International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 3 Issue 2 ǁ Feb. 2015 ǁ PP.45-53

Detection of Gear Fault Using Vibration Analysis

V.Ranjith Kumar, P. Venkata Vara Prasad, G DIWAKAR

Asst. professor Automobile engineering Department, PACE Institute of Technology, Valluru, Ongole, Andhra Pradesh, India

Asst. professor Mechanical engineering Department, DBS Institute of Technology, Kavali, Andhra Pradesh, India

Assoc professor Mechanical engineering Department, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India

Abstract: To achieve reliable and cost effective diagnosis, Motor current signature analysis is used to investigate the use of an induction motor as a transducer to indicate the faults in multistage gearbox via analyzing supply parameters such as phase current and instantaneous power. In gearboxes, load fluctuations on the gearbox and gear defects are two major sources of vibration. Further at times, measurement of vibration in the gearbox is not easy because of the inaccessibility in mounting the vibration transducers. This analysis system can be used for measuring the characteristics for a perfectly working gearbox and use the data as a standard for measuring faults and defects in other gearboxes. The objective of this paper is to design and diagnose fault in the gearbox using motor current analysis system at different gear operations on different loads. Steady load conditions on the gearbox are tested for current signatures during different gear operations. Also found the minimum power required to run on different gears and gear ratio. The motor current analysis system can be used further to specify mainly faults in the gear, misalignment of meshed gears, loss of contact of the gears and bearing wear.

I. Introduction

The monitoring of a gearbox condition is a vital activity because of its importance in power transmission in any industry. Therefore, to improve upon the monitoring techniques for finding the gear ratios in the gearbox and the current passing through the motor running the gearbox has been a constant endeavor for improvement in these monitoring techniques. Techniques such as wear and debris analysis, vibration monitoring and acoustic emissions require accessibility to the gearbox either to collect samples or to mount the transducers on or near the gearbox. But dusty environment, background noise, structural vibration etc. may hamper the quality and efficiency of these techniques. Hence, there is a need to monitor the gearbox away from its actual location, which can be achieved through Motor current signature analysis (MCSA) which has already been successfully applied to condition monitoring of induction motor for finding friction in bearings.[15] Personnel at Oak Ridge National Laboratory have found that MCSA can also provide information about system vibrations and imbalances similar to the information provided by an accelerometer. As a result, MCSA techniques for monitoring the status of the equipment, such as pumps, compressors and gear drives driven by induction motors have been developed and used in dedicated monitoring systems. Also we can find in particular, if there are some faults in a gear box drive, the main current signal will be modulated by additional waveforms induced by fault components. [11]

II. Literature Review

Gear box fault detection can mainly be done through vibration and motor current analysis. The former method uses the fact that Vibration Faults, when they begin to occur, alter the frequency spectrum of the gear vibration. Particular faults are identified by recognizing the growth of distinctive sideband patterns in the spectrum. [1] The spectrum is recorded with the help of oscilloscope when the accelerometer is placed on the gearbox to be tested. The noise signature is affected by the background noise and the noise field.[5]These limitations of prevalent techniques bolster the justification of using the motor current signature analysis (MCSA), which has already been used for condition monitoring of motor operated valves of nuclear plants [3], [4], worm gears [5], induction motor and bearings [6]–[11],and multistage gearbox [12], [13].

The basis of fault detection is the difference in normalized current RMS values of both healthy and faulty bearings. Broken rotor and eccentricity in the rotor and stator of an induction motor result in side bands of electric supply line frequency. Prior knowledge of spatial position of fault and the load torque with respect to the rotor is necessary as the effects of load torque and faulty conditions are difficult to separate.

Motor current signals can be obtained from the outputs of current transducers which are placed non intrusively on one of the power leads. The resulting raw current signals are acquired by computers after they go through conditioning circuits and data interfaces. [14] These signals are then studied to determine faults occurring in gearbox. Although numerous techniques are available of non intrusive type of testing for fault detection, they have their own limitations. The present work thus aims to develop and propose a method which is simpler to find speed of gearbox and fault in gearbox by finding power consumption of motor.

