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Detection of rotor and eccentricity faults in three phase induction motors using sound analysis

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Abstract - *This paper deals with the sound analysis of three phase induction motors. The sound of the test motors is analyzed in order to obtain information for the detection of faults. Significant noise spectrum differences between healthy motor and motors with different faults are observed. The faults analyzed are broken rotor bar fault and eccentricity faults. The wavelet spectral analysis of noise provides a method to detect faults.*

Key Words: three phase induction motor, rotor, beagleboard, wavelet, eccentricity

1. INTRODUCTION

A fundamental interpretation of the problem in the actual construction of the motor is the primary need for fault diagnosis. The understanding of how the fault indicators provide the details of the fault is also an important aspect. While choosing the fault indicator, it is important to keep in mind the accessibility of the indicator. One example can be that of the current of the motor, which a potential indicator of the faults in the motor (MCSA). Thus, the important considerations while performing fault diagnosis are the accessibility of the indicator, pertinence of the indicator and appropriate processing technique which is needed for accurate diagnostic results [1]-[6].

Condition monitoring aids the diagnosis of faults at the evolving stage itself. The finding of incipient faults in the motors also provides a secure operating environment for the operation of the motor. Condition monitoring not only detects the faults but also schedules maintenance and repairs for the motors. Hence, one can totally depend on the diagnostic data provided by the condition monitoring system for maintaining the motors. This will increase the safety and dependability and productivity of the motors [7][8].

The aspects which define the primary causes of the faults must be scrutinized to develop an effective condition monitoring technique. This is because the fundamental cause lead to a slow degradation of the motor which can be stopped if the causes are found out. These causes include the winding faults which mainly occur in the higher rating induction motors due to high voltages used, the rotor faults in all the motors due to excessive wear and tear of the motor or due to bearing and manufacturing defects. Also, in the higher rating induction motors, the larger size bearings result in more wear and tear, thus; inducing faults in the motor. Thus, the parameters which can be considered as potential indicators are current from the motor, leakage flux, vibrations of the motor, insulation conditions [9][10]

2. BROKEN ROTOR BAR FAULT

Out of the total faults affecting the induction motors 10% faults are the rotor faults. Due to mechanical and thermal cycling or increase in the amount of vibration, the structure and geometry of the rotor is disturbed, this results in formation of cracks in the rotor. This type of fault produces twice slip frequency components in the sensed signals [1]-[3].

The literature review done explains that the techniques which are associated with the use of external search coils for diagnosing rotor bar faults prove to be the most efficient and less expensive techniques. An external search coil held against the casing of the motor has the same potential as that of an internal search coil mounted on a stator tooth in order to detect a fault related to rotor. The frequencies from which the broken rotor bar fault can be detected are given by:

$$f_{broken\ rotor} = f_s\left[\left(\frac{k}{p}\right)(1-s) \pm s\right]$$ ....Equation 1

or

$$f_{broken\ rotor} = s.f_s = f_s(2s \pm 1)$$ ....Equation 2

The diagnostic data provided by the search coil mounted internally is highly accurate to detect the broken rotor bar faults but this techniques can be invasive as internal search coil is generally not preferred [10].

The axial leakage flux obtained by placing a search coil around the shaft i.e.; the search coil placed external to the motor, detect the rotor bar faults when analyzed in the frequency domain.

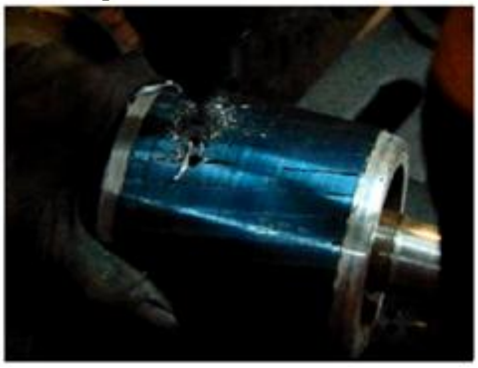
3. HARDWARE IMPLEMENTATION

Two test motors of the same specifications are used so that the readings in both the cases that is healthy and faulty can be obtained and faults can be diagnosed by comparing the readings. The test motors have been analyzed right from the manufacturing process to avoid any kind of imperfections so that accurate readings can be obtained.

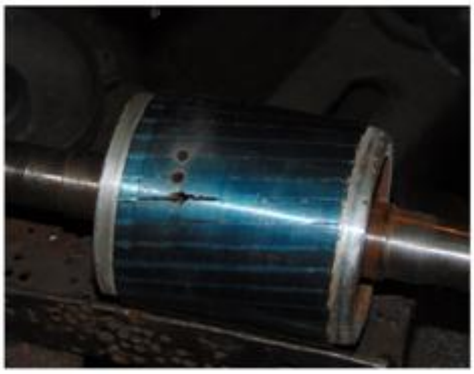
Table 1. Specifications of the test motor

Rated power	0.5 Hp
Rated frequency	50 Hz
Rated voltage	415 V
Rated Current	0.8 A
Stator connection	Star
RPM	700

Broken rotor bar fault is induced by drilling holes in the rotor as shown in figure 6.2 (b). This fault can lead to a serious damage in the motor as every crack, hole or fracture in the bar will eventually break the entire bar, this broken bar will cause an increase in current in all the other bars which as a consequence will come out of the slot damaging the stator winding.



