International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 4, October 2013

Research Paper

INNOVATIVE METHODS OF MODELING GEAR FAULTS

Prashant Bagde[1]*, A V Vanalkar[1] and S R Ikhar[1]

*Corresponding Author: Prashant Bagde, ✉ prashu.bagde79@gmail.com

The gearbox is an important element of any machine so it is very important to make study on that and finding out faults accouring in the gearbox. It is possible every time to observe the gearbox for its faults so the vibration changes in the gearbox is used for the possible faults. In this thesis the faults accouring in the gears are studied and how the vibrations are changes for a particular faults are studied. The modeling of the elements will be done on the CATIA.

Keywords: Gearbox, Vibrations, Faults

INTRODUCTION

Gear box is a very important part of any mechanism so if any fault accour in the gearbox it will totally affect the working of machine so it is important to study the various faults occurring in the gear box and modeling of that faults. Gears and gearboxes are generally robust and reliable devices.

What Causes Vibration?

Forces generated within the machine cause vibration. These forces may:

- Change in direction with time, such as the force generated by a rotating unbalance.
- Change in amplitude or intensity with time, such as the unbalanced magnetic forces generated in an induction motor due to unequal air gap between the motor armature and stator.
- Result in friction between rotating and stationary machine components in much the same way that friction from a rosined bow causes a violin string to vibrate.
- Cause impacts, such as gear tooth contacts or the impacts generated by the rolling elements of a bearing passing over flaws in the bearing raceways.
- Cause randomly generated forces such as flow turbulence in fluid-handling devices such as fans, blowers and pumps; or combustion turbulence in gas turbines or boilers.

[1] Department of Mechanical Engineering, K. D. K. College of Engineering, Great Nag Road, Nandanvan, Nagpur 440009, India.

Some of the Most Common Machinery Problems that Cause Vibration Include

- Misalignment of couplings, bearings and gears
- Unbalance of rotating components
- Looseness
- Deterioration of rolling-element bearings
- Gear wear
- Rubbing
- Aerodynamic/hydraulic problems in fans, blowers and pumps
- Electrical problems (unbalance magnetic forces) in motors
- Resonance
- Eccentricity of rotating components such as "V" belt pulleys or gears

The Sources of Gear Vibration

Gears are very widely used in machines to transmit power from one shaft to another, usually with a change in speed and torque. The study of the dynamic behavior of gearboxes has received moderate attention in literature, but due the great dynamics complexity of gears, it remains an insufficiently understood area. In practice out of balance and bearing forces are active in gear dynamics, but also the geometry of the gear profile has a crucial effect on the vibration behavior. In general flexural vibration will be more important then torsional vibration because flexural vibrations are transferred directly to the housing via the bearings. In practice, the situation is not so ideal, as the teeth defor under load, introducing a 'meshing error' or 'transmission error', even when the tooth profiles are perfect. In addition there are geometric deviations from the ideal profiles, both intentional and unintentional. Since perfect gears cannot be made, there is always transmission error. Looking at the gearbox vibration mechanism of the most important vibration sources are: time variations in the mass stiffness, caused by variation of the number of teeth in contact and variation in the stiffness of the individual teeth; dynamic effects due the deviation from the ideal tooth profile, in practice all gears contain teeth manufacturing errors, such as errors due to the gear cutting process, deviation in the mesh angle, deviations from the involutes profile, surface roughness of the gears; oscillations on the sliding velocity, where during the transmit ion of power there will be rolling and slipping in the point of contact and also oscillation may occur because of stick-slip effects. Due to these mechanisms, amplitude or frequency vibration signal modulation may be caused, resulting in sideband structures around the tooth meshing frequency and its harmonics. The fact that the vibration amplitude varies with the mean load also means that vibration measurements must only be compared for condition monitoring purposes for the same load each time. Sometimes the only fixed load that can be relied upon is zero loads, but in general this is not a good choice for monitoring purposes, because the teeth can lose contact and give rise to chaotic vibrations which are not very repeatable and which do not necessarily respond to faults in the gears.

Principal Causes of Gear Failure are

An Error in Design: It may be caused due to improper gear geometry, use of wrong material, quality, and lubrication.

An Application Error: It may cause due to Vibration, mounting, installation, cooling and maintenance.

Manufacturing Error: Mistake in machining or problem in heat treatment.

Various Gear Faults

The various gear faults accouring in the gears are listed in the following Table 1.