III. Experimental Setup

The experimental set up consists of a four pole three-phase induction motor coupled to a 4-speed automotive gearbox. The coupling used is a shaft coupling. The input speed of the gearbox is the mechanical speed of the induction motor. Induction motor is also connected to dimmer stat which controls the power to the motor by varying the input voltage which further drives the gearbox output shaft.Then there are current probes to measure the current response. Voltmeter and an Ammeter are used here for measuring voltage and current readings.

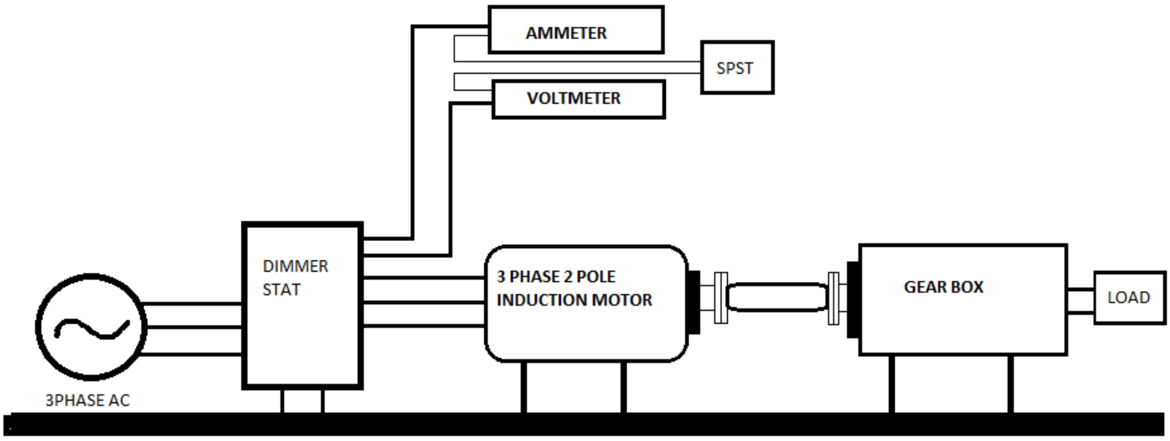


Fig 1: Schematic diagram of Experimental setup.

Description of various parts of the experimental setup is as follows:
1.3 Phase Induction Motor
The motor has the following Configuration,
Make : Siemens
Rated Power : 1.48 kW.
Rated Speed : 1440rpm
Frequency : 50 Hz.
Voltage : 440 V.
Current : 0.5 A.

2. Dimmer Stat

Fig 2: DIMMER STAT used in the experiment

The DIMMER STAT used in the experiment has the following configuration

Type : 15D-3P
Max KVA : 12.211

Connection for Max output voltage to input equal

Input at A_1 A_2 A_3 V-3 | 415 | Ø -50/60HZ

Output at E_1 E_2 E_3 Volts | 0-415 |

Connection for Max output voltage higher than input

Input at B_1 B_2 B_3 V-3 | 415 | Ø -50/60HZ

Output at E_1 E_2 E_3 Volts | 0-470 |

Output current 15amp per line

3: Gearbox

A gearbox or transmission provides speed and torque conversions from a rotating power source to another device using gear ratios. The most common use is in automobiles where the transmission adapts the output of the internal combustion engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process.

The gearbox used in the experiment is a 4-speed manual transmission automotive gearbox.

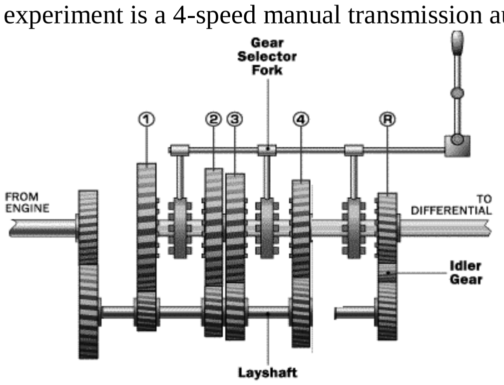


Fig.3: 4-speed manual transmission gearbox

IV. FABRICATION

The setup was placed on a Cast iron rectangular block. Induction motor and gearbox were connected on the rectangular block. Channel was used for placing the 3-phase induction motor so that the motor and the gearbox are properly aligned with each other. Both the motor and gearbox are coupled by a shaft so that the gearbox is fixed completely and does not vibrate during high rotational speeds. Loading arrangement is done with a pulley connected to spring balances at gearbox output shaft.

