Design of Pattern Analyzer for Fault Detection in Running Machines

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Abstract----Machines after failure stop production and then need maintenance. In this situation, industries pay not only in the form of maintenance but also in low and poor production. There is a need to design intelligent machines that can detect faults in the running machines before the faults occur. Thus, a low cost fault detector has been designed based on a unique frequency spectrum obtained from specific fault vibrations which actually detect faults in the running machines. The detector has the ability to detect the majority of faults occurring in industries, particularly those consisting of rotary and reciprocating machines. The proposed system sends warning alarms to the maintenance staff as soon as any type of disorder is detected and before any failure occurs.

Keywords- Maintenance, Intelligent Machines, Fault Detector, Unique Frequency, Microcontroller, Vibration Analyzer

1. INTRODUCTION

THE main problem associated with industries regarding low production is unpredicted maintenance which may not only cost the industry but also dangerous to the maintenance staff and workers [1-4]. Detection of failures in the earlier stages in machines is one of the most important concerns in present days because it guarantees the accurate operation of machines in industries as shown in[1, 5]. It was also investigated that online monitoring can effectually diagnose faults in many rotary and reciprocating machines and can avoid costly damages and unscheduled shut downs in industries [4, 6, 7].

Many techniques have been developed for earlier fault detection in machines like infrared thermography, x-ray, ultrasound technique, tribology, process parameters, current spectrum, lubrication analysis, and vibration analysis[8, 9]. Among all these, vibration analysis is the most effective technique because of low cost, fast processing, accurate result and non-invasive property[6, 10]. It has been founded in [8, 11] that vibration analysis technique is not only used to identify and predict failures but also prevent them from failures in rotary machines. H. Guesmi et. al [6, 7] . reported that most of the rotating machine failures are concerned to a change on its dynamics, therefore, vibration analysis in the frequency domain is the most effective and used technique. It is also concluded that as compared to time-domain analysis, frequency-domain analysis gives more detailed

information about the health of a machine[7]. Every part of a machine has its own vibration and similarly each fault produce in machines has its unique vibration which can be measured and matched with reference ones for detecting or diagnosing the fault as explained in[1, 6]. Similarly, each part's vibration or fault's vibration has its own characteristic frequency spectrum was

discussed in [6, 12]. Based on this unique spectrum, each fault in machine can be detected. Bearing defect frequency analysis method, enveloped spectrum method, and high frequency shock pulse and friction force methods are few of the methods using frequency analysis[6].

It is also investigated that improper lubrication is one of the main causes of accidents as overheating occurs due to insufficient lubricant. Vibration Analysis is also an effective technique[10] for monitoring the condition of rolling bearing lubrication of rotating machines [8]. Vibration Analysis not only predicts the deficiency of lubrication in rotary machines[13] but also predicts when the rotary parts like rolling bearing enters first stage of wear[8]. Using vibration analysis major faults occurring in rotary and reciprocating machines like misalignment, imbalance, mechanical looseness, lubrication issues, motor faults etc. can be detected[14].

Industrial efforts are producing quality products, minimizing risk and the use of raw materials. Therefore, it is needed to shift over to the concept of environmental sustainability[15]. Many researchers[16] worked on this area i.e. how to surge the quality of products by using minimum resources. They considerably indicated the outcome of predictive maintenance on environmental sustainability of an industry[17]. For example, in the final stage of automobile's bearings external grinding is done and during the process some vibration is observed which is

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produced due to this process, not due to flaw of the machine. These bearings can cause injury as its quality is affected by this undesirable vibration. Work was done on such industry products and vibration spectrum techniques were used to choose quality final products which are free from unwanted and harmful vibrations. The approach simply favors the environment as quality problems are prevented in the finally produced products and so more efficient use of resources will be needed in the succeeding batch of production to overcome all the limitations.