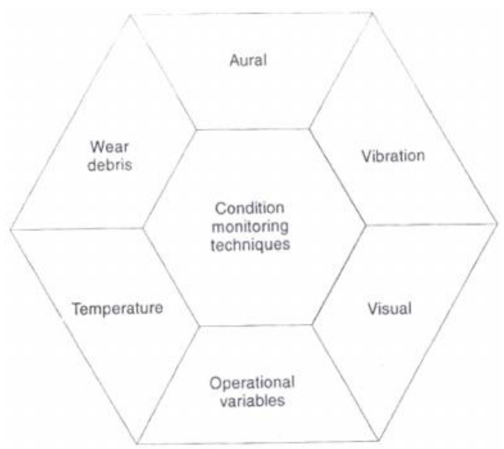
Table 1: Various Faults Detection

Failure	Failure mode	Causes	Contributing factor
Shaft fracture	Fatigue	unbalance	
		Misalignment	Coupling bearing failure
		Bent shaft	
	Overload	Inferences	Incorrect assembly
			Bearing failure
Gear fracture	Fatigue	Life limit exceeded	
		Surface damage	
		Resonance	Design
Tooth fracture	Bending Fatigue	Life limit exceeded	
		Surface damage	process related
		Thin tooth	excessive wear
			Destructive scoring
	Random fracture	Surface damage	process related
			foreign object
			pitting/ spalling
	Overload	Interference	Incorrect assembly
			Bearing failure
		operational	

Techniques for Fault Detection

The Figure 1 shows the various methods of gear faults detections

Figure 1: Techniques for Faults Detection



Why Vibration Monitoring?

- Almost all faults show themselves up in a changed vibration behavior. For most structural and rotor parts gears, bearings, rotors, belts, cracks, couplings, etc.
- Vibration is very sensitive to fault severity.
- Machine never required shutting down, stopped and inspected.
- The process of vibration measurement is online continuous and convenient.
- Non-intrusive, nondestructive.
- Offline inspections.
- Most faults show up in vibration response.
- Convenient and most suitable to online diagnostics.

Fault Detection and Diagnosis from Vibration Analysis

Diagnosis requires a skill in identifying machine's condition from symptoms. The term diagnosis is understood here similarly as in medicine. It is generally thought that vibration is a symptom of a gearbox condition. Vibration generated by gearboxes is complicated in its structure but gives a lot of information. We may say that vibration is a signal o a gearbox condition. To understand information carried by vibration one have to be conscious/ aware of a relation between factors having influence t vibration and a vibration signal. In order to detect (and diagnosis) an impending failure, a good understanding of the evidence relating to the failure mode and methods of collecting and quantifying the evidence is needed. Although many faults may be easily detectable by physical examination of a component, using techniques such as microscopy, X-ray, dye penetrates, magnetic rubber, etc., these methods usually cannot be performed without removal of, and in some cases physical damage to, the component. Whilst physical examination techniques still play a critical role during manufacture, assembly and overhaul, they are impractical in an operational large transmission system and other (non-intrusive) fault detection methods need to be employed for routine monitoring purposes. Most modern techniques for gear diagnostics are based on the analysis of vibration signals picked up from the gearbox casing. The common target is to detect the presence and the type of fault at an early stage of development and to monitor its evolution, in order to estimate the machine's residual life and choose an adequate plan of maintenance. It is well known that the most important components in gear vibration spectra are the Gear Meshing Frequency (GMF) and its harmonics, together with sidebands due to modulation phenomena. The increment in the number and amplitude of such sidebands may indicate a fault condition. Moreover, the spacing of the sidebands is related to their source. Source identification and fault detection from vibration signals associated with items which involve rotational motion such as gears, rotors and shafts, rolling element bearings, journal bearings, flexible couplings, and electrical machines depend upon several factors: (1) the rotational speed of the items, (2) the background noise and/or vibration level, (3) the location of the monitoring transducer, (4) the load sharing characteristics of the item, and (5) the dynamic interaction between the item and other items in contact with it. The main causes of mechanical vibration are unbalance, misalignment, looseness and distortion, defective bearings, gearing and coupling in accuracies, critical speeds, various form of resonance, bad drive belts, reciprocating forces, aerodynamic or hydrodynamic forces, oil whirl, friction whirl, rotor/stator misalignments, bent rotor shafts, defective rotor bars, and so on. Some of the most common faults that can be detected using vibration analysis are summarized.

