FAULT DIAGNOSIS OF SPUR GEAR BOX USING WAVELET TRANSFORM

[1]Akhil Kumar S R, [1] A R Kaushik Anand, [1]Chandan

[2] Sharath G S, Assistant professor

[1]Graduate Student,
School of Mechanical Engineering
REVA University, Bengaluru, Karnataka

Abstract: The wavelet transform is a non-destructive testing process used in the condition monitoring of rotating equipments such as gearboxes. This method is used in determining the gear tooth failure procedure. In this work the wavelet transform method is opted to recognize the cracks in gears and its failures. This paper involves the designing of the gear box using UG NX10 and experimental work is carried out by using wavelet transform technique at various loading conditions. However, the use of wavelet transform signal analysis for machine condition monitoring and fault diagnosis is still rare. The final result obtained portraits the parameters of the wavelet transform process. wavelet transform technique is capable to diagnosis the crack in the gear tooth at different load condition. It is concluded that the technique of wavelet transform is capable of detecting the cracks in a healthy gear and in a cracked gear as well. Hence the wavelet transform method is potentially fit for the evaluation of condition of the gearbox.

Index Terms **– Wavelets, Gearbox, Frequency analysis, Tooth failure.**

1.INTRODUCTION

Gear is the most important part used in any power transmission system. Gears are generally used to transfer power from one shaft to another shaft. A gear box consisting of many number of gears inside it to transmit power coming from engine to the wheels. Various types of gears are used such as spur, helical, bevel and epicycle gears. Toothed gears are used to transmit the power with high velocity ratio. The characteristics of these various gear types are discussed in most mechanical design texts like all mechanical components, gears can and do fail in service for a variety of reasons. In most cases, except for an increase in noise level and vibration, total gear failure is often the first and only indication of a problem. The faults like tooth damage, wear, pitting, chipping are getting created in the gears due to various reasons like excess loading, large friction and fatigue loading. Fatigue is the most common failure in gearing. Tooth bending fatigue and surface contact fatigue are two of the most common modes of fatigue failure in gear. Several causes of fatigue failure have been identified. These include poor design of the gear set, incorrect assembly or misalignment of the gear, overloads, inadvertent stress raisers of subsurface defects in critical areas and the use of incorrect materials, heat treatment, backlash, eccentricity, run out and alignment error are caused during assembling and manufacturing of gear. The faults will create the noise and vibrations during its working condition. These parameters can be used to identify the fault condition as each and every fault condition creates a different vibration spectrum. So it becomes necessary to identify the fault conditions in gear box by using proper vibration analysis technique.
The wavelet transform is a mathematical tool that decomposes a signal into a representation that shows signal details an trends as a function of time. Wavelet transforms are based on small wavelets with limited duration. Wavelet transforms performs signal analysis when signal frequency varies over time. For certain classes of signals and images, wavelet analysis provides more precise information about signal data than other signal analysis techniques.

2.EXPERIMENTAL STUDY

The experimental work in this paper consist of a spur gear box which is powered by using a motor of 1HP. The motor has a capacity to deliver 1500rpm. There are two gear boxes which further lead the motor, these gear boxes are connected to each other and to the motor by means of rigid couplings. The sleeve gear box consist of one gear of 48 teeths and one pinion of 24 teeths the pinion and the gear in the sleeve gear box has both the pressure angle and module same which are 20^0 deg & 2mm respectively. The test gear box consist of another gear of 24 teeths and a pinion of 12 teeths. The module and pressure angle of the gear and pinion in the test gear box are also same which are 3mm and 20^0 respectively. The spur gear box is run for 70hrs continuously to obtain the signals for the analysis. these signals are captured at different loading conditions with the help of the loading arm between the sleeve gear box and the test gear box. The signals are captured by mounting the accelerometer on the test gear box using suitable magnets. The gears are equipped with splash lubrication using SAE 90 grade lubricant.

