realized by monitoring following characteristics: vibration, aural, visual, operational variables (state of the system), temperature and wear debris (e.g. oil analysis).

Xihui Liang (2018) has reviewed techniques for fault diagnosis on all types of gear faults including gear tooth pitting, tooth cracking/spalling, wear, tooth tip chipping, manufacturing errors, misalignment, eccentricity and so on. Gearbox contains many components such as bearings, shaft, gears and pinions, belt drives, etc. Failure can occur in any of the components. These failures can cause major losses and damage to the components. Hence, early fault diagnosis need to be done.[1]

Amar Pawar (2016) presents the fault detection technique in two stage helical gear box. This paper present the work on condition monitoring of a lab-scale, two stage, gearbox using different non-destructive inspection methodologies and of the acquired waveforms with advanced signal processing technique. The Acoustic emission (AE) and vibration measurements were utilized for this purpose. The experimental setup and the instrumentation of each monitoring methodology are presented in detail. The signal processing of the acquired vibration and acoustic emission signals are obtained from the set up. The results are generated in waveforms. The parameters involved in diagnosis are well obtained from the acoustic signals. [2]

Manoj Kumar Dwivedi (2015) presents the comparative analysis of healthy and cracked spur gear using vibration signal in single stage gear box. This paper deals with the analysis of a healthy gear and faulty spur gearbox having crack defect on multiple teeth at different angle on driving gear using frequency domain technique through MATLAB software. Using the vibration signals and the sudden burst in the vibrations, analysis is carried out and frequency of the faulty gear is found out. [3]

T Praveenkumar (2014) addresses the use of vibration signal for automatic fault detection of gearbox. Using the vibration signals, the performance of the gearbox can be found out. In this study, they examine good gears and face wear gears to collect vibration signals for good and faulty conditions of the gearbox. Hence, the comparative study of faulty and good gears is carried out.[4]

Jimeng Li (2017) summarized into two terms: (1) an adaptive VMD (variation mode decomposition) method was developed, (2) an underdamped SR model based on improved coupled bistable system was proposed, and the relationship between the system parameters and the system output SNR was analysed through numerical simulation to verify the validity of the proposed model. VMD decomposes the vibration signals into the intrinsic mode functions (IMF).This results in automatic determination of the appropriate mode number according to correlation kurtosis (CK). Stochastic resonance (SR), as a kind of Noise assisted signal processing method, can realize the extraction and enhancement of weak signal features by utilizing noise instead of eliminating noise. [5]

Nilson Barbieri (2019) identified the presence of damages and diagnosed the damaged component in automotive gearboxes by comparing the vibration signals of the damaged and undamaged systems. The vibration analysis was done for ten samples of the gearboxes. Firstly subjective method was used based on human hearing. Secondly, three gearboxes were taken out of which two with bearing damage and one with gear tooth damage. Five accelerometers were used to obtain the signals by positioning in the samples and ten different steps with different configuration of the gears. Different signal analysis techniques based on wavelet transform, mathematic morphology and energy (entropy) were used to verify the presence of damage in the systems. The energy level of the signals in the damaged and undamaged systems is compared. A signal processing technique combining pattern spectrum and selective filtering in certain frequencies ranges was used for identification of component failures. This technique can further be used to detect early damages. [6]

Dongsik presented a paper on Detection of faults in gearboxes using acoustic emission signals. In this paper noise parameter such as Power spectrum, Sideband peaks, Hilbert Transform or low pass filtering used to detect the fault. Here the detection result of the test was shown by power spectrum and comparison of the harmonic level of the rotating speed. The paper presents the result, we can understand that Acoustic emission signals can detect fault more easily than accelerometer. It can be used in condition monitoring system Acoustic emission signal can be shown the clean result with harmonic and sidebands .It is a better technique for condition monitoring system. For condition monitoring of the machinery, the Acoustic emission system is a powerful method to detect fault earlier, Acoustic emission sensor can detect the fault earlier than an accelerometer because of high sensitivity. In the power spectrum the harmonic of rotating speed and gear meshing frequency clearly occurred. [7]

2. EXPERIMENTATION

This paper presents project work the early detection of a gear fault (i.e. a real tooth pitting). Therefore, a gear test rig has been used to obtain relevant diagnostic information about this gear fault. Experimentation is performed on the single stage gear box (number of teeth on pinion is 32 and number of teeth on gear is 56) module of gear is 2.5mm. The power is transferred from motor to gearbox by means of belt drive.

