# Fault Diagnosis of Gear Box by Using Motor Current Signature Analysis

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## Abstract

*Despite the fact that there are various condition observing and examination strategies, specialists are looking for a straightforward method to screen vibration of a gearbox, which is an inescapable and an essential power transmission part in any apparatus. Engine current mark investigation (MCSA) has been the new expansion as a non-meddling and simple to quantify condition checking strategy In gearboxes, load fluctuations and gear defects are two major sources of vibration in gearbox. Further at times, measurement of vibration in case of the gearbox is not easy because of the inaccessibility in mounting the vibration transducers. The fundamental point of this paper is to distinguish falsely presented absconds in apparatuses of a multistage car transmission gearbox at various rigging activities utilizing Motor Current Signature Analysis as a condition checking procedure .Analysis as a condition monitoring technique. Steady and fluctuating load conditions on the gearbox are tested for both vibration and current signatures during different gear operations.*

***Index Terms-*** *Motor current signature analysis, Condition monitoring, load fluctuations, Gear defects.*

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## 1.INTRODUCTION

Gearbox is an certainly one of important equipment element in any industry. Any illness in gears result in machine downtime ensuing in lack of production in enterprise. Some of methods have been carried out to be able to diagnose the fault.Oak Ridge National Laboratory develop an electric machinery monitoring technology it is Motor Current Signature Analysis (MCSA) . It provides a extraordinarily sensitive, selective, and cost-effective means for online tracking of a huge type of heavy industrial machinery. It's been used as a check approach to improve motor bearing put on assessment for inaccessible vehicles during plant operation. In 1989, ORNL used it to screen a diffusion of electric motor driven devices at the Philadelphia electric powered enterprise Eddystone generating Station for detecting the degradation in growing older electricity plant gadget. MCSA is primarily based on the recognition that a traditional electric powered motor powering a device additionally acts as an efficient and completely connected transducer, detecting small time structured motor load versions generated within the mechanical gadget and changing them into electric powered contemporary signals that go with the flow alongside the cable presenting electricity to the motor. These signals, though small in relation to the average current drawn by the motor, can be extracted reliably and non intrusively and processed to The fashion of those signatures may be determined through the years to give statistics regarding the motor and the load.provide indicators of the condition (signatures) of the motor. The idea of fault detection is the difference in normalized current RMS values of both healthful and faulty bearings. Broken rotor and eccentricity inside the rotor and the stator of an induction motor bring about facet bands of electrical deliver line frequency. Previous information of spatial role of fault and the burden torque with appreciate to the rotor is essential because the consequences of load torque and faulty situations are difficult to separate. Contemporary indicators can be analyzed in the time-domain or the frequency-area. The currents have imbedded facts on the pushed hundreds, with the facts being available inside the frequency area or the time area. To gain rotor velocity, frequency-domain evaluation is chosen.

## 2.BACKGROUND

The Motor Current Signature evaluation (MCSA) is one of the most popular fault detection method now a days because it may without problems detect the not unusual gadget fault consisting of flip to turn quick ckt, cracked /damaged rotor bars, bearing deterioration and so on. The existing paper discusses the fundamentals of Motor current Signature evaluation (MCSA) plus condition monitoring of the induction motor the usage of MCSA. Similarly, this paper affords four case studies of induction motor fault analysis. Contemporary rotating machinery regularly takes benefit of recent designs of used gearwheels and rolling bearings. Usage of those new additives permits gadget to work quieter, increase its reliability, and extend working life. Machine vibration analysis belongs to essential strategies used for rotating machine conditions monitoring.An automated characteristic extraction system for gear and bearing fault diagnosis using wavelet-based signal processing. Vibration signals recorded from two experimental set-ups were processed for gears and bearing conditions.4 statistical capabilities have been decided on: standard deviation, variance, kurtosis, and fourth primary moment of continuous wavelet coefficients of synchronized vibration signals (CWC-SVS). How current signature analysis can reliably diagnose rotor winding problems in induction motors. Traditional CSA measurements can result in misdiagnosis and/or false alarms of healthy machines due to the presence of current frequency components in the stator current caused by non-rotor related conditions such -as mechanical load fluctuations, gearboxes, etc. The principle components in gear vibration spectra are the tooth-meshing frequency and its harmonics, collectively with sideband systems due to modulation outcomes. Sideband systems can be used as an crucial diagnostic symptom for gear fault detection. The primary objective of the present paper is to unravel amplitude modulation effects which might be liable for producing such sidebands.

