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Research Article

Detection of Current consumption using Motor Current Signature Analysis

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Abstract

In order to achieve reliable and cost effective diagnosis, Motor current signature analysis (MCSA) 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. Gears are important elements in a variety of industrial applications such as machine tools and gearboxes. An unexpected failure in gear may cause significant economic losses. The vibration signal analysis can be carried out the signature of the fault in the gears and used to determine early fault detection of the gearbox by using different signal processing techniques. In this paper, vibration analysis techniques are used for condition monitoring in gear fault. This analysis can be used for measuring the characteristics for a perfectly working gearbox and used the data as a standard for measuring faults and defects in other gearboxes. The objective of this paper is to design and fabrication of a gearbox for motor current analysis system at different gear operations on different load conditions. Current signatures are tested for during different gear operations. Also the minimum power required to run different gears are determined by using different loads. 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.

Keywords: *MCSA, gear box, load, bearing, speed.*

1. Introduction

Now a days, production plants are expected to run continuously, industry has created a demand for techniques that is capable of recognizing the development of a fault condition within a machine system. Machine Condition Monitoring was developed to meet this need. The failures of rotating machineries can be very critical because these lead to machinery damage, production losses and personnel injury. So, a very important duty of the maintenance department was to prevent these failures when they were in its initial stage. The predictive maintenance by vibration analysis is the best tool for this purpose. The vibration analysis was a technique which is used to track machine operating conditions and trend deteriorations in order to reduce maintenance costs and downtime simultaneously. The monitoring of a gearbox condition was a vital activity because of its importance in power transmission in any industry. Therefore, to improve the monitoring techniques for finding the gear ratios in the gearbox and the current passing through the motor running the gearbox had been a constant endeavor for improvement in these monitoring techniques and no additional sensors were necessary. Because of the basic electrical quantities associated with electromechanical plants such as current and voltage was readily measured by tapping into the existing voltage and current transformations that were always installed as part of the protection system. As a result, current monitoring was non-intrusive and even may be implemented in the motor control center remotely from the motor being monitored. Motor current signature analysis (MCSA) and Park's vector approach fall under current monitoring. The MCSA is used the current spectrum of the machine for locating characteristic fault frequencies. When a fault is presented, the frequency spectrum of the line current becomes different from healthy motor and that fault modulates the air-gap and produces rotating frequency harmonics in the self and mutual inductances of the machine. It depends upon locating specific harmonic component in the line current.

2. 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

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vibration. Particular faults are identified by recognizing the growth of distinctive sideband patterns in the spectrum. [Laszlo Boros *et al*,] 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.[D. M. Eisenberg *et al*, 1993]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 [B. D. Joshi *et al*,1996], [S. Mukhopadhyay *et al*,1995], worm gears [D. M. Eisenberg *et al*, 1993], induction motor and bearings [M. E. H. Benbouzid,2000]–[Mansaf R. Haram],and multistage gearbox [A. R. Mohanty *et al*, 2006], [R.B. Randal, 2002].

All electric machines generate noise and vibration, and the analysis of the produced noise and vibration can be used to give information on the condition of the machine. Even very small amplitude of vibration of machine frame can produce high noise. Noise and vibration in electric machines are caused by forces which are of magnetic, mechanical and aerodynamic origin [M.E.H. Benbouzid, 1999]. There will be difference in consumption of current and fluctuations in voltage and current readings. Thus by analyzing the Voltage and current reading signal of an electric machine, it is possible to detect various types of faults and asymmetries [Belahcen *et al*, 1999]. Bearing faults, rotor eccentricities, gear faults, speed and unbalanced rotors are the best candidates for Voltage and current reading based diagnostics of the machine. Vibration-based diagnostics is the best method for fault diagnosis, but needs expensive accelerometers and associated wiring. This limits its use in several applications, especially in small machines where cost plays a major factor in deciding the condition monitoring method. Randy R. Schoen [Randy R. Schoen *et al*, 1995] presented a method for on-line detection of incipient induction motor failures which requires no user interpretation of the motor current signature, even in the presence of unknown load and line conditions. A selective frequency filter learns the characteristic frequencies of the induction machine while operating under all normal load conditions.