Fig 4: the Final fabricated set-up.

V. shaft coupling

Shaft coupling is a coupling used to connect two rotating shafts of different diameters. The shaft is connected to one end at the motor and the other end at gearbox.

Fig.5: shaft coupled to motor and gearbox

VI. FFT Analyser:

Fig.6: Fast Fourier transducer

Fig.7: Gears before removing teeth.

Fig.8: Gears after removing teeth.

VII. OBSERVATIONS

The basic aim of the experiment was to detect the gear fault . For this the arrangement was done and the motor connected to gearbox made to run at constant motor speed which was controlled by the dimmer stat. output shaft of the gearbox is connected with springs loads.Readings were taken for the 4 different gears at different loads.i.e 0,1,2,3 kgs for the normal gearbox and then 2 teeths are removed from the 2nd and 3rd gears by using gas welding.Again readings are taken for the 4 different gears at different loads.i.e 0,1,2,3 kgs. The results are given in the table below:

2nd GEAR readings

S.NO	**Direction**	**parameters**	**MNDE**		**MDE**		**GDE**		**GNDE**	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	HORIZONTAL	Acceleration	9.87	54.9	18.7	55.8	59.4	250	42.9	197
		Velocity	19.8	10.2	16.3	17.2	14.9	25.8	14.1	207
		Displacement	352	129	306	245	249	288	327	2501
2	VERTICAL	Acceleration	10.9	42.3	8.71	20.9	31.5	178	35.2	275
		Velocity	3.45	17.8	8.51	18.4	6.92	10.4	17.2	89.5
		Displacement	52.7	86.0	147	195	100	244	291	8426
3	AXIAL	Acceleration	20.6	57.6	14.7	40.8	41.8	99.8	172	67.7
		Velocity	11.3	22.6	11.2	25.5	52	27.6	27.9	21.5
		Displacement	168	207	158	138	889	305	528	140

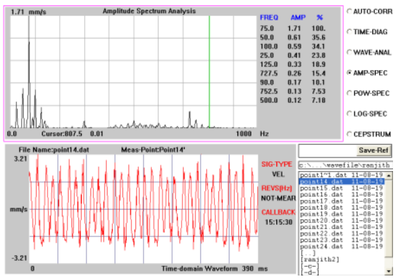
3rd GEAR readings

S.NO	**Direction**	**parameters**	**MNDE**		**MDE**		**GDE**		**GNDE**	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	HORIZONTAL	Acceleration	10.3	36.5	15.4	73.3	46.0	179	51.3	200
		Velocity	24.0	9.25	24.1	9.62	27.4	24.4	20.8	83.1
		Displacement	459	104	425	152	463	844	421	7526
2	VERTICAL	Acceleration	11.6	50.3	8.85	26.9	31.3	223	50.6	188
		Velocity	4.07	13.9	10.6	20.0	7.45	24.8	16.9	91
		Displacement	47.3	117	180	187	117	143	277	7018
3	AXIAL	Acceleration	26.5	56.2	13.7	40.0	42.6	55.5	16.7	62.6
		Velocity	9.01	12.2	12.0	16.8	50.2	17.4	25.0	17.4
		Displacement	170	200	221	217	918	259	439	134

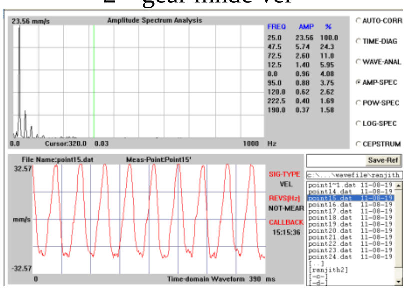
B.B-Before breaking **A.B**-After breaking

Spectrums before removing teeth:

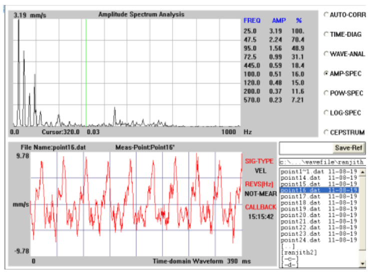
2nd gear mnde hor



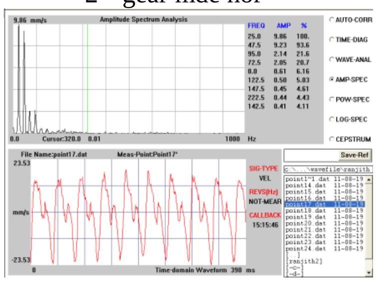
2nd gear mnde ver



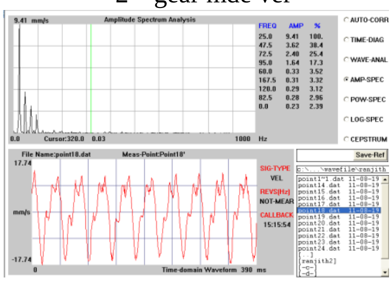
2nd gear mnde axi



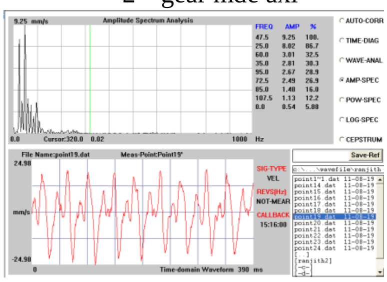
2nd gear mde hor



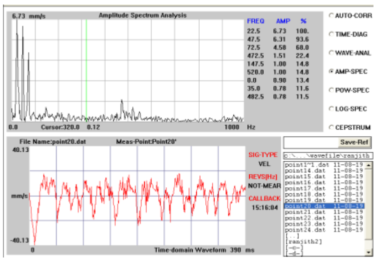
2nd gear mde ver



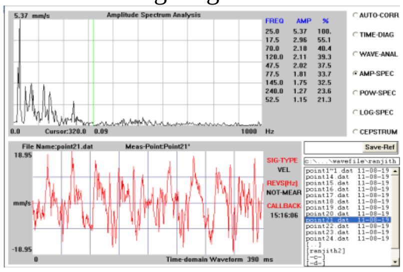
2nd gear mde axi



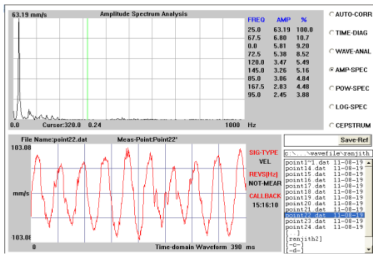
2nd gear gde hor



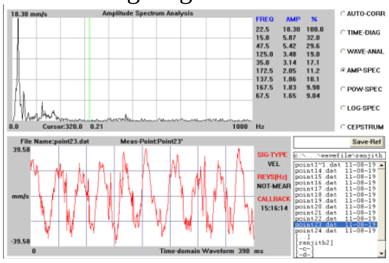
2nd gear gde ver



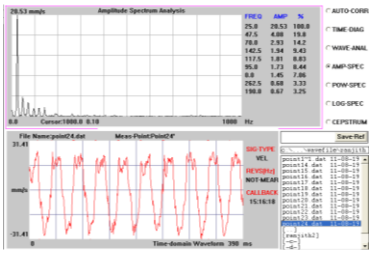
2nd gear gde axi



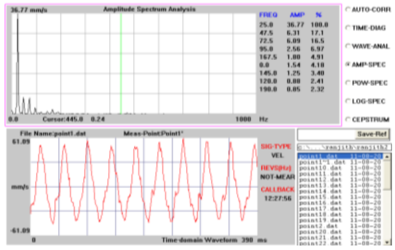
2nd gear gnde hor



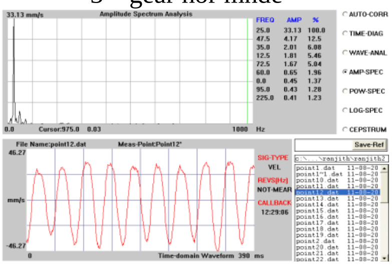
2nd gear gnde ver



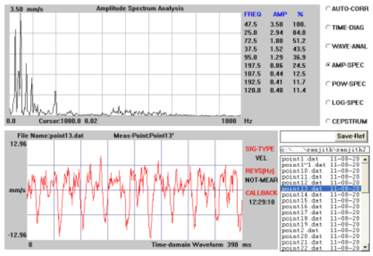
2nd gear gnde axi