## 3..MOTOR CURRENT SIGNATURE ANALYSES

A common approach for monitoring mechanical failures is vibration monitoring. Due to the nature of mechanical faults, their effect is most straightforward on the vibrations of the affected component. Since vibrations lead to acoustic noise, noise monitoring is also a possible approach. However, these methods are expensive since they require costly additional transducers. Their use only makes sense in case of large machines or highly critical applications. A cost effective alternative is stator current based monitoring since a current measurement is easy to implement. Moreover, current measurements are already available in many drives for control or protection purposes. However, the effects of mechanical failures on the motor stator current are complex to analyze. Therefore, stator current based monitoring is undoubtedly more difficult than vibration monitoring. Another advantage of current based monitoring over vibration analysis is the limited number of necessary sensors. An electrical drive can be a complex and extended mechanical systems. For complete monitoring, a large number of vibration transducers must be placed on the different system components that are likely to fail e.g. bearings, gearboxes, stator frame, and load. However, a severe mechanical problem in any component influences necessarily the electric machine through load torque and shaft speed. This signifies that the motor can be considered as a type of intermediate transducer where various fault effects converge together. This strongly limits the number of necessary sensors. However, since numerous fault effects come together, fault diagnosis and discrimination becomes more difficult or is sometimes even impossible. A literature survey showed a lack of analytical models that account for the mechanical fault effect on the stator current. Most authors simply give expressions of additional frequencies but no precise stator current signal model. In various works, numerical machine models accounting for the fault are used. However, they do not provide analytical stator current expressions which are important for the choice of suitable signal analysis and detection strategies. The most widely used method for stator current processing in this context is spectrum estimation. In general, the stator current power spectral density is estimated using Fourier transform based techniques such as the period gram. These methods require stationary signals i.e. they are inappropriate when frequencies vary with respect to time such as during speed transients. Advanced methods for non-stationary signal analysis are required.

## 4.GEAR BOX FAULT ANALYSIS USING FFT BASED POWER SPECTRUM

### *A. Bearing fault analysis*

**Figure 1: Damage Bearing**

THE bearing consists of mainly of the outer race and inner race way, the balls and cage which assures equidistance between the balls. The different faults that may occur in bearing can be classified according to the affected element are as follow,

1) Outer raceway defect.
2) Inner raceway defect.
3) Ball defect.

The relationship of bearing vibration to the stator current spectra can be dictated by reviewing that any air gap eccentricity produces anomalies in the air gap flux density. Since ball bearings support the rotors, any bearing deficiency will make an outspread movement between the rotor and stator of the machine. The mechanical displacement resulting from damaged bearing causes the machine air gap to vary in a manner that that can be depicted by a blend of rotating eccentricities moving in both directions. Because of rotating eccentricities, the vibrations produce stator streams at frequencies given by

$$f_{bearing} = f_1 \pm m f_{io} \qquad (1)$$

where m=1,2,3,4……..and $f_{io}$ is one of the characteristic frequencies which are based upon the bearing dimension

$$f_{io} = \frac{N_b}{2} \times f_r \left(1 \pm \left(\frac{D_b}{D_c}\right) \times cos\beta\right) \qquad (2)$$

Where,

$N_b$ = number of bearing balls.

$f_r$ = mechanical rotor speed in hertz.

$D_b$ = Ball diameter.