The generated frequency table is reduced to a manageable number through the use of a set of expert system rules based upon the known physical construction of the machine. Li *et al*. [Chow *et al*, 2000] carried out vibration monitoring for rolling bearing fault diagnoses. The final diagnoses are made with an artificial NN. The research was conducted with simulated vibration and real measurements. In both cases, the results indicate that a neural network can be an effective tool in the diagnosis of various motor bearing faults through the measurement and interpretation of bearing vibration signatures. In this study Voltage and current reading signal of an electric machine before and after breaking of tee in gear box was noted by varying load. By taking reference of the good condition motor readings as reference and can be verified at regular intervals. This list of frequencies forms the neural network clustering algorithm inputs which are compared to the operational characteristics learned from the initial motor performance. This only requires that the machine be in “good” operating condition while training the system. Since a defect continues to degrade the current signature as it progresses over time, the system looks for those changes in the original learned spectra that are indicative of a fault condition and alarms when they have deviated by a sufficient amount. The combination of a rule based (expert system) frequency filter and a neural network maximizes the system’s ability to detect the small spectral changes produced by incipient fault conditions. Compete failure detection algorithm was implemented and tested. An impending motor failure was simulated by introducing a rotating mechanical eccentricity to the test machine. After training the neural network, the system was able to readily detect the current spectral changes produced by the fault condition. Schoen and Habetler [R. Schoen *et al*,1993- B. K. Lin *et al*, 1995] investigated the effects of a position-varying load torque on the detection of air gap eccentricity. The torque oscillations were found to cause the same harmonics as eccentricity. These harmonics are always much larger than eccentricity-related fault harmonics. Therefore, it was concluded that it is impossible to separate torque oscillations and eccentricity unless the angular position of the eccentricity fault with respect to the load torque characteristic is known.

Motor current signals can be obtained from the outputs of current transducers which are placed none 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. [G.Diwakar *et al*, 2011] 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.

3. 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.

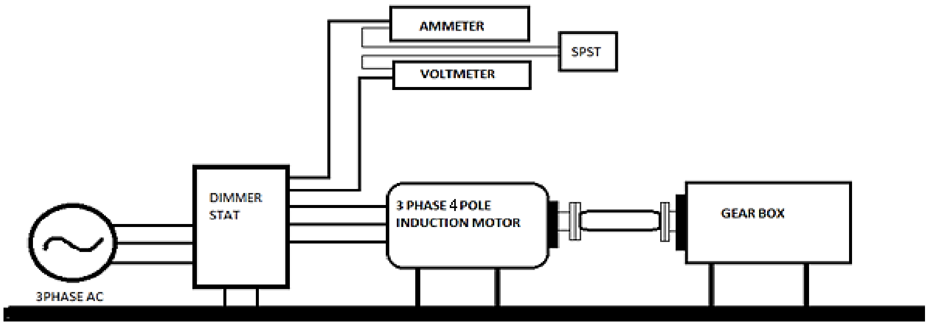


Fig 1: Schematic diagram of Experimental setup

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-3Ø-50/60HZ 415

Output at E_1 E_2 E_3 0-415 Volts

Connection for Max output voltage higher than input

Input at B1 B2 B3 V-3Ø-50/60HZ 415

Output at E_1 E_2 E_3 0-470 Volts

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.

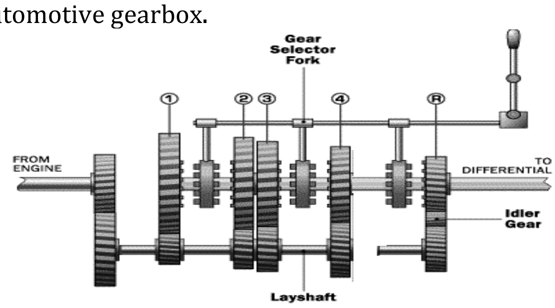


Fig.3: 4-speed manual transmission gearbox

4. Fabrication

The setup was placed on a Cast iron rectangular block.

Fig 4: The Final fabricated set-up

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.