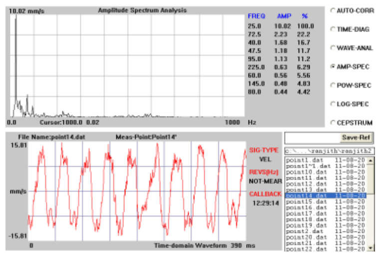
3rd gear hor mnde



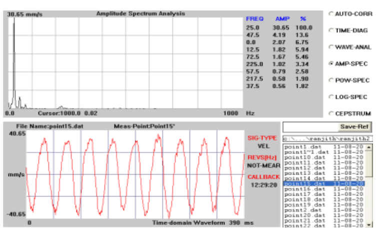
3rd gear ver mnde



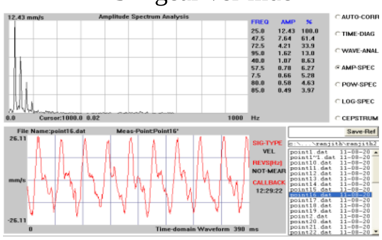
3rd gear axi mnde



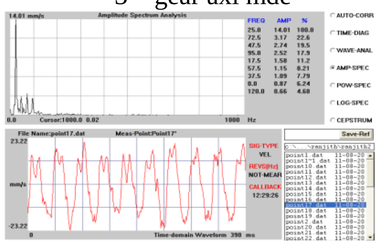
3rd gear hor mde



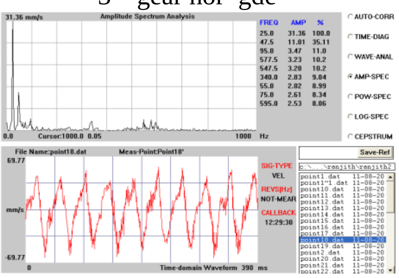
3rd gear ver mde



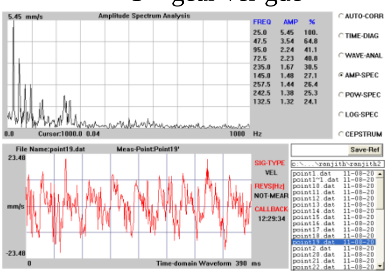
3rd gear axi mde



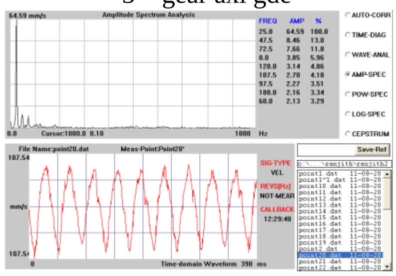
3rd gear hor gde



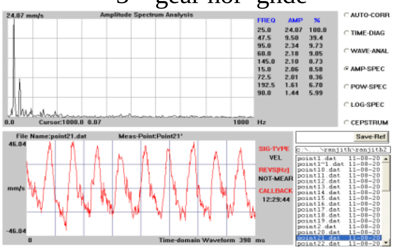
3rd gear ver gde



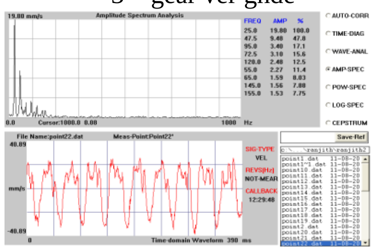
3rd gear axi gde



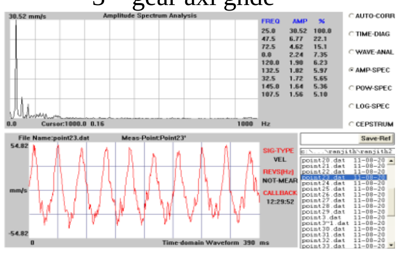
3rd gear hor gnde



3rd gear ver gnde

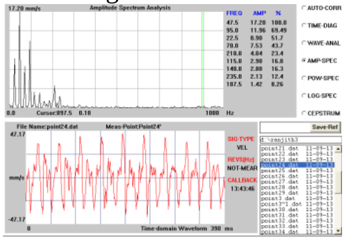


3rd gear axi gnde

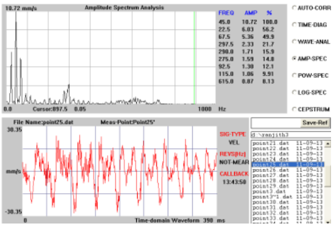


Spectrums after removing teeth:

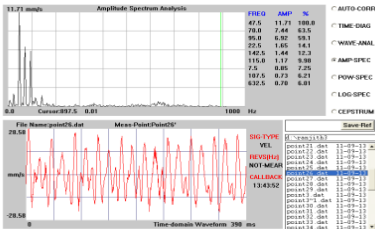
2nd gear hor mnde



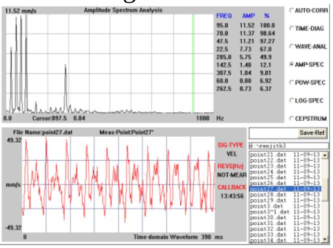
2nd gear ver mnde



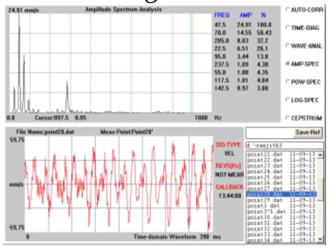
2nd gear axi mnde



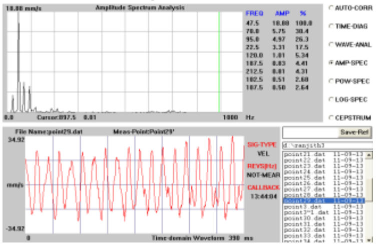
2nd gear hor mde



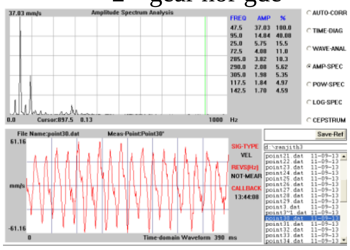
2nd gear ver mde



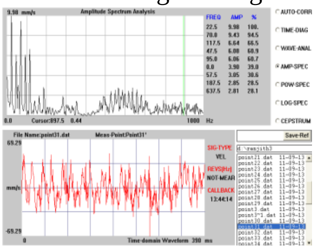
2nd gear axi mde



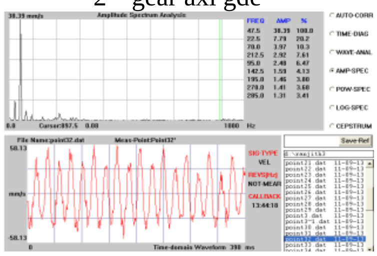
2nd gear hor gde



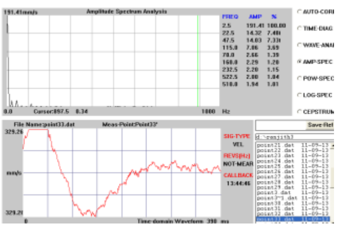
2nd gear ver gde



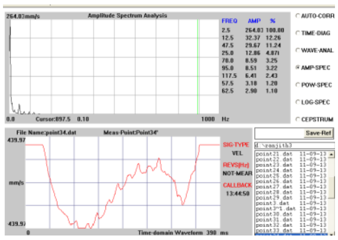
2nd gear axi gde



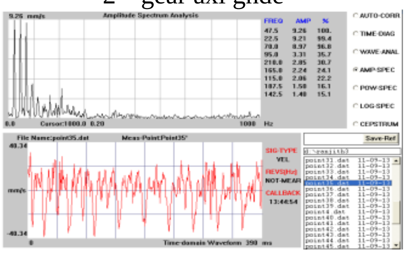
2nd gear hor gnde



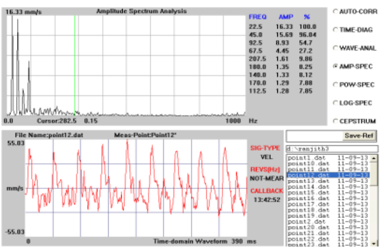
2nd gear ver gnde



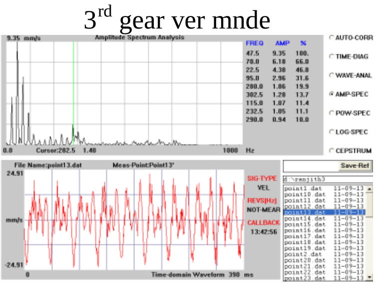
2nd gear axi gnde



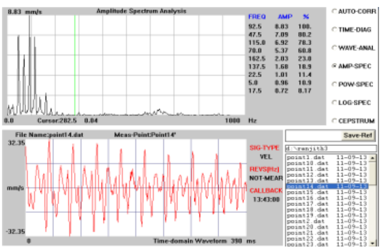
3rd gear hor mnde



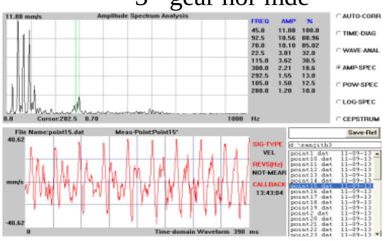