Dc = Bearing pitch diameter.

β = Contact angle of the balls on the races.

It should to be noted from 2 that particular data concerning the bearing construction is required to calculate the exact characteristic frequencies. Be that as it may, these qualities race frequencies can be approximated for most bearings with in the range of six and twelve balls.

$f_o = 0.6\ N_b\ f_r$ (3)

$f_i = 0.4\ N_b\ f_r$ (4)

In this manner from above condition we can compute expected fault frequencies for inward race fault and external race fault at different load condition.Keeping in mind the end goal to analyze the bearing fault in gearbox, above test setup will be utilize. The heading of gearbox is single line,deep groove ball bearing, type 6206. Each bearing has eight balls. Tests will lead on four course; two of these are undamaged while two bearing are damaged

### *B. Gear fault analysis*

GEARS are used to transmit motion from one shaft to another or between the shafts. In most systems, the gear forms a part of the mechanical load that is coupled to an electrical device, which usually is an electric motor .Several faults can occur in the gear arrangement A gear often consists of a pinion and a driven wheel. The motor is coupled to gear box. A gear defect such as a damaged tooth produces an abnormality in the load torque seen” by the motor. This abnormality is transferred to the motor current from the load. Depending on the abnormality, unique frequencies can be seen in the current frequency Spectrum. Mechanical oscillations in gear box changes the air-gap eccentricity results in changes in the air-gap flux waveform. Consequently this can induce stator current components given by

$$f_e = f_1 \pm m f_r \quad (5)$$

$f_1$ = supply frequency

$f_r$ = rotational speed frequency of the rotor m = 1,2,3............harmonic number

$f_e$ = current components due to airgap changes

As observed from above, mechanical motions will offer ascent to extra current parts in the recurrence range. Gearboxes may likewise offer ascent to current segments of frequencies near or like those of broken bar segments. In particular, moderate spinning shafts will offer ascent to current segments around the principle supply recurrence segments as endorsed by condition

(5). Keeping in mind the end goal to analyze the apparatus blame of gearbox, above test setup will be utilize. The gear of gearbox is spur gear. Experiments will conduct on two gears; one of these are undamaged while other will be were gear.

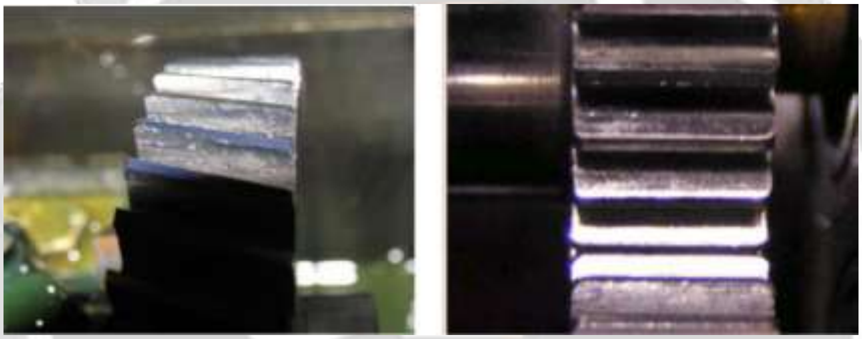


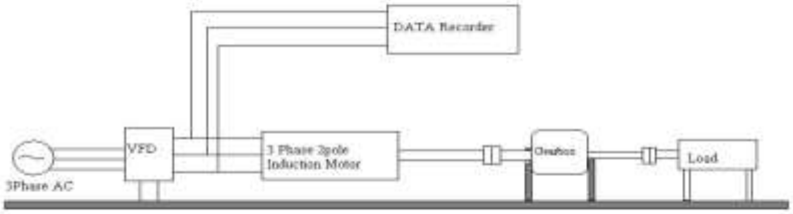
**Figure 2: Were gear.**

**Figure 3: Gear tooth break**

## 5.EXPERIMENTAL SETUP

With a specific end goal to finding the fault of gear box ,motor current analysis method use.Block diagram of these two trial setup as appeared in figure. Test setup comprises of single stage DC engine, single stage goad outfit box, Resistance, acquisition card, Pentium-4 PC with softwear Labview. LabVIEW 2010 software is used to analyze the signals. It is not difficult to take any estimation with NI LabVIEW. The estimations can be mechanized from a few devices and information can be broke down expectedly with this product.Data acquisition card are utilized to procure the current examples from the motor under load. NI M Series rapid multifunction information securing