2. METHODOLOGY

For designing of online fault detector, an AVR-AT Mega 328 P model microcontroller was taken as the central component. Algorithm designed was saved in this microcontroller. Condenser mic was used as a sensor for getting the vibration signal from the rotary machines. After getting the time domain signal, its frequency domain spectrum was calculated using Fast Fourier Transform (FFT), which is fast computation algorithm for Discrete Fourier Transform (DFT). High pass filters were also used to let only specific frequencies through the circuit. An Alphanumeric LCD was used to show that either the machine is in normal condition or some disorder is present. The LCD displays the current condition of the machine continuously and if any harm situation is detected, the buzzer gets ON and alarms the maintenance staff. An Arduino board was used for interfacing of microcontroller and LCD. The programming was written in language C.

Frequency of the fault free rotary machine (sewing machine's motor) was saved and then other frequencies were compared with this frequency. If the incoming frequency matches with the saved one then the machines hasn't any fault but if its frequency doesn't match, then there is some disorder. The expected frequencies of all the disorders or failures e.g. misalignment, looseness, overload etc. were compared and saved. These frequencies were saved when such faults were in their initial stages. For omitting the errors and for a constant frequency graph, fifteen samples were taken and then graph was plotted from its average. The step-by-step process is shown in Fig.1.

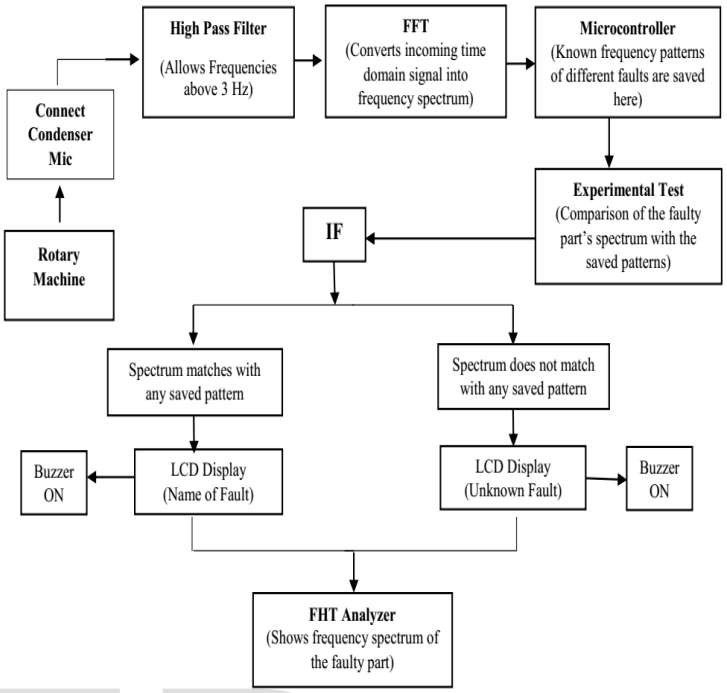

Figure1. Working Methodology of the Fault Detector

3. CALIBRATION

Three new sewing machine motors of National Company were taken for the calibration purposes. These motors need 150W power and 100/125V voltage. These produced 7500 rpm and their frequency was 50-60 Hz. The frequency spectrum of these motors were recorded and compared with their standard frequency spectrum, which matched. Afterward, for all experiments, before the mic was mounted to any defective part, its function was checked by detecting the spectrum of that new machine. Before performing all tests, it matched, which indicated that the sensor hasn't any error. If the mic has some error then the frequency of the new motor will not match with its standard frequency pattern and then you need to calibrate it before each measurement. For calibration any external calibrator can also be used by putting it on mic and turn it on, which will calibrate the mic. An Insert voltage technique can also be used to calculate the open circuit sensitivity of a condenser mic for calibration of condenser mic.