Typical Gear Faults and Defects that Can be Detected by Vibration Analysis

The various faults that can be detected by vibration analysis are listed below

- Tooth meshing fault
- Misalignment
- Crack or worm teeth
- Localized surface damage
- Wear or inadequate lubrication
- Tooth root cracks, missing tooth
- Pitch error
- Eccentricity

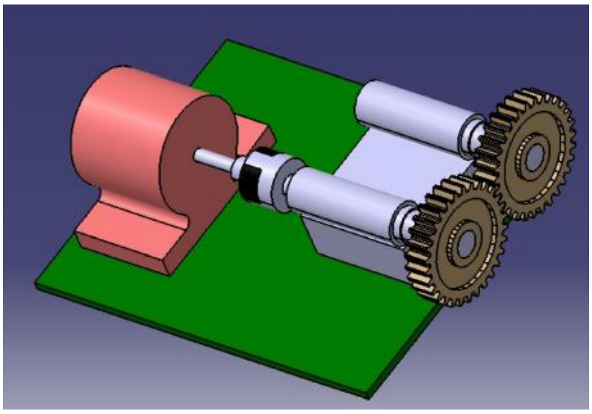
Five Steps for Vibration Analysis

- Acquire noise or vibration signals and tachometer signal.
- Preprocess the noise or vibration signals.
- Process the tachometer signal to get the rotational speed profile.
- Perform order analysis with the noise or vibration signals and speed profile.
- Display the analysis results in different formats.

Modeling of Machine

Modeling of machine to measure vibration signature is done using Catia.

Figure 2: Modeling of Machine Using CATIA



Vibration Signature

The following Figure shows various gear fault signatures. The first figure shows the good condition of gear fault and second figure shows the signature with gear fault.

