CONDITIONING MONITORING OF GEARBOX USING VIBRATION AND ACOUSTIC SIGNALS

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ABSTRACT

Vibration analysis is widely used in machinery diagnostics and the wavelet transform has also been implemented in many applications in the condition monitoring of machinery.Incontrast to previous applications, this paper examines whether acoustic signal can be used effectively along vibration signal to detect the various local faults in gearboxes using the wavelet transform. Four commonly encountered local faults, tooth wear, tooth crack, broken tooth and insufficient lubrication of the gear tooth breakage and tooth crack, were simulated. The results from acoustic signals were compared with vibration signals. The results suggest that acoustic signals are very affective for the early detection of faults and may provide a powerful tool to indicate the various types of progressing faults in gearboxes.

Keywords: Acoustic Spectral Analysis, Inadequate Lubrication, Spectrum, Vibration Analysis.

I. INTRODUCTION

Gears are critical elements in complex machinery, so predictive maintenance is often applied to them. Signal analysis has been an important and indispensable part of fault diagnosis. Vibration analysis has successfully been applied towardsmonitoring and diagnosis in many practical areas forthree decades. In the application of machine faultdiagnosis, vibration signal analysis is used to detectthe dynamic characteristics of machines and toextract fault characteristics if a fault occurs and thenidentify its cause [1,2].While a local defect such as crack occurred ongear tooth, a short duration impulsive signal will begenerated. The impact will produce additionalamplitude and phase modulation effects to the gearmeshing components. As a consequence, a few ofsidebands of the tooth-meshing frequency and itsharmonics will spread over a wide range frequency. Itis difficult to detect the spacing and evolution ofsideband families in the frequency spectrum due tonoise and vibration from other mechanicalcomponents [3,4,5].Diagnosing a gear system by examiningvibration signals is the most commonly used methodfor detecting gear failures. The conventional methodsfor processing measured data contain the frequencydomain technique, time-domain technique and timefrequencydomain technique. These methods havebeen widely employed to detect gear failures. The useof vibration analysis for gear fault diagnosis andmonitoring has been widely investigated and itsapplication in industry is well established [6,7,8].
This is particularly reflected in the aviationindustry where the helicopter engine, drive trains androtor systems are fitted with vibration sensors forcomponent health monitoring. These methods havetraditionally been applied, separately in time andfrequency domains. A time domain analysis focusesprincipally on statistical characteristics of vibrationsignal such as peak level, standard deviation,skewness, kurtosis, and crest factor. A

frequencydomain approach uses Fourier methods to transform the time-domain signal to the frequency domain,where further analysis is carried out, andconventionally using vibration amplitude and powerspectra. It should be noted that use of either domainimplicitly excludes the direct use of informationpresent in the other. Time-frequency based energydistribution method was employed for early detectionof gear failure [4]. The frequency domain refers to adisplay or analysis of the vibration data as a functionof frequency. The time-domain vibration signal istypically processed into the frequency domain byapplying a Fourier transform, usually in the form of afast Fourier transform (FFT) algorithm[9, 10 ,11].

This paper presents an investigation carried out concerning progressing local faults in a gearbox using acoustic signals along with vibration signals.

II. EXPERIMENTATION CREATION OF FAULTS ON GEAR TOOTH

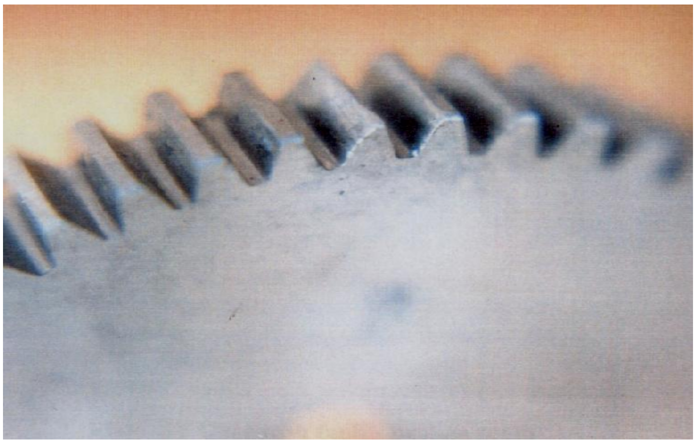
For creation of artificial faults on gear tooth, four different gears are procured. For that, the spur gear having 48 teeth and module of 1.5 is selected.