4. EXPERIMENTAL SETUP AND RESULT

In the first phase, the sensor (mic) was mounted on a new sewing machine's motor and its frequency pattern in FHT_128_ahannel_analyser was recorded as shown in Fig.2. It was saved by the name "Healthy Part". Next, normal motors were taken and LCD displayed them as "Healthy Part" and their frequency patterns matched with the saved pattern of healthy part as shown in Fig.2. In the same way, known faulty parts were taken and their patterns were saved on their names. For example, a small load (a side cutting plier of length 200mm, jaw length 32.5 mm, jaw width 26.2 mm, jaw thickness 12.7 mm, knife length 19.1 mm and weight 299 g was used to disturb the movement of motor) was added to that healthy part and it was taken as fault one. It was named as "Loaded Healthy Part" and its spectrum is shown in Fig.3. For second fault, a loose sewing machine motor (adjustment washer, used to keep the rotor at center, were removed) was taken and it was saved in the microcontroller as "Misaligned/Loose Part". The frequency spectrum of this pattern is shown in Fig.4. Again, the same plier was used as a load in this motor and it was taken as third fault. In the microcontroller it was saved by the name "Overloaded Misaligned/Loose Part". The frequency spectrum of this pattern is shown in Fig.5. After this, unidentified faulty motors were taken and their patterns were compared with the saved patterns. Those matched with the saved patterns were displayed in LCD by their names while those not saved in the microcontroller were displayed as "Unknown Fault". The next step was to find that what type of fault was this. When the nature of fault is detected by the experts, then its frequency will be saved by its name. In this way patterns of almost all types of faults can be saved.

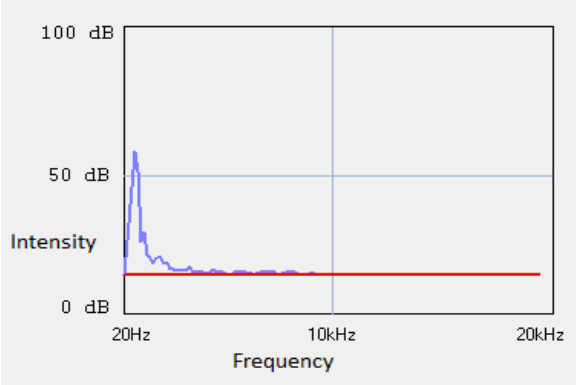

Figure2. Frequency Spectrum of Healthy Motor

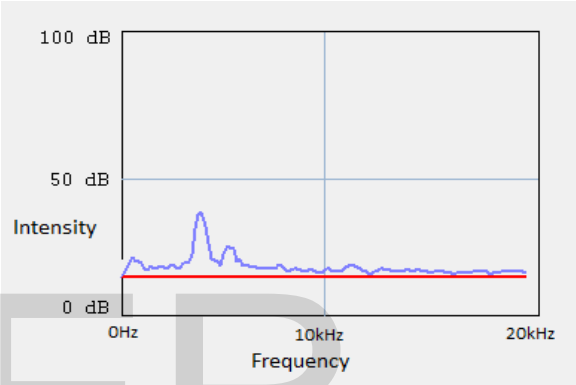

Figure3. Frequency Spectrum of Overloaded Healthy Motor

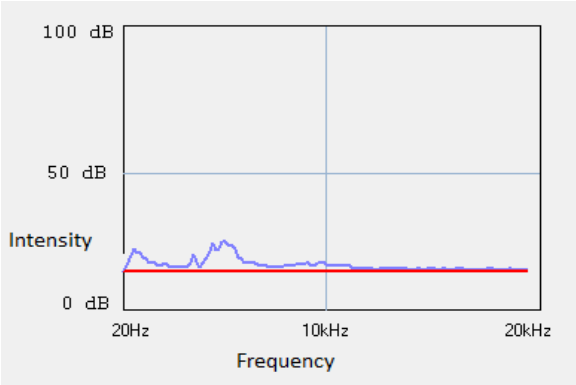

Figure4. Frequency Spectrum of Misaligned/Loose Motor

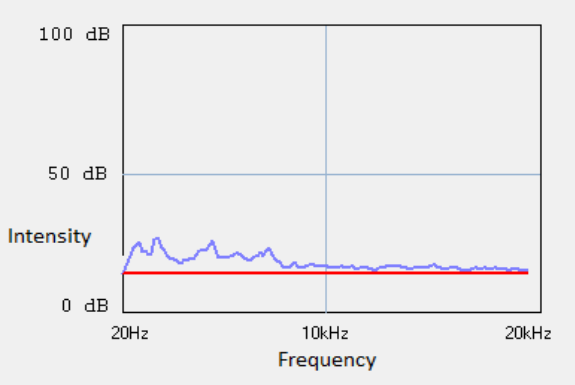

Figure5. Frequency Spectrum of Overloaded Misaligned/Loose Motor

5. EXPERIMENTAL RESULTS DISCUSSION

The frequency spectrum of the Healthy Motor shown in Fig.2 illustrates that the maximum intensity (60 db) occurs at the range of 20 Hz to 1 kHz. After this range, the intensity is almost uniform (20 db) up to the end i.e. 20 kHz. Spectrums comparison of Healthy and Overloaded motor shown in Fig.6, shows that the key difference in the intensity of their frequencies were observed at 6-7 kHz. Overall pattern's frequency was similar to that normal part's frequency. The difference observed is due to load factor. If load is varied then variations can be observed at other points too.