3rd gear ver mnde



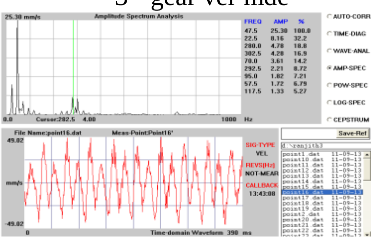
3rd gear axi mnde



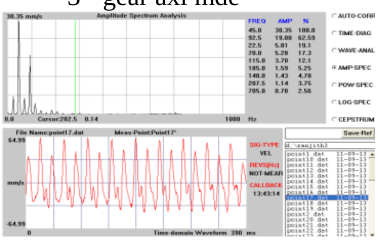
3rd gear hor mde



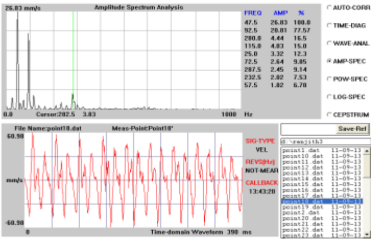
3rd gear ver mde



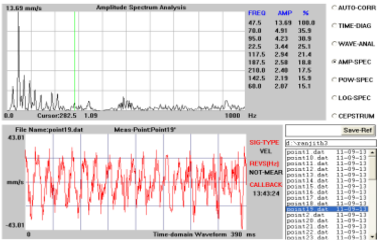
3rd gear axi mde



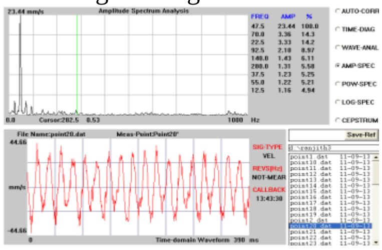
3^{rd} gear hor gde



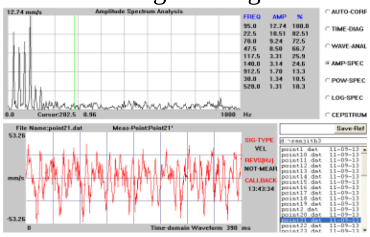
3^{rd} gear ver gde



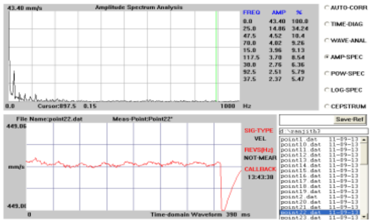
3^{rd} gear axi gde



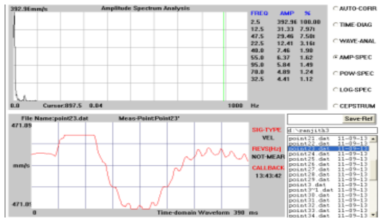
3^{rd} gear hor gnde



3^{rd} gear ver gnde



3^{rd} gear axi gnde



VIII. RESULTS

It has been found that the motor current decreases with increasing input speed of gearbox. For low rpm of the input shaft the current withdrawn by the induction motor is maximum and minimum for high rpm of the input shaft.