(DAQ) gadget can quantify the flag with unrivaled precision at quick testing rates.This device has NI-MCal adjustment innovation for enhanced estimation precision and six DMA channels for fast information throughput.It has an onboard NI-PGIA2 amplifier intended for quick settling circumstances at high filtering rates, guaranteeing 16-bit precision even when measuring all channels at maximum speeds. This gadget has at least 16 analog inputs, 24digital I/O lines, seven programmable input ranges,analog and digital triggering and two counter/timers. The PCI-6251 data acquisition card which is used in experiment.



Schematic Diagram of Experimental Setup.

**Figure 4: Experimental Setup**

**Table I : Expected fault frequencies for input shaft Inner race Of bearing at various load conditions**

| Load | Speed | Frequency(fr) | frequency(fi) | fault frequency | |
|---|---|---|---|---|---|
| | | | | m =1 | m =2 |
| 0 | 1000 | 16.666 | 79.99 | 79.99 | 159.99 |
| 2 | 890 | 15.833 | 75.98 | 75.98 | 151.968 |
| 5 | 830 | 14.80 | 69.19 | 69.19 | 138.38 |
| 8 | 830 | 13.834 | 64.38 | 64.38 | 128.76 |
| 10 | 770 | 12.60 | 59.29 | 59.29 | 118.58 |

| load | speed | Frequency(fr) | Frequency($f_i$) | fault frequency | |
|---|---|---|---|---|---|
| | | | | m =1 | m =2 |
| 0 | 1000 | 16.6666 | 13.33 | 13.33 | 26.66 |
| 2 | 890 | 15.8333 | 11.46 | 11.46 | 22.93 |
| 5 | 830 | 14.80 | 9.8656 | 9.865 | 19.73 |
| 8 | 830 | 13.834 | 8 | 8 | 16 |
| 10 | 770 | 12.60 | 5.866 | 5.866 | 11.73 |

**Table II : Expected fault frequencies for input shaft outer race Of bearing at various load conditions**

| load | speed | frequency(fr) | fault frequency | |
|---|---|---|---|---|
| | | | m =1 | m =2 |
| 0 | 1000 | 16.6666 | 16.6666 | 33.333 |
| 2 | 890 | 15.83333 | 15.83333 | 31.6667 |
| 5 | 830 | 14.80 | 14.80 | 29.66 |
| 8 | 830 | 13.834 | 13.834 | 27.66 |
| 10 | 770 | 12.60 | 12.60 | 25.66 |

**Table III :Expected fault frequencies for Input shaft wear gear at various load conditions**

## 6.RESULTS AND DISCUSSION

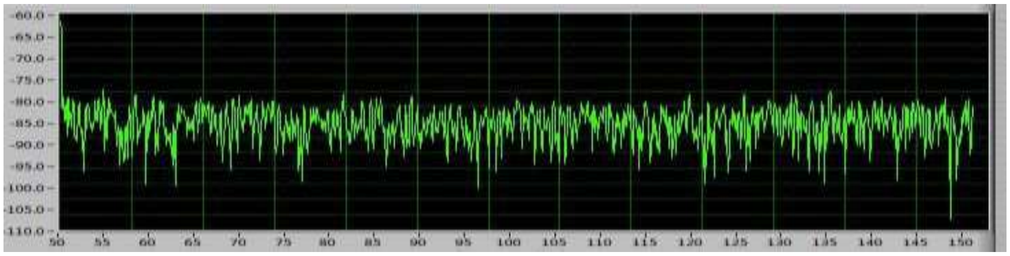
The analyses have been performed to distinguish bearing issue, wear adapt, broken gear in gearbox utilizing Lab VIEW programming. Gearbox is tried with three diverse inadequate conditions. Deficient condition creates eccentricity in the air gap with mechanical vibrations. The air gap eccentricity causes variety noticeable all around air gap flux density that produces obvious changes in the stator current. These progressions are resolved in control ranges of engine because of various blame. Bearing issue, wear adapt, broken teeth gear in gearbox are analyzed under no load and full load.