The signals captured form the accelerometer are analysed by using wavelet transform. The wavelet transform is an app in the MATLAB. An FFBP algorithm is implemented for the analysis and the vibrational disturbances is recorded and plotted in the frequency- amplitude graph. These results are analysed and compared with the signals acquired from the equipment failed location from the industry. Both the signals are compared and brought to a conclusion.

3.EXPERIMENTAL SETUP

The aim of the experiment was to initiate and propagate wear under accelerated test conditions. Lubricant temperature, lubricant film thickness, vibration acceleration and tooth stiffness analyses were used in the detection and quantification of advancement of wear incurred by spur gear teeth. The experimental setup used for this study was designed in standard back-to-back arrangement as shown in fig 1.

The arrangement consists of two parallel steel shafts and four gears (two pinions with 12 and 24 teeth and the other two gears with 24 and 48 teeth) and a pair of pinions; gears have been assembled on either side of the shafts. The gear sets used in this experiment are made of En19 steel which heat treated for 1mm depth, 40HRC. The gears with 12 and 24 teeth had a module of 3mm and pressure angle of 20° FDI. The gears with 24 and 48 teeth had a module of 2mm and pressure angle of 20° FDI.

The setup consists of a 1 HP two stage spur gearbox. The gear box is driven by a 1 HP, 3-phase induction motor with a rated speed of 1500 rpm. The speed is controlled by sleeve gearbox and for the present study the motor is operated at 1500 rpm. In other words, the speed of gear shaft

in the first stage of the gearbox is 750 rpm. With a step-up ratio of 1:2, the speed of the pinion shaft in the second stage of the gear box is 1500 rpm.

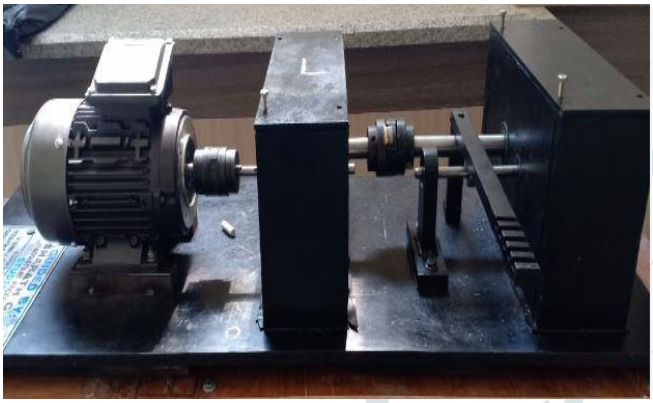


Fig: 1. Final assembly of gear box

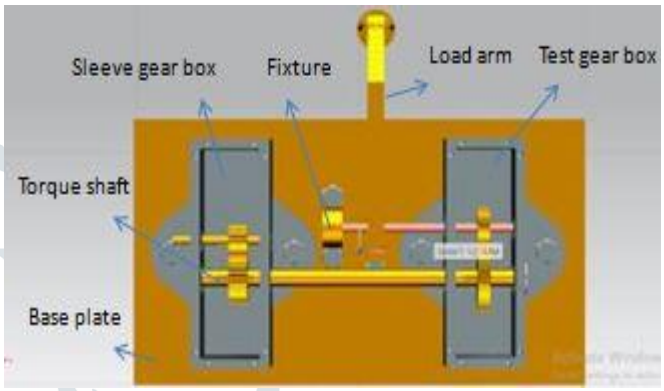


Fig:2. Top view of gear box

Table:1 summarizes the specifications of the test rig.

	First stage	**Second stage**
Number of teeth	12/24	48/24
Pitch circle diameter (mm)	36/72	96/48
Pressure angle (°)	20	20
Speed of shafts (rpm)	1500 (input) 750 (output)	750 (input) 1500 (output)
Modules (mm)	3	2

A piezo-electric accelerometer mounted to measure the vibration signals generated on the test gear box. The accelerometer outputs are conditioned using charge amplifier. Overhaul time of a new gear box is more than one year. It is very difficult to study the fault detection procedures without seeded fault trials. The loss of a part of tooth due to breakage of tooth at root or at a point on working tip (broken tooth or chipped tooth). There are different methods to simulate faults in gearboxes. The simplest approach is partial tooth removal. This simulates the damage due to breakage at a point on the working tip. This type of fault is common in many industrial applications. In the present experiment, depth wise damage is simulated on the spur gear tooth by wire EDM (Electrical discharge machining) technique.