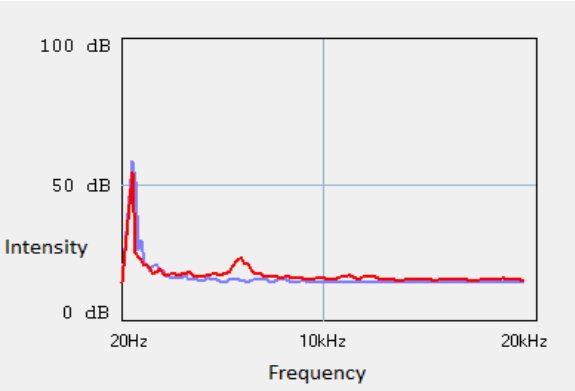

Figure6. Comparison of Healthy and Overloaded Motor's Frequency Spectrums

The frequency spectrum of the Misaligned/Loose motor was almost irregular which was completely different from the Healthy motor's spectrum as shown in Fig.7. The prominent variance in intensities was observed at the range of 20 Hz to 1 kHz range and 4 kHz to 6 kHz range. Similarly, the frequency spectrum of the Misaligned/Loose motor was completely different from the Healthy motor's frequency spectrum as shown in Fig.8. However, the noticeable difference in intensities was observed at the range of 20 Hz to 6 kHz. Here, if load is varied then differences can also occur at other points.

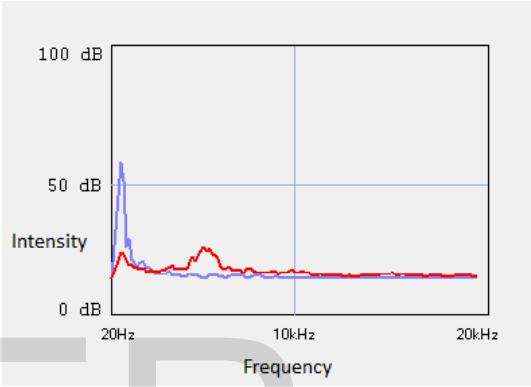

Figure7. Comparison of Healthy and Loose/Misaligned Motor's Frequency Spectrums

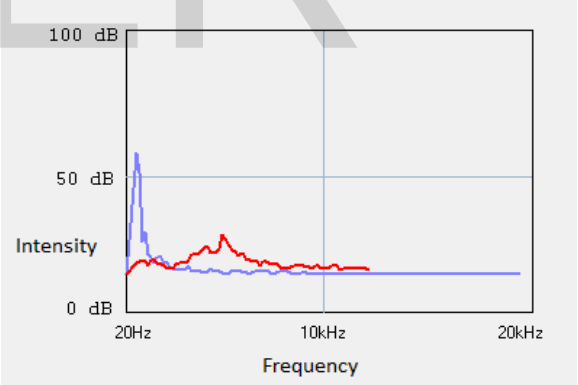

Figure8. Comparison of Healthy and Overloaded Loose/Misaligned Motor's Frequency Spectrums

6. CONCLUSION

In this paper, a complete approach for developing a low cost vibration analyzer for online fault detection in different rotating machines was presented. The designed analyzer was tested on different rotating

machineries which proved the anticipated result. The core component of the system was a fast processing microcontroller in which the vibration signals obtained through vibration sensor were sent and it produced its corresponding spectrum. FFT was used for calculating the frequency spectrum. Additionally, fault's name was also showed on the Alphanumeric LCD. Experimental results indicated that the vibration analyzer works accurately and it can be replicated and used in industries with a low cost.

7. REFERENCES

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