**Table IV: Expected Fault Frequencies for input Shaft one broken teeth gear at Various Load Conditions**

| Load | speed | frequency(fr) | fault frequency(mfr) | |
|---|---|---|---|---|
| | | | m =1 | m =2 |
| 0 | 980 | 16.33 | 16.33 | 32.66 |
| 2 | 820 | 13.66 | 13.66 | 27.33 |
| 5 | 740 | 12.33 | 12.33 | 24.66 |
| 8 | 700 | 11.66 | 11.66 | 23.33 |
| 10 | 660 | 11 | 11 | 22 |

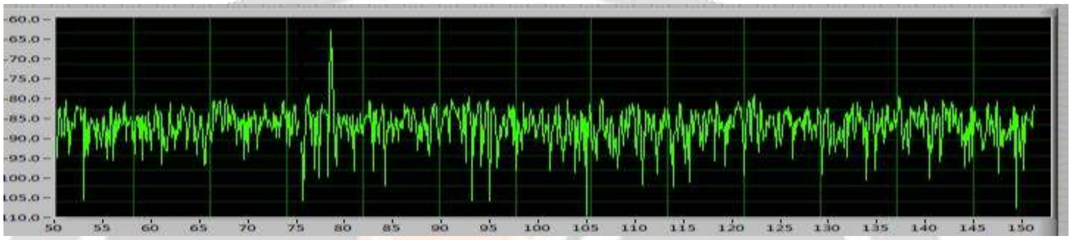
**TableV: Expected Fault Frequencies for input Shaft two broken teeth gear at Various Load Conditions**

| load | Speed | frequency(fr) | fault frequency(mfr) | |
|---|---|---|---|---|
| | | | m =1 | m =2 |
| 0 | 910 | 15.25 | 15.25 | 30.50 |
| 2.5 | 760 | 12.66 | 12.66 | 25.33 |
| 5 | 680 | 11.33 | 11.33 | 22.66 |
| 8 | 600 | 10 | 10 | 20 |