Table1. Gear Dimensions

SR. No.	Parameter	Dimension of pinion	Dimension of gear
1	Module	2.5mm	2.5mm
2	No. of tooth	32	56
3	Material	En8M	En8M
5	Addendum	2mm	2mm
6	Deddendum	2.5mm	2.5mm
7	Pitch circle diameter	64mm	112mm
8	Face width	20mm	20mm
9	Teeth thickness	3mm	3mm

Fig1. Test set up

Fig2. FFT Analyser

Fig3. Polarized microscope

Four spur gear pairs are manufactured for the experimentation. The experimentation is to be performed on healthy gear and defective gears. Initially, the gears and pinions of above mentioned sizes are fabricated. According to the calculated number of pits, the pits are created on the three gears and pinions.

1. First gear pair is kept as manufactured. It is called healthy gear pair which has no defect.

2. Slight pitting is done one gear pair. Slight means 5 numbers of pits are created, i.e., 12% of the area of tooth is pitted.

3. Moderate pitting is done in second gear pair. In moderate pitting, 50% of the area of tooth is pitted. Number of pits is calculated.

4. Severe pitting is created in third gear pair. Severe pitting has 75% area of tooth pitted.

Fig4. Healthy gear and pinion

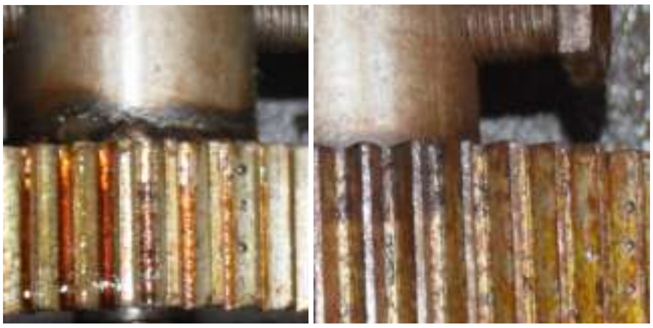

Fig5. Slight pitting on gear and pinion

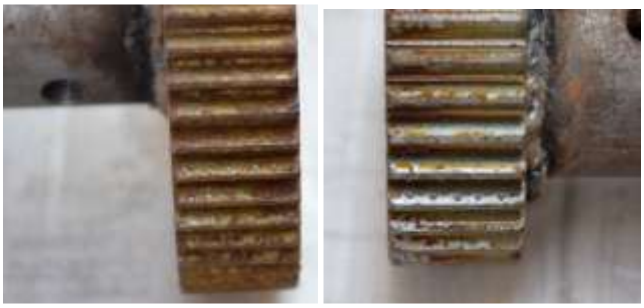

Fig6. Moderate pitting on gear and pinion

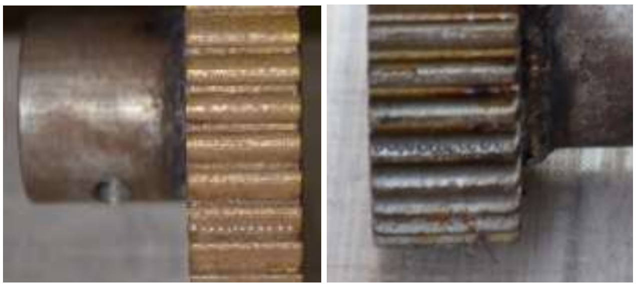

Fig7. Severe pitting on gear and pinion

3. METHODOLOGY

In this trail set up, the gearbox is allowed to run at an input speed of 1440 rpm. The gearbox runs at constant speed. The trails are taken for constant load conditions and constant speed. The microphone is used to record the noise created by the gearbox. Initially, the gearbox has healthy pair assembled in it.

Formation of fault on tooth

Another three gear pairs are used for fault diagnosis. The different intensity of pitting is created on the gears and pinions. Forming different conditions by altering the gears and pinions, trails are carried out.

Sr. No	Gear	Pinion
1	Healthy	Healthy
2	Healthy	6.3% pitting
3	Healthy	27.8% pitting
4	Healthy	41.7% pitting
5	Healthy	Healthy
6	6.3% pitting	Healthy
7	27.8% pitting	Healthy
8	41.7% pitting	Healthy
9	27.8% pitting	Healthy

Table2. Conditions for gearbox trails

4. RESULTS AND OBSERVATIONS

The basic aim of this project work is to design a test rig and to carry out experimentation to detect different types of faults. The pitting is a very common fault found in various gearboxes. This produces noise in gearbox. Hence, this project is to diagnose the gearbox failure by measurement of noise. In the experimentation, vibration response measured from the gear box is analyzed to detect different faults. For this analysis gear rotates at loading condition and at constant speed of motor.

The following graphs show the different parameters to be measured and considered in noise analysis.