The common faults of gear tooth are as follows.

1. Wear on one tooth
2. Crack on one tooth
3. One tooth broken or missed
4. Lack of lubrication

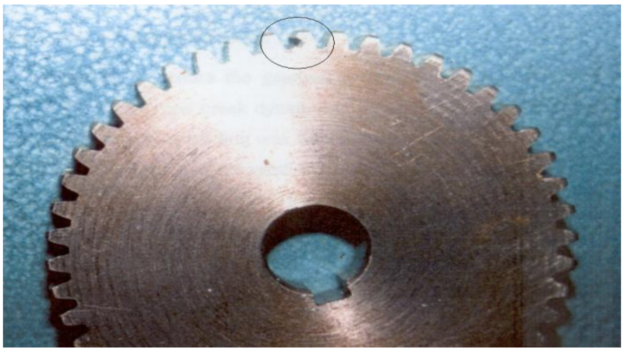
2.1 Wear

Wear on one tooth of gear is made by filing one tooth and removing material from tooth in direction of rotation. The wear is made near the pitch circle.



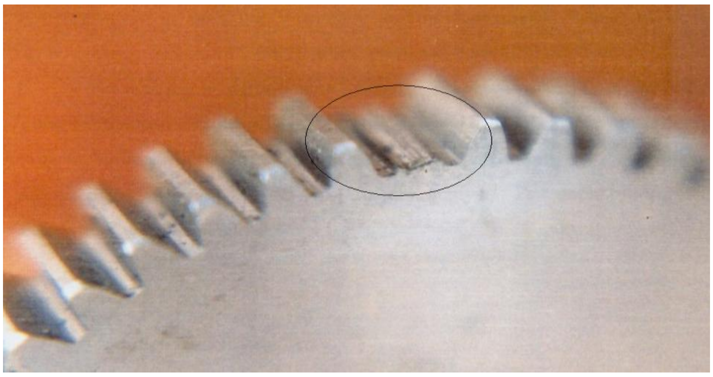
2.2 Crack on one Tooth

A crack is produced on tooth of gear. This is made by cutting the tooth with hacksaw blade at root of tooth in the direction of rotation.



2.3 Broken Tooth

For making this fault, one tooth of gear is removed by hacksaw blade and original non-defective gear is replaced with this gear.



2.4 Inadequate Lubrication or No Lubrication

Many times unsatisfactory operation of gearbox may be caused by failure of lubrication. To enable one to identify this condition an experiment is carried out by completely darning lubrication oil from the gearbox. The gearbox will run for 15 minutes so that exact condition of no lubrication will achieved.

III. EXPERIMENTAL SETUP

3.2 Schematic Setup for Vibration Measurement

2) The specifications of gearbox:

Power	0.25 Hp
Input rpm	1420 rpm

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ISSN 2348 - 7550

Input frequency 1420/60 = 23.67 Hz

Output rpm 200 rpm

Output frequency 200/60 = 3.33 Hz

No. of stapes 2 stage

Types of gears:

First pinion

Type **Spur**

No. of teeth 12

Pitch circle diameter 18 mm

Module 1.5

Speed 1420 rpm

Rotational frequency $1420/\ 60 = 23.67$ Hz (rpm/60) Hz

Tooth meshing frequency $1420 \times 12/\ 60$ = 284 Hz

(rpm x no. of teethes/60)

First gear:

Type **Spur**

No. of teeth 48

Pitch circle diameter 72

Module 1.5

Speed 3

Rotational frequency $355/60 = 5.92$

Tooth meshing frequency $355 \times 48/60$ = 284 Hz

(rpm x no. of teeth /60)

Second pinion:

Type **Helical**

No. of teeth19

Pitch circle diameter 32.37 mm

Module7.1

Speed 355rpm

Rotational frequency 355/60 = 5.19 Hz

Tooth meshing frequency $355 \times 19 / 60$ = 112.42 Hz

(rpm x no. of teeth/60)

Second gear:

Type **Helical**

No. of teeth 34

Pitch circlediameter 57.8mm

Module 1.7

Speed 200 rpm

Tooth meshing frequency $355 \times 19 / 60$ = 112.42 Hz

(rpm x no. of teeth/60) 200/60 = 3.33 Hz

IV.RESULTS

4.1 Spectrum of Healthy Gear

Fig.1 shows the vibration spectrum of healthy (non-defective) gear. It shows that there is remarkable vibration level at gear mesh frequency, which is may be due to the inherent unbalance in gear and manufacturing defects. It is, therefore obvious that, there will be some vibration level at gear mesh frequency due to created faults.

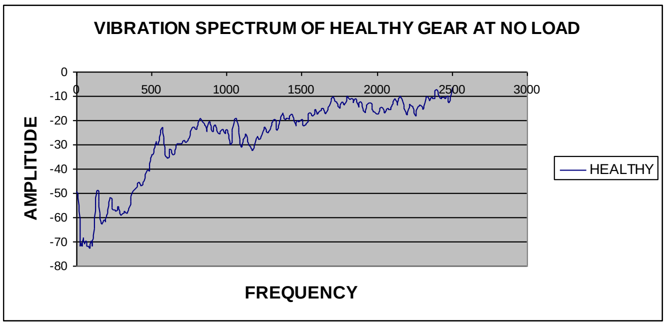

Fig 4.1

Fig. III.2, III.3,III.4,III.5 respectively shows comparison of cracked tooth and healthy gear spectrums, Broken tooth and healthy gear ,wear of teeth and healthy gear , Improper lubrication and healthy respectively. As the crack was produced on the gear, it reflects the change in vibration spectrum. From above results following characteristics can be associated to fault.

1. The amplitude level increases considerably at gear mesh frequency.
2. The amplitude level increases by considerable margin at side bands.