- The decreasing motor current with increasing input speed is due to the fact that as the rpm increases the torque value decreases and so the current withdrawn by the induction motor decreases.
- For different gear ratios the plot of motor current vs input speed remains almost same.
- At constant speed current drawn from first gear to fourth gear increases and voltage decreases from 1^{st} gear to 4^{th} gear.

IX. CONCLUSIONS

- These plots can be taken as a standard for measuring defects in gearboxes. Any deviation from this plot means there is some defect in the gearbox which is tested.
- Vibration monitoring is affected by the base excitation motion because of the presence of a number of machinery in the factory. Moreover, because of the intricate location of the machine, there may be a problem of mounting transducers on the gearbox at times
- A method for continuously monitoring the condition of a motor and which interprets condition of faulty and healthy gear box.
- For future work, if there is any misalignment of the gears, or any gear tooth is broken then there is sudden upsurge in the current withdrawn by the induction motor can be determined using the developed system.

REFERENCES:

[1] Early Detection of Gear Faults Using Vibration Analysis in a Manufacturer's Test Department by Laszlo Boros, RABA, Gyor, Hungary and Glenn H. Bate, Bruel&Kjser, Denmark

[2] N. Byder and A. Ball, “Detection of gear failures via vibration and acoustics signals using wavelet transform,” Mech. Syst. Signal Process., vol. 17, no. 4, pp. 787–804, Jul. 2003.

[3] B. D. Joshi and B. R. Upadhyaya, “Integrated software tool automate MOV diagnosis,” P*ower Eng.*, vol. 100, no. 4, pp. 45–49, 1996.

[4] S. Mukhopadhyay and S Choudhary, “A feature-based approach to monitor motor-operated valves used in nuclear power plants,” *IEEE Trans.Nucl. Sci.*, vol. 42, no. 6, pp. 2209–2220, Dec. 1995.

[5] D. M. Eisenberg and H. D. Haynes, “Motor current signature analysis,” in *ASM Handbook*, 10th ed, vol. 17. Materials Park, OH: ASM International, 1993, pp. 313–318.

[6] M. E. H. Benbouzid, “A review of induction motor signature analysis as a medium for faults detection,” *IEEE Trans. Ind. Electron.*, vol. 47, no. 5, pp. 984–993, Oct. 2000.

[7] “Bearing damage detection via wavelet packet decomposition of the starting current,” *IEEE Trans. Instrum. Meas.*, vol. 53, no. 2, pp. 431–436,Apr. 2004.

[8] A. R. Mohanty and C. Kar, “Gearbox health monitoring through three phase motor current signature analysis,” in *Proc. 4th Int. Workshop Struct.Health Monitoring*, Stanford, CA, 2003, pp. 1366–1373.

[9] C. Kar and A. R. Mohanty, “Monitoring gear vibrations through motor current signature analysis and wavelet transform,” *Mech. Syst. Signal Process.*, vol. 20, no. 1, pp. 158–187, Jan. 2006.

[10] Neeraj kumar ”EXPERIMENTAL INVESTIGATION OF FAULTY GEARBOX USING MOTOR CURRENT SIGNATURE ANALYSIS”, may 2009.

[11] K. N. Castlcberry, ” High-Vibration Detection Using Motor Current Signature Analysis”OAK RIDGE NATIONAL LABORATORY, sept. 09, 1996.

[12] Mansaf R. Haram, "Gearbox Fault Detection using Motor Current Signature analysis"1stYear PhD Supervised by Prof. A. Ball and Dr. F.Gu The University of Huddersfield,Queensgate, Huddersfield HD1 3DH, UK
[13] A. R. Mohanty and Chinmaya Kar, "Fault Detection in a Multistage Gearbox by Demodulation of Motor Current Waveform" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 53, NO. 4, AUGUST 2006
[14] R.B. Randal, State of the art in monitoring rotor machinery, Proceeding of ISMA, vol-IV, 2002, pp. 1457–1478.
[15] G.Diwakar and V.Ranjith Kumar, "DETECTION OF BEARING FAULT USING MOTOR CURRENT SIGNATURE ANALYSIS," ICMBD-2011, K L University.