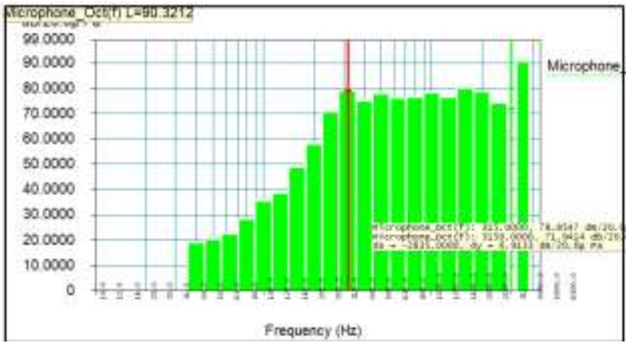

Fig8. Octave band spectrum

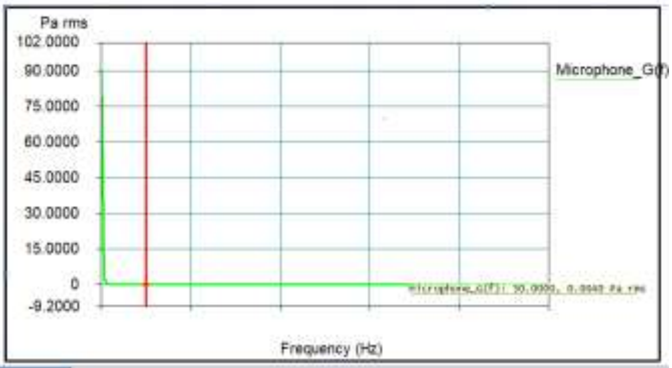

Fig9. Frequency Vs Sound Pressure level

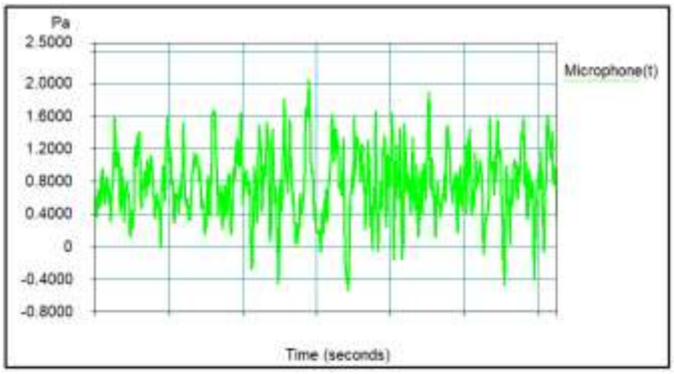

Fig9. Time Vs Sound Pressure level

5. CONCLUSION

Sound measurements are made always together with noise measurements. It is very well necessary to detect the faults in the gearbox at early stage. The equipments' or motors' working is followed by vibrations, oscillations which are in hearing domain, so monitoring the right functioning of these can be made through sound and noise measurement and analysis. To analyze noise, both frequency and amplitude need to be taken into account. To determine the distribution of the sound level frequency octave analysis is used. In noise measurement and analysis there are specific frequencies due to the rotating element. These specific frequencies are proportional with the fundamental frequency. If a damage in tooth of gear is found, the noise can be easily detected. Hence, a comparative study for different conditions of faulty gear pairs is done to obtain satisfactory results in noise measurement or noise analysis.

REFERENCES

[1] Xihui Liang, Ming J. Zuo, Zhipeng Feng, "Dynamic modeling of gearbox faults: A review", Mechanical Systems and Signal Processing 98 (2018)

[2] Amar Pawar1, Yogesh Hinge, Mahesh Kotwal, "Fault Detection Techniquesin Two Stage Helical Gearbox by using Vibration Analysis" International Journal of Innovative Research in Science, Engineering and Technology Vol. 5, Issue 5, May 2016.

[3] Manoj Kumar Dwivedi, Vijay Kumar Karma (2015) "Comparative Analysis Of Healthy And Cracked Spur Gear Using Vibration Signal In Single Stage Gear Box" International Journal Of Engineering Sciences & Research Technology 4(7): July, 2015

[4] T. Praveenkumar, M Saimurugan, P Krishnakumar& K I Ramachandran (2014). "Fault diagnosis of automobile gearbox based on machine learning techniques", 12th Global Congress On Manufacturing And Management, Gcmm 2014, Procedia Engineering, Vol. 97, pp. 2092 – 2098

[5] Jimeng Li, Hui Wang, Jinfeng Zhang, Xifeng Yao, Yungang Zhang, "Impact fault detection of gearbox based on variational mode decomposition and coupled underdamped stochastic resonance"

[6] Nilson Barbieri, Gabriel de Sant'Anna Vitor Barbieri, Bruno Matos Martins, Lucas de Sant'Anna Vitor Barbieri, Key Fonseca de Lima, "Analysis of automotive gearbox faults using vibration signal",Mechanical Systems and Signal Processing 129 (2019)

[7] Dongsikgu, Jaegukim ,Youngsu, "Detection of faults in gearboxes using acoustic emission signals", Journal of mechanical Science and Technology.