4.2 Crack on One Tooth

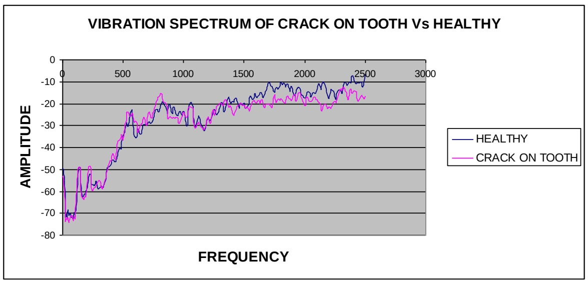

Fig 4.2

4.3 Gear with Broken Tooth

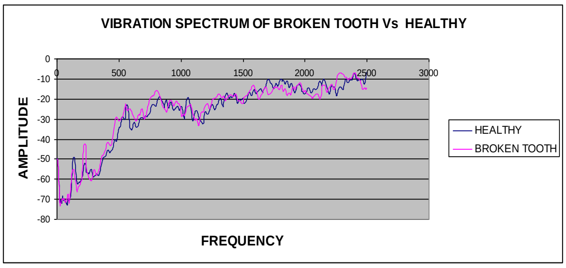

Fig. 4.3

4.4 Wear of Teeth

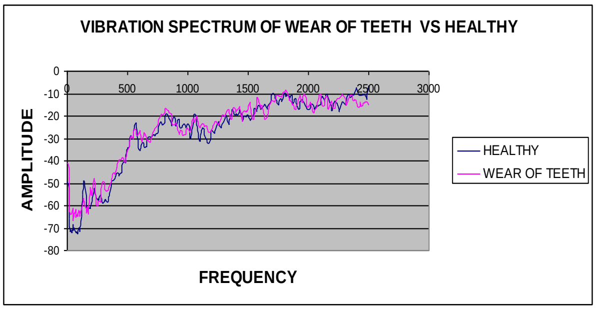

Fig 4.4

4.5 Improper Lubrication Condition

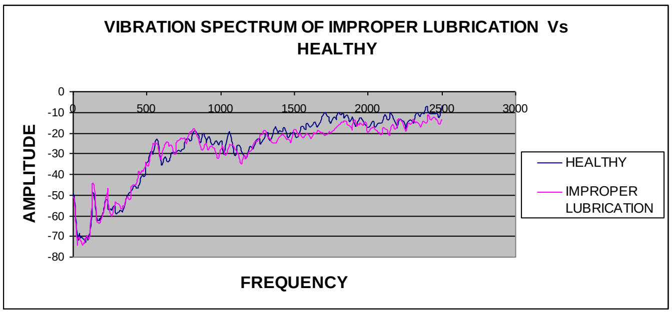

Fig 4.5

V. ACOUSTIC SPECTRAL ANALYSIS

Various acoustic spectrums are taken for healthy and various defective gears and are discussed below

5.1 Spectrum of Healthy Gear

Fig. IV.1 shows the acoustic spectrum of healthy (non-defective) gear. It shows that there is remarkable sound pressure level at gear mesh frequency, which is may be due to the inherent unbalance in gear and manufacturing defects. It is, therefore obvious that, there will be some sound pressure level at gear mesh frequency due to created faults.

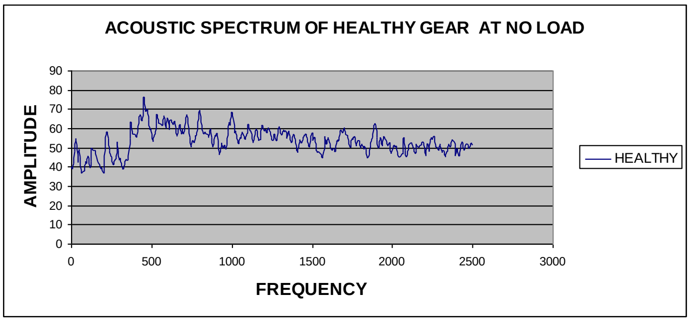

Fig. 5.1

Fig IV.2,IV.3,IV.4,Iv.5 Shows comparison of cracked tooth and healthy gear spectrums, Broken tooth and healthy gear ,wear of teeth and healthy gear , Improper lubrication and healthy respectively. As the fault was produced on the gear, it reflects the change in acoustic spectrum. It is observed from figure the amplitude of gear mesh frequency has increased considerably. From above results following characteristics can be associated to fault.

1. The amplitude level increases considerably at gear mesh frequency.
2. The amplitude level increases by small margin at side bands.