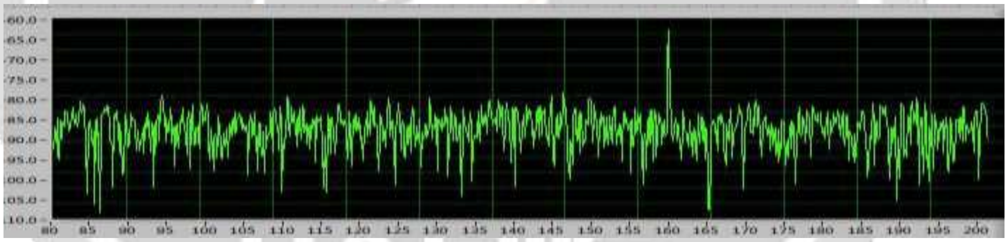
**Frequency [Hz]**

**Figure5: Power spectrum of healthy gearbox under no load condition**



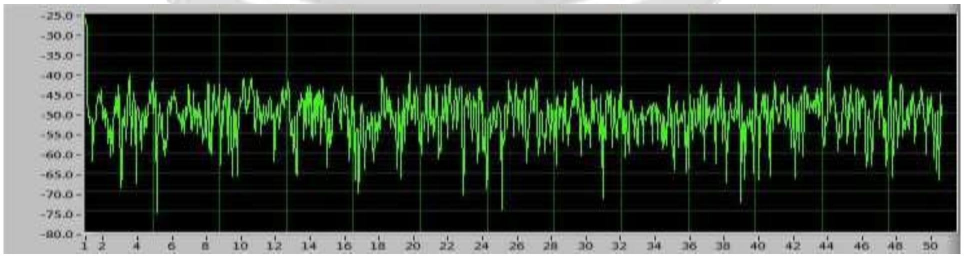
**Frequency [Hz]**

**Figure6: Power spectrum of faulty gearbox with inner race of bearing under no load condition (m=1)**



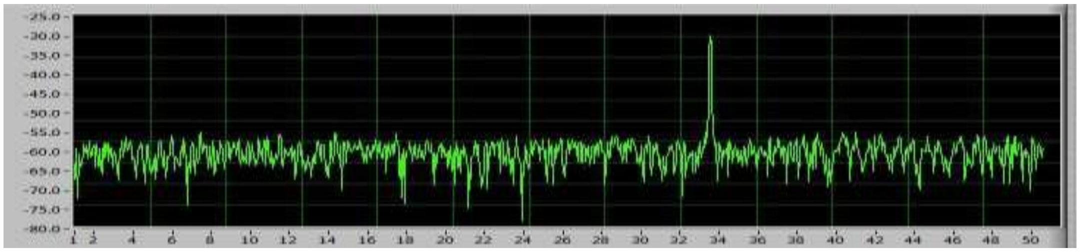
**Frequency [Hz]**

**Figure7: Power spectrum of faulty gearbox with inner race of bearing under no load condition (m=2)**



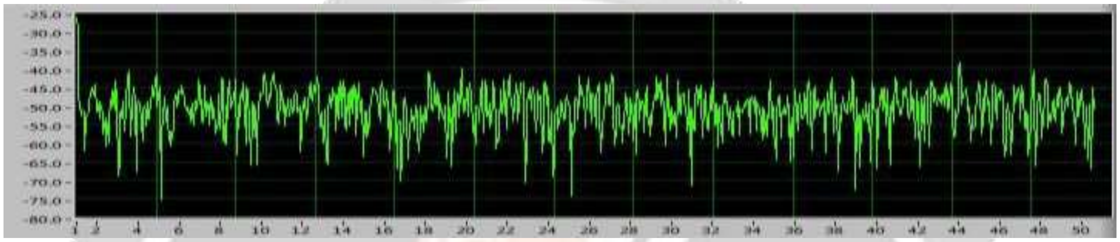
**Frequency [Hz]**

**Figure8: Power spectrum of healthy gearbox under no load condition**



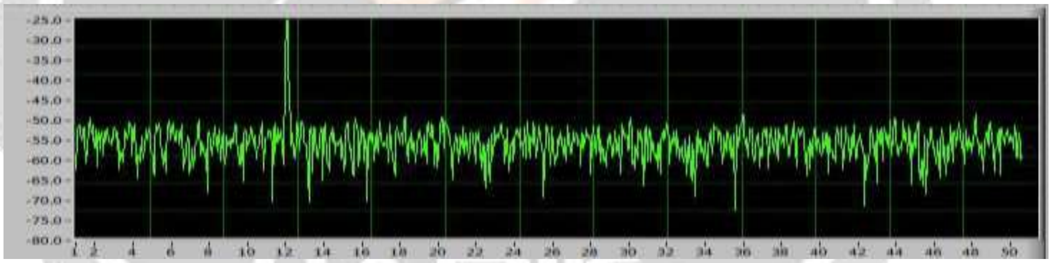