Five conditions of the gear are investigated such as: healthy gear and gear with four stages of depth wise tooth removal i.e. 0%, 25%, 50%, 75% and 100% tooth removal conditions across the tooth width. Fig. (a–e) shows healthy gear and tooth removal cases at different stages. For all operating conditions vibration signals are acquired and recorded after proper signal conditioning. The acquired signals are decomposed using wavelet transform method developed in MATLAB.

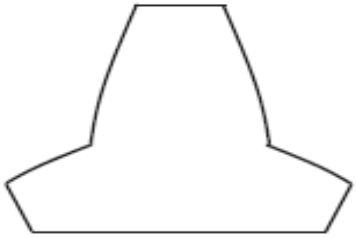


Fig: (a)

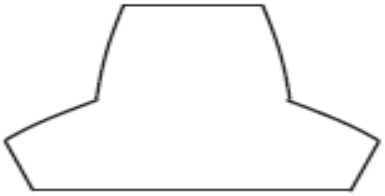


Fig: (b)

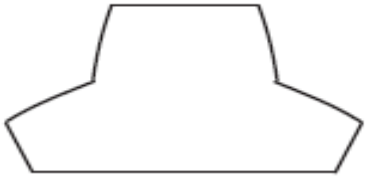


Fig: (c)

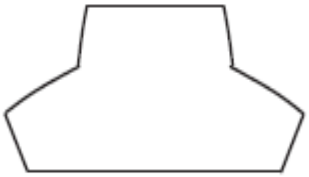


Fig: (d)

Fig: (e)

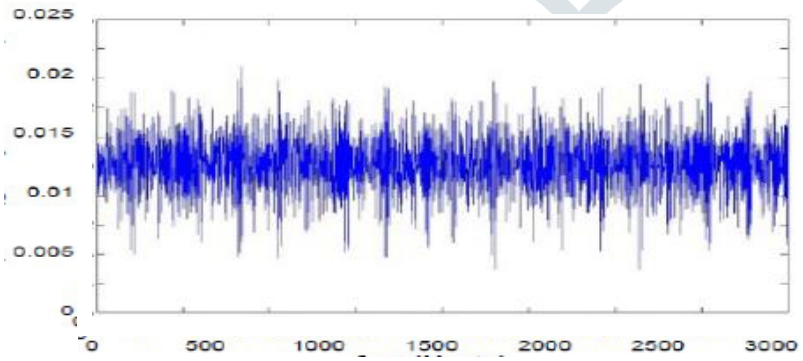
4.SCOPE OF THE PROJECT

It is purpose to make vibration analysis of single stage spur gearbox, when both gear and bearing are defective. A condition monitoring set up is designed for analyzing the defect in outer race of bearing and damaged tooth of gear. MATLAB is used for feature extraction and wavelet transform method is used for diagnosis.