5.2 Gear with crack on tooth

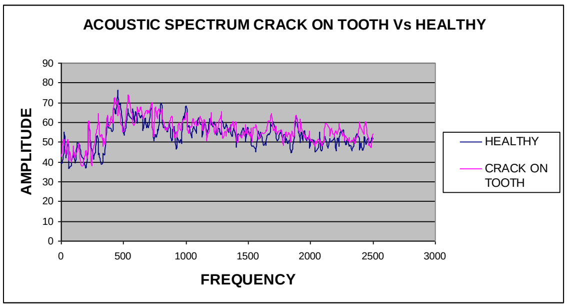

Fig 5.2

5.3 Gear with Broken Tooth

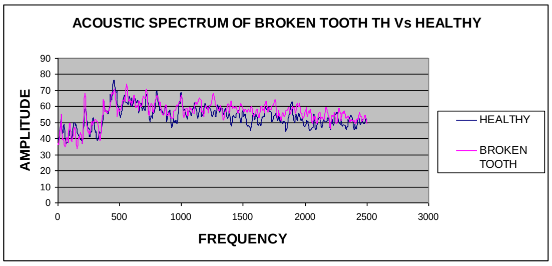

Fig 5.3

5.4 Wear of Teeth

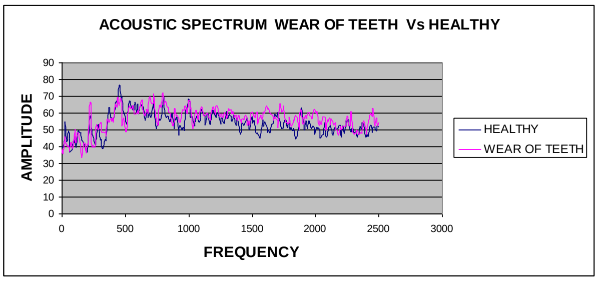

Fig 5.4

5.5 Improper Lubrication Condition

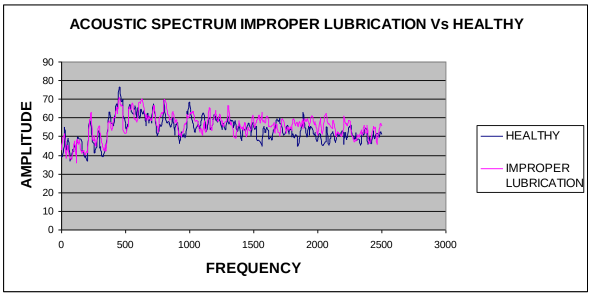

Fig 5.5

VI. OBESERVATION TABLE

RMS VALUES

	HEALTHY	CRACK ON TOOTH	BROKEN TOOTH	WEAR OF TEETH	IMPROPER LUBRICATION
VIBRATION	0.9331	1.0233	1.3712	1.5736	1.7933
ACOUSTIC	13404.7	14624.2	15277.4	15401.5	16886.6

VI. CONCLUSION

The condition monitoring of gears can significantly reduce the costs of maintenance. Firstly it can allow the early detection of major faults, which could be extremely expensive to repair. Secondly it allows the implementation of condition based maintenance rather than periodic or failure based maintenance. In these cases delaying scheduled maintenance can make significant savings until convenient or necessary.

In this research, vibration and acoustic signals were used in a two-stage gearbox. It was shown that various types of gear failures can be detected successfully by both acoustic and vibration signals analysis.

The acoustic analysis method has gained wide industrial acceptance for gearbox condition monitoring. Condition monitoring using acoustics tool is presented in this paper shows the considerable freedom in positioning of the microphones - distance and plane with respect to the source, and being able to detect the characteristic frequency spectrum of the gearbox and consequently fault detection and diagnosis using advanced signal processing.

In this paper, experimentation is carried out to detect gear tooth defects through acoustic and vibration analysis and feasibility of practical application is investigated. The acoustic and vibration spectrums obtained for different tooth defects on which following conclusions can be drawn.

6.1 Using Frequency Domain Acoustic Spectrums and Vibration Spectrums

With comparison of faulty crack on tooth and healthy gear spectrums, Broken tooth and healthy gear ,wear of teeth and healthy gear , Improper lubrication and healthy respectively it is shown that as the fault was produced on the gear, it reflects the change in acoustic and vibration spectrum. It is observed from the amplitude of gear mesh frequency has increased Theconsiderably. From above results following characteristics can be associated to fault.

1. The amplitude level increases considerably at gear mesh frequency.
2. Amplitude level increases by small margin at side bands.

It is also observed that as load is increased on the crack on tooth or broken tooth, there is change in acoustic and vibration spectrum. The amplitude level also increases at gear meshing frequency as load increases.

6.2 Using Time Domain Acoustic Spectrums and Vibration Spectrums

With comparison of time domain acoustic and vibration spectrum, it is observed that an RMS value was increased as fault was produced in the gear.

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