Table 1 1st Gear reading

S.No	Load (kgs)	Motor speed(rpm)	Gearbox speed(rpm)		Voltage readings(volts)		Current readings(amp)	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	0	1400	92.7	264.9	124	156	0.35	0.4
2	1		91.2	252.3	124	156	0.44	0.44
3	2		90.7	240.5	124	160	0.52	0.48
4	3		89.1	231.6	124	160	0.55	0.52

Table 2 2nd Gear reading

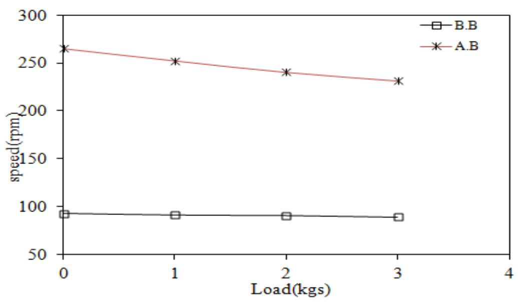
S.No	Load (kgs)	Motor speed(rpm)	Gearbox speed(rpm)		Voltage readings(volts)		Current readings(amp)	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	0	1400	145.3	351.5	128	176	0.4	0.6
2	1		143.5	346.1	128	176	0.47	0.64
3	2		141.7	336.3	128	176	0.55	0.73
4	3		138.8	328.6	128	176	0.6	0.78

5. Observations

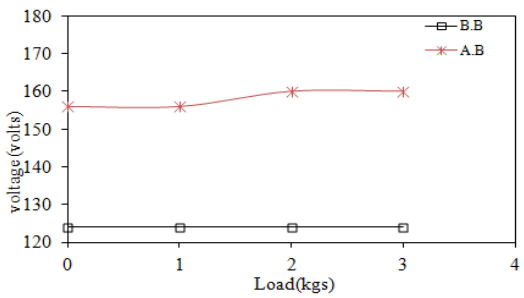
The basic aim of the experimentation was to design the arrangement in order to predict the gear ratio of the gearbox and to get the motor current signature of the input motor. For this the arrangement was done and the motor was made to run in various RPM which was controlled by the dimmer stat. The motor was run on four different speeds between 1300 to1440 RPM respectively and the speed of the driven shaft was measured using a Tachometer. 4 such readings were taken each for the 4 different gears. The results of the run are given in the table below:

1st gear readings

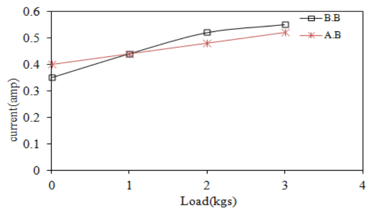
It is shown in Table 1



Load v/s Speed



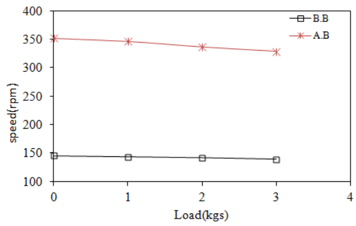
Load v/s Voltage



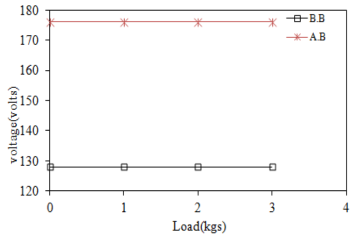
Load v/s Current

2nd gear readings

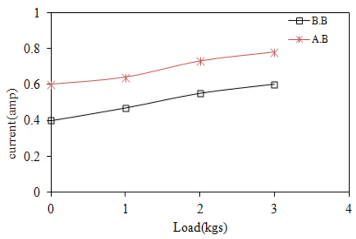
It is shown in Table 2



Load v/s Speed



Load v/s Voltage



Load v/s Current

Table 4 3rd Gear reading

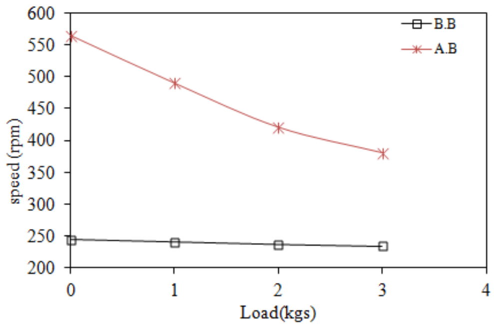
S.No	Load (kgs)	Motor speed(rpm)	Gearbox speed(rpm)		Voltage readings(volts)		Current readings(amp)	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	0	1400	244.3	564.1	144	196	0.48	0.76
2	1		240.8	489.5	144	200	0.53	0.80
3	2		237.1	420.3	144	202	0.58	0.82
4	3		234.2	380.3	144	202	0.65	0.88