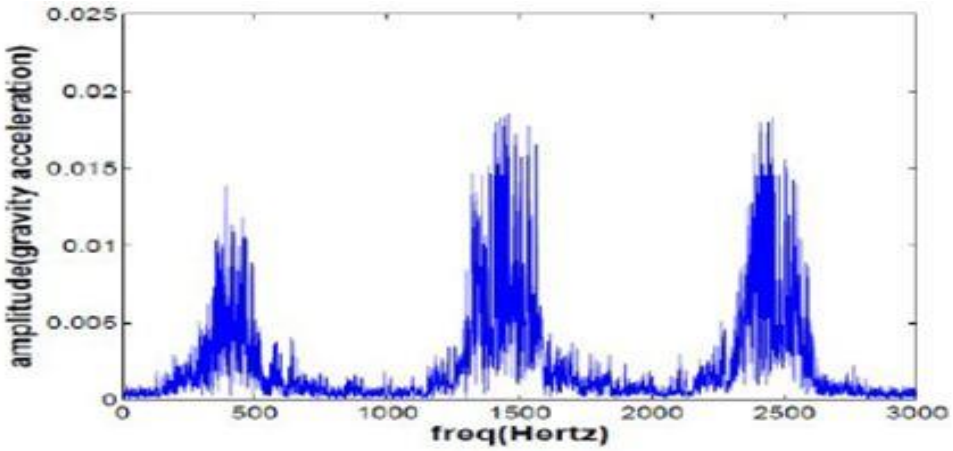
4.1 COMPONENTS OF SPUR GEARBOX

Sl. no	Item	Quantity
1	Gears	2
2	Pinions	2
3	Bearings	10
4	DC Motor	1
5	Shafts	2
6	Hinged beam	1