**Frequency [Hz]**

**Figure9: Power spectrum of faulty gearbox with input shaft wear gear under no load condition (m=2)**



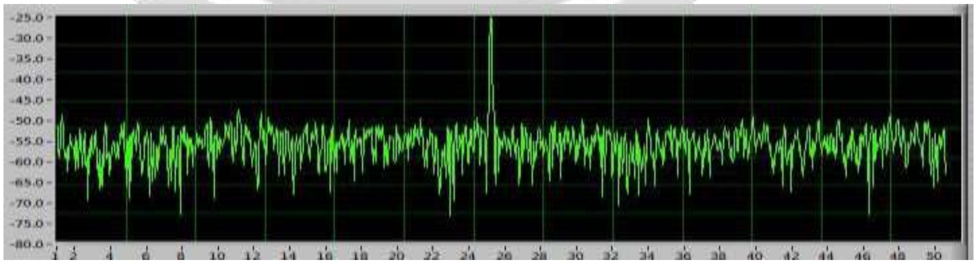
**Frequency [Hz]**

**Figure 10: Power spectrum of healthy gearbox under 10kg load condition**



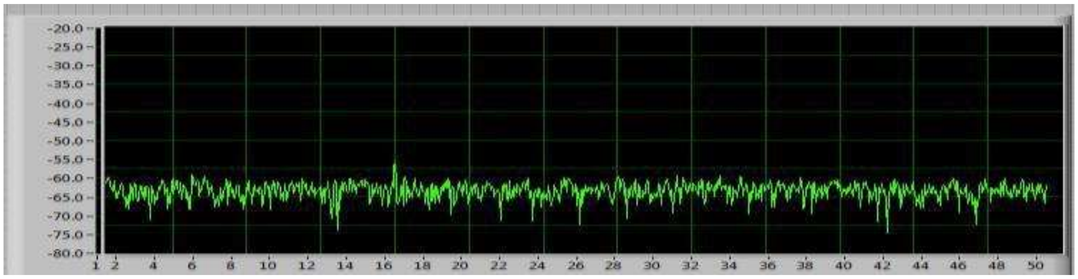
**Frequency [Hz]**

**Figure11: Power spectrum of faulty gearbox with input shaft wear gear under 10kg load condition (m=1)**

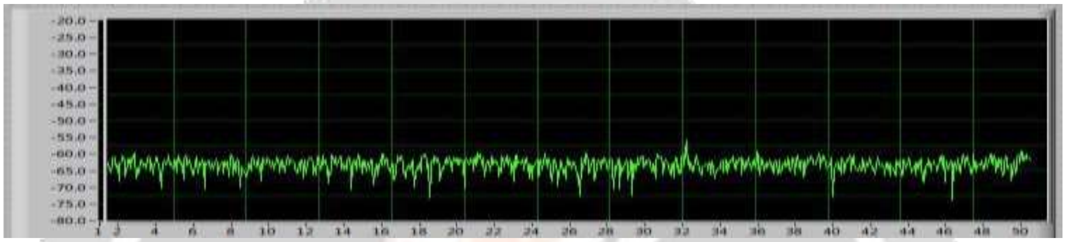


**Frequency [Hz]**

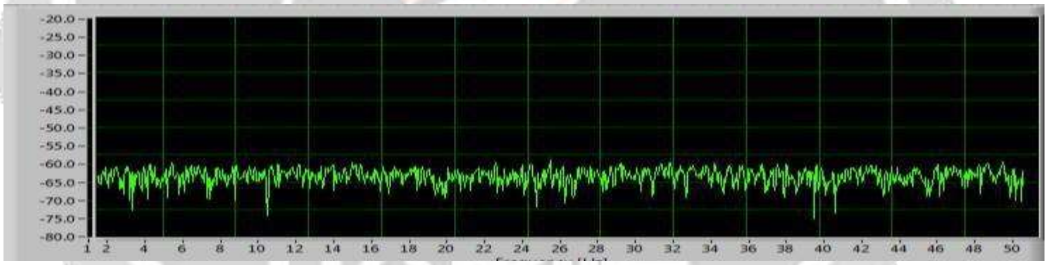
**Figure12: Power spectrum of faulty gearbox with input shaft wear gear under 10kg load condition (m=2)**