Figure 3: Signature for Tooth Meshing Fault

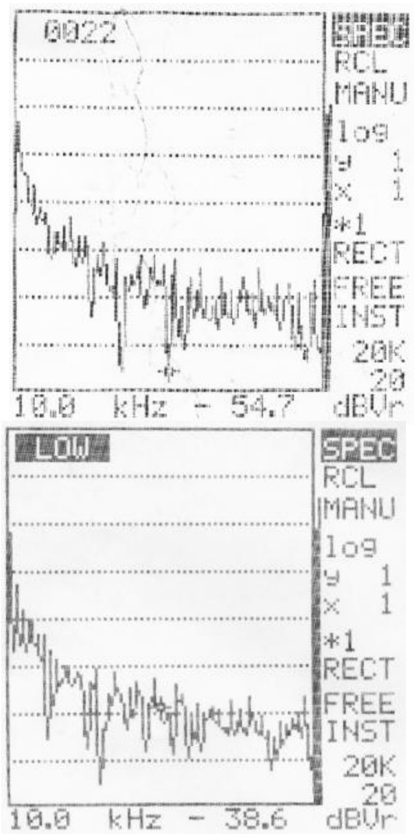


Figure 4: Signature for Misalignment

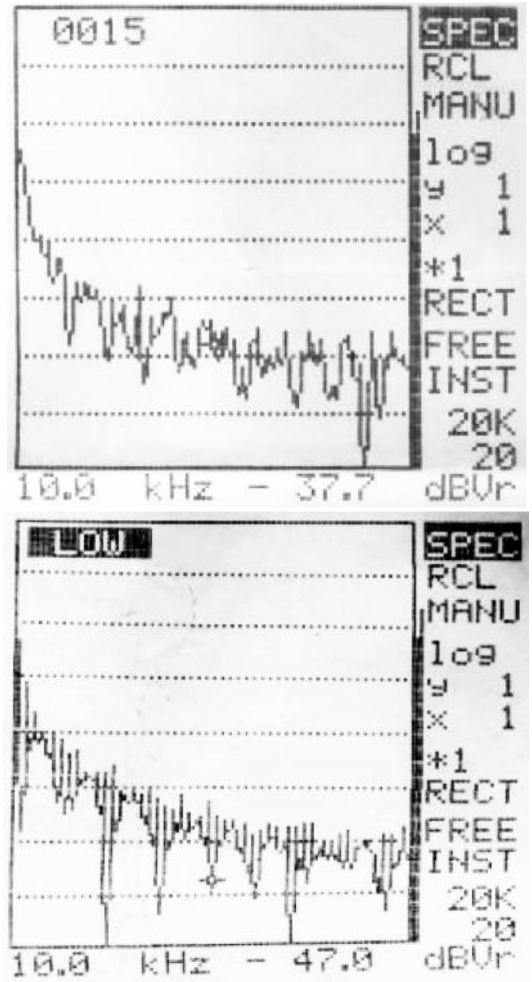


Figure 5: Signature for Crack or Worm Teeth

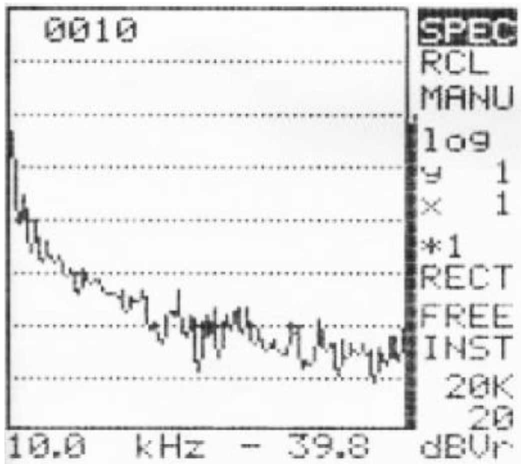


Figure 5 (Cont.)