Table 4 4th Gear reading

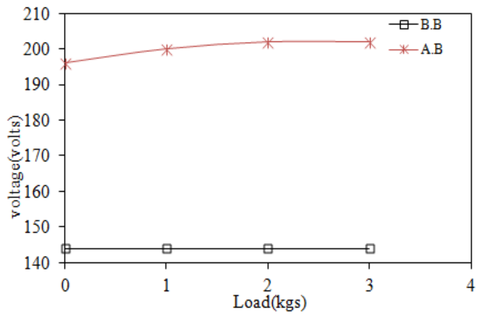
S.No	Load (kgs)	Motor speed(rpm)	Gearbox speed(rpm)		Voltage readings(volts)		Current readings(amp)	
			B.B	**A.B**	**B.B**	**A.B**	**B.B**	**A.B**
1	0	1400	362.9	844.2	224	208	0.58	0.78
2	1		359.2	833.1	224	208	0.6	0.81
3	2		353.1	821.3	224	208	0.63	0.95
4	3		349.6	810.3	224	208	0.68	1

3rd gear readings

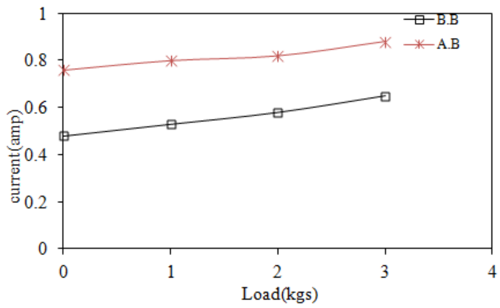
It is shown in Table 3.



Load v/s Speed



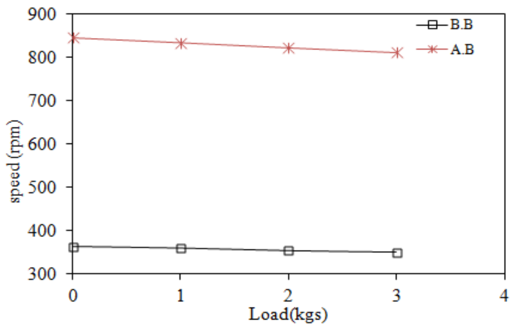
Load v/s Voltage



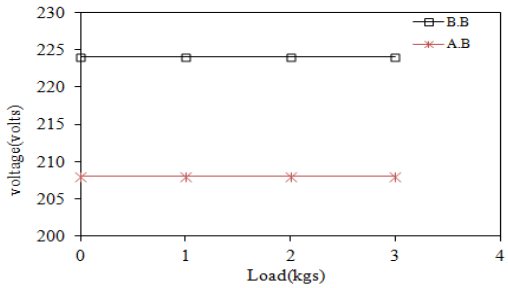
Load v/s Current

4th gear readings

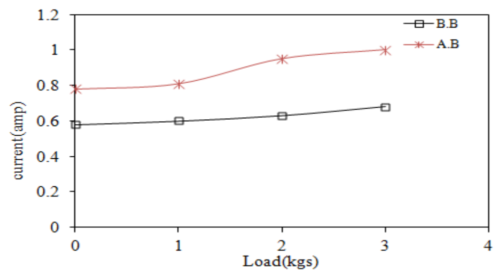
It is shown in Table 4



Load v/s Speed



Load v/s Voltage



Load v/s Current

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

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 drawn 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.
- The voltage utilized by motor at different loads is almost constant. But its value for healthy and faulty gear is different and voltage drawn by motor increases for faulty gear.
- Voltage and current increases for faulty gear compared to healthy gear. power consumed by motor also increases which indirectly reduces the efficiency of the system.
- The 1st and 4th gears are good gears. Hence there is no considerable change in voltage or current before and after removing gear teeth of 2nd and 3rd gear.

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.
- Industrial case histories have clearly demonstrated that MCSA is a powerful online monitoring technique for assessing the operational condition of 3-phase induction motors.
- The avoidance of catastrophic failures can be achieved via MCSA and other major benefits include the prevention of lost down time avoidance of driven faults and reducing replacement costs.

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