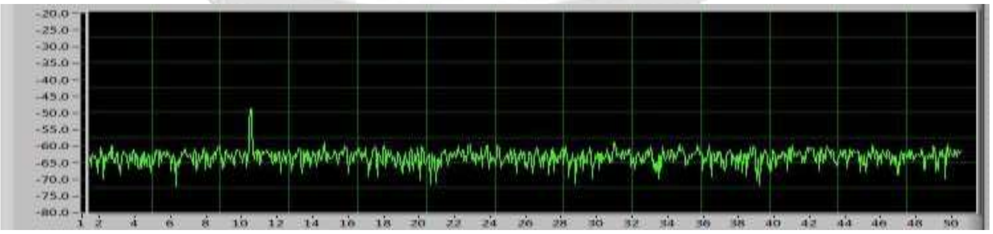
**Frequency [Hz]**
**Figure13: Power spectrum of faulty gearbox with fault gear under no load condition (m=1)**



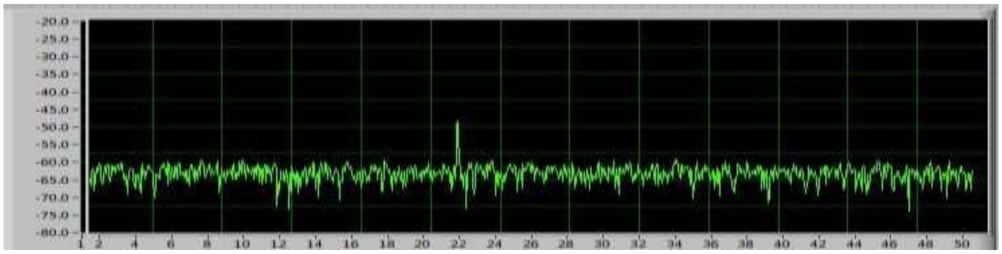
**Frequency [Hz]**
**Figure14: Power spectrum of faulty gearbox with fault gear under no load condition (m=2)**



**Frequency [Hz]**
**Figure 15: Power spectrum of healthy gearbox under 10 load condition**



**Frequency [Hz]**
**Figure16: Power spectrum of faulty gearbox with fault gear under 10 load condition (m=1)**



**Frequency [Hz]**
**Figure17. Power spectrum of faulty gearbox with fault gear under 10 load condition (m=2)**

## 7.CONCLUSIONS

The aim of this research is to advance the field of condition monitoring and fault diagnosis in gearbox operating under different load conditions. The common types of faults in gearbox are studied in the project. The various types of current based condition monitoring and fault diagnosis techniques are reviewed. The main aim of the research work is to diagnose the common mechanical faults experimentally with help of suitable signal processing techniques. In order to perform accurate and reliable analysis on gearbox, an experimental set up is designed that can accurately repeat the measurements of signals and can introduce a particular fault of the gearbox faults. In the present research work, Lab VIEW environment is used to diagnose the faults with direct online condition monitoring.

This research work investigates the feasibility of detecting mechanical faults such as bearing failure and wear gear failure, gear tooth broken failure using the spectrum of current of a motor. Defective bearings, wear gear failure, gear tooth broken failure generate eccentricity in the air gap with mechanical vibrations. The air gap eccentricities cause vibrations in the air gap flux density that produces visible changes in the current spectrum. The signal processing techniques FFT are applied to detect the bearing fault and gear faults of gearbox. Experimental results show that the characteristic frequencies could not seen in the power spectrum if bearing fault and gear fault are small in size. As severity of fault increases, the characteristic frequencies become visible. In the research work, an experiment has also been conducted to detect the gear box fault.

## ACKNOWLEDGMENT

We would like to give sincere thanks to all the members who are directly or indirectly part of this work

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