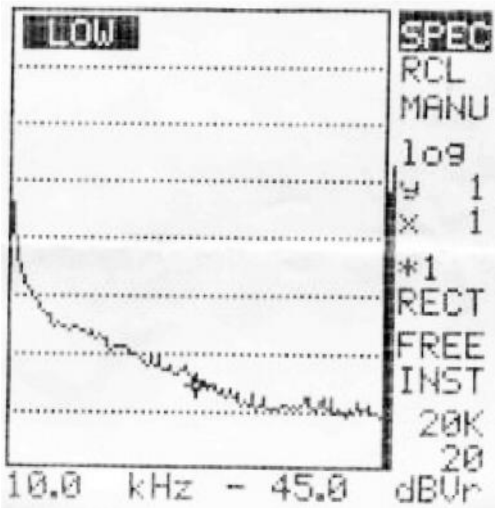


Figure 6: Signature for Localized Surface Damage

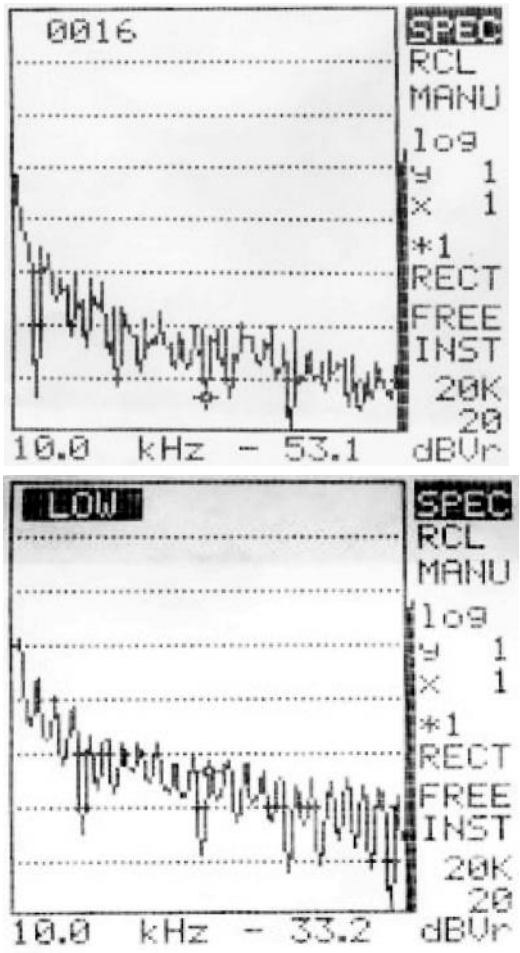


Figure 7: Signature for Wear or Inadequate Lubrication

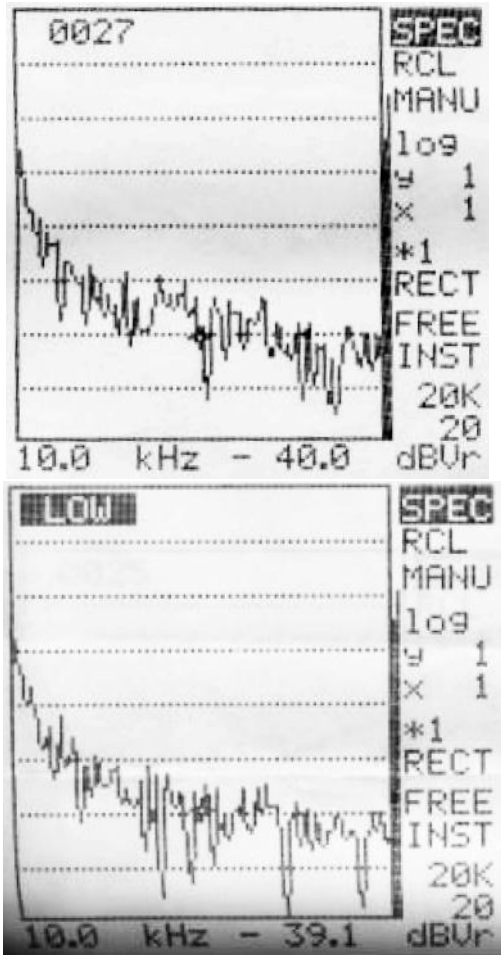


Figure 8: Signature for Tooth Root Cracks, Missing Tooth

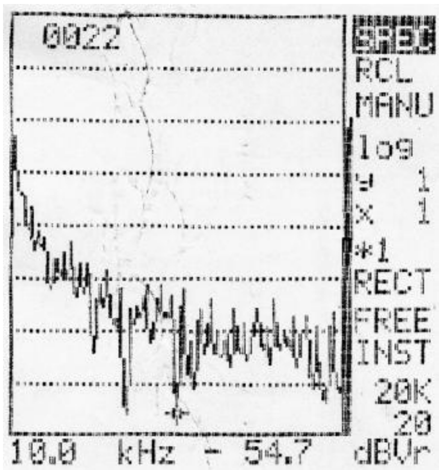
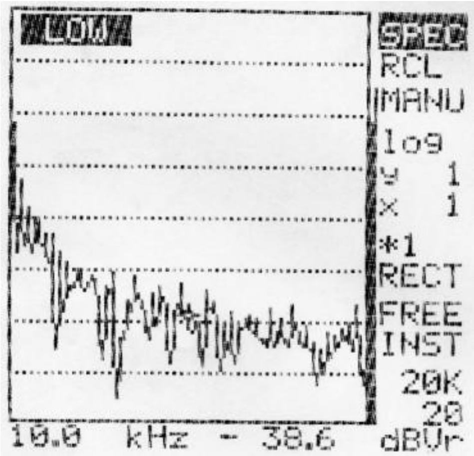


Figure 8 (Cont.)



RESULTS

The amplitude distribution of the vibration signal without gear mesh frequencies differs more from Gaussian distribution as the gearbox wears. The changes in amplitude distribution during the test are depicted. The condition of the tested gearbox is very well represented by the RMS value of the vibration signal. The trend of the RMS, peak and crest factor value is depicted. The energy ratio has a steady trend except at the start of the test. The skewness and kurtosis do not reflect any explicit trend. The RMS slightly increases during the test. The peak value has a similar trend as the RMS value. The trend of the crest factor depends on the trends ofthe RMS and peak values. FM0 follows the trend of the crest factor. The trend of FM4, NA4 and NB4 are similar, and reflect the very fine wear of the teeth. At about 60%of the test FM4, NA4 andNB4 rapidly increase in value, but the gearing does not show abnormal wear.

REFERENCES

1. Amit Aherwar and Saifullah Khalid (2012), "Vibration Analysis Techniques for Gearbox Diagnostic: A Review", *International Journal of Advanced Engineering Technology*, Vol. 3, No. 2, pp. 4-12.
2. Cesar San Martin, Edgar Estupinan and Daniel San Martin (2010), "A Methodology for the Detection and Diagnostic of Localized Faults in Gears and Rolling Bearings Systems", *Ingeniare. Revista chilena de ingeniería*, Vol. 18, No. 1, pp. 44-52.
3. Hongyu Yang, Joseph Mathew and Lin Ma (2003), "Vibration Feature Extraction Techniques for Fault Diagnosis of Rotating Machinery—A Literature Survey", Asia-Pacific Vibration Conference, Australia.
4. Marcos Pellegrini Ribeiro (1999), "Inaccessible Equipment Monitoring Via Vibratory Signature Analysis Utilizing Data Collected by Remote Accelerometers", Ph.D Thesis submitted to the University of London.
5. Randall R B (1982), "A New Method of Modeling Gear Faults".
6. Rusmir Bajric, Denijal Sprecic and Ninoslav Zuber (2011), "Review of Vibration Signal Processing Techniques Towards Gear Pairs Damage Identification", *International Journal of Engineering & Technology*, Vol. 11, No. 4, pp. 124-128.
7. Shawki A Abouel-Seoud and Mohamed S Elmorsy (2012), "Enhancement of Signal Denoising and Fault Detection in Wind Turbine Planetary Gearbox Using Wavelet Transform", *International Journal of Science and Advanced Technology*, Vol. 2, No. 5, pp. 120-131.
8. Vecer P, Kreidl M and Smid R (2005), "Condition Indicators for Gearbox Condition Monitoring Systems", *Acta Polytechnica*, Vol. 45, No. 6, pp. 35-43.