(a)



(b)

Figure 1 (a), (b) Rotor fault (broken rotor bar) is induced by drilling holes in the rotor. [11]

Eccentricity of approximately 45% was obtained by reducing the air gap size by 0.3 mm, the diameter of the rotor was increased as in figure 6.2 (c). The presence of such a fault causes the stator and rotor to rub against each other, increases the amount of vibration, deteriorates the bearings, resulting in damage to the machine.

(a)

(b)

Figure 2 (a), (b) Eccentricity fault is induced y cutting some material from the circumference of the rotor using lathe machine [11]

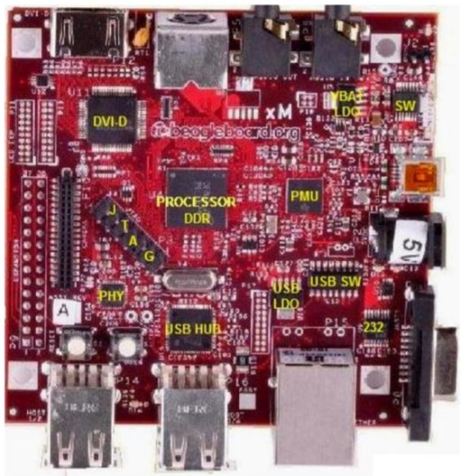


Figure 3. Beagleboard-xM with main components

A microphone is used to sense the sound of the motors which gives its output to the beagleboard. The output of the microphone is connected to the audio in pin of the beagleboard. This signal is filtered using a 47 pf capacitor and a 3.3 µH inductor by an inbuilt filter and further processed by internal ADC present on the auxiliary expansion header with the pin name as AUX_ADC. This ADC is controlled and powered by the processor with the help of I2C1 interface using TPS65950 by which power is regulated due to voltage limitations at these pins. This acquired signal is displayed on the LCD connected to the beagle board.

Wavelet transform is performed on this signal by TMS320C64x+™ DSP Core to indicate the presence noise and increase in the dB level which indicates the presence of faults.

4. RESULTS

The sound of the test motors is analyzed in order to obtain information for the detection of faults. Significant noise spectrum differences between healthy motor and motors with different faults are observed. The faults analyzed are broken rotor bar fault and eccentricity faults. The wavelet spectral analysis of noise provides a method to detect faults.

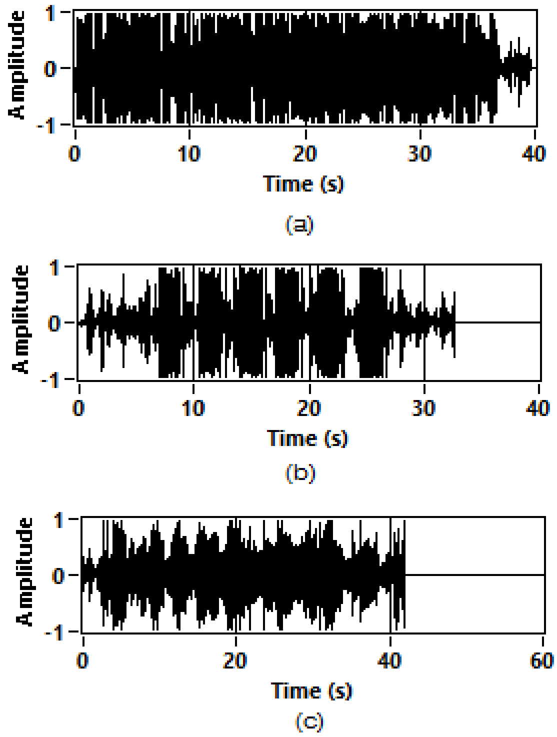


Figure 4. Sensed sound signals in time domain (a) healthy motor (b) motor with rotor fault (c) motor with eccentricity fault

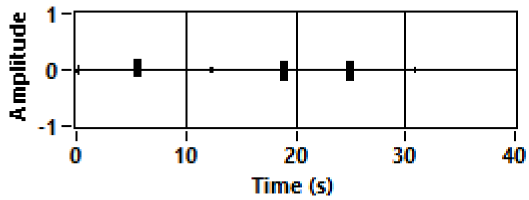


Figure 5. Wavelet transform of faulty motor

The sound level for healthy motor is 30-33 dB and for the motor having rotor fault is 45-50 dB. The measured sound level for motor with eccentricity fault is 55-60 dB. The waveforms are compared with the reference noise spectrum obtained from the healthy motor.

5. CONCLUSIONS

Sound analysis can be used for measuring faults in motors. The analysis of noise spectrum obtained for eccentricity fault shows more number of spikes as compared to the rotor fault and also there is an increase in the noise level of the motor.

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