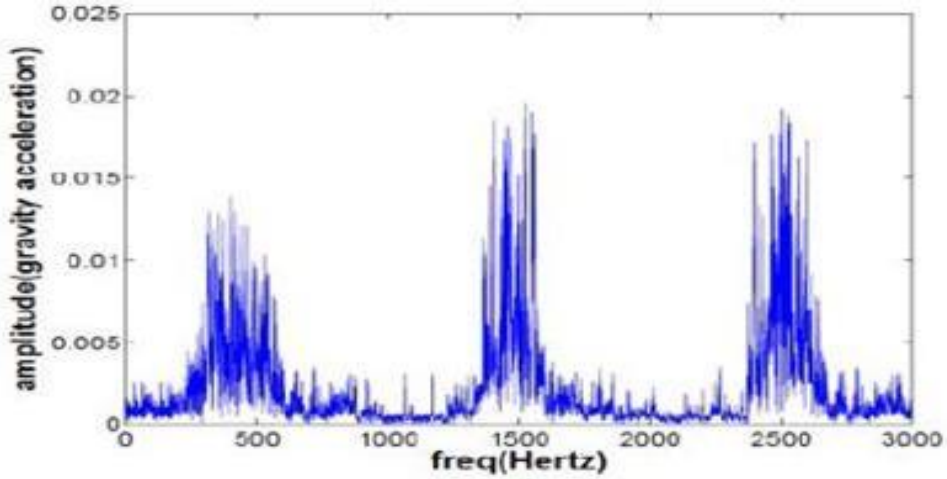
5.RESULTS



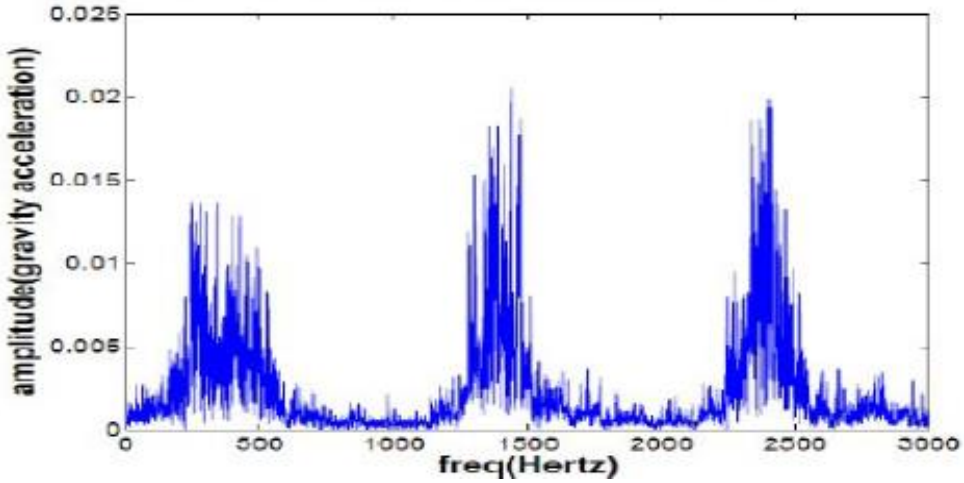
(a) Healthy Gear (0%) tooth



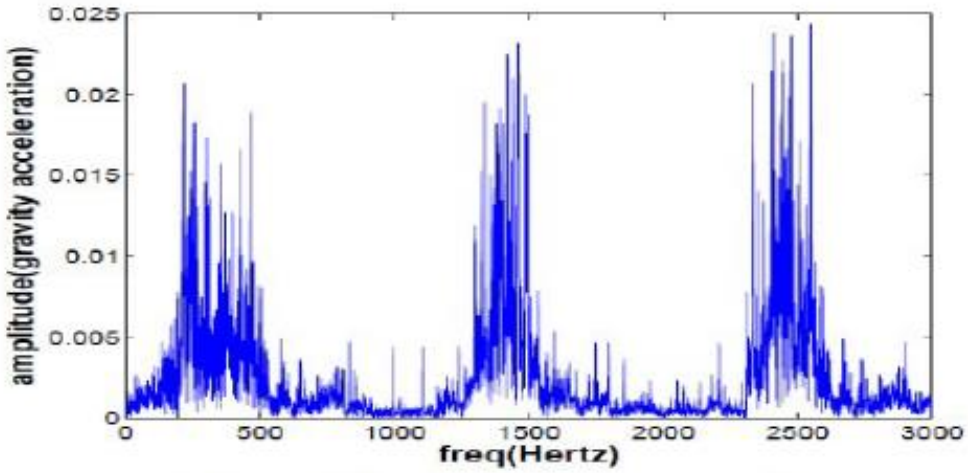
(b) Faulty Gear (25%) Tooth



(c) Faulty Gear (50%) Tooth



(d) faulty gear (75%) tooth



(e) faulty gear (100%) tooth

6.CONCLUSION

The main task in the condition monitoring of spur gear box is to identify the presence of defect to avoid the catastrophic failures. The present study examines a wavelet transform technique using time-scale representation of vibration gear box. The CWM is found to be good during testing and gives very good result in prediction and classification. The present study concludes that CWM is having better performance, prediction, classification, and less error. The architecture and topology of the network through specific systems can be used for online monitoring of gear box and to predict any causes of failure of spur gear operation.

ACKNOWLEDGEMENT

It is a pleasure for us to present this paper where guidance plays an invaluable key and provides a concrete platform for completion of the paper. We would like to thank our internal guide, Assistant Professor Sharath GS, Department of Mechanical Engineering, for his valuable encouragement and constant guidance without which we wouldn't have looked deeper into our work and realized both our shortcomings and our feats. This work would not have been possible without him.

REFERENCE

1. C.K. Sung , H.M. Tai, "Locating defects of a gear system by the technique of wavelet transform", Mechanism and Machine Theory, vol.35, pag.no 116-1182, year 2000.
2. W.J.Staszewskl, G.R.Tomlinson, " Application of the wavelet transform to fault detection in a spur gear", Mechanical systems and signal processing, vol.8(3), pag.no 289-307, year 1994.
3. N. Saravanan , K.I. Ramachandran, "Fault diagnosis of spur bevel gear box using discrete wavelet features and Decision Tree classification", vol.36, pag.no 9564–9573, year 2009.
4. G. Meltzera, Nguyen Phong Dienb, "Fault diagnosis in gears operating under non-stationary rotational speed using polar wavelet amplitude maps", vol.18, pag.no 985–992, year 2004.
5. H. Zheng, Z. Li and X. Chen, "Gear fault diagnosis based on continuous wavelet transform", Mechanical Systems and Signal Processing, vol.16, pag.no 447-457, year 2002.
6. Ales Belsak , Joze Flasker, "Wavelet analysis for gear crack identification", Engineering Failure Analysis, vol.16, pag.no 1983–1990,year 2009.
7. Ruqiang Yan , Robert X. Gao, "Wavelets for fault diagnosis of rotary machines: A review with applications", signal processing, vol.96, pag.no 1-15, year 2014.
8. Akira Yoshida , Yuji Ohue, "Diagnosis of tooth surface failure by wavelet transform of dynamic characteristics", Tribology International, vol.33, pag.no 273–279, year 2000.