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DATA MINING APPROACH TO ASSESS CONDITION OF ROTATING MACHINE USING SOUND SIGNAL

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ABSTRACT

Retrieval of beneficial information, knowledge and development of new methods can be carried out using data mining for visualizing and analyzing the data. In the environment several kinds of data are present and can be converted into distinct patterns. In automobile, every rotating machine components emit some kind of sound signals. These signals are due to vibration or friction of the rotating machine components. The emitted sound signal contains noise as well as useful data. The useful data provides the significance information about the machine operational status and can be employed for condition assessment of a rotating machine. This paper aims to describe the condition of automobile rotating machine using data mining approach through sound signals.

Key words: *Information System, Signal Processing, Data mining, MCI*

1. INTRODUCTION

The information systems play an imperative role in our daily life and development of varieties of business sectors. The application of information systems can be identify as a huge umbrella which covers plenty of research areas. One of the application areas is production and trouble shooting of a machine. The machine is the single most defining entity of the modern era. Its role at the turn of the twentieth century was a central one, which led to its application in almost all fields of human development viz invention of automobiles. An automobile is the combination of structure and complex machines. A machine is any device that uses energy to perform some activity. In common usage, it is a device having parts that perform or assist in performing any type of work. There are several types of machines most of them are rotating machines. The rotating machines have become mandatory part of all sectors of the industry. One of the biggest applications of a machine was in the form of motorized technology which became an integral part of the early automobile industry. Finally, in today's world we are very much reliant on machines. One can't imagine the life without support of machines. Any disruption in machines has affect on human life. Therefore, there is a continuing struggle to be able to keep the machines in working condition. Any breakdown or disruption in the working of these machines leads to virtual chaos conditions. The uncontrollable faults in the processes may cause considerable economical losses, degrade the quality of the process performance or even cause serious damage to human life or health and to his very existence. Condition assessment is essential for improving the reliability of machines by supporting proactive control of the primary root cause of machine failure such as misalignment, unbalance, looseness and poor lubrication. Also, it minimizes harassment, collateral machine damage during failure which reduces the machine's health. In this paper integrated techniques from several areas of research have been adapted for condition assessment information system. The condition assessment method has been proposed for automobile rotating machine using sound. Sound is a form of vibrations produced in a medium, by a vibrating object. In recent times, many investigations have been motivated by the engineering applications of vibration such as the design of a machine, engine and control systems. Almost every rotating machine components generate some kind of sound signals. These signals may be due to vibration or friction of the rotating machine components. Small level of machine vibrations are acceptable, however higher level and increasing trends of vibrations are symptoms of abnormal machine performance or existence of a fault in machine. The emitted sound

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signals also contain imperative information about the operational status of a machine and can be used in condition assessment of a rotating machine [11]. Stationary features are appropriate for machine condition assessment. The machine emits continuous acoustic signals, and condition is reflected in altered sound patterns. Hence, the changes in emitted sound signal and its parameters are very well suited for condition assessment [13].

The problem of condition assessment is of utmost importance and constitutes an imperative issue in maintenance management strategies in order to reduce the failures and their consequences. Early detection of fault can increase machinery reliability and performance, reduce consequential damage, prolong machine life and reduce spare parts inventories and breakdown maintenance. So, condition assessment has received considerable attention in recent years [5]. By performing an aural inspection, an expert human operator or technician detects the fault in a machine while the machine is in operation. In such method, on several occasion the human ear may not able to differentiate sound patterns accurately. So, to make machine-computer interaction (MCI) more natural and friendly, it would be beneficial to give computers the ability to recognize the situation in the same way as a human does [17].

Manual condition assessment process essentially involves hands on rich experience about symptomatic features. Adoption of personal diagnostic skills and previous knowledge or experience does play an important role in condition assessment. Thus there is an increasingly need to develop computerized programs, techniques or systems that would be able to do so without the disassembling the unit.

The amount of data in the world seems to be increasing continuously. It results overwhelmed. It requires devoted efforts to discover interesting exceptions from data in data mining. An exception differs from the rest of data and thus is interesting and can be a clue for further discoveries [3]. Data mining becomes our hope for elucidating the useful data. Currently, saving of data via computer is too easy that previously we would have trashed. The data may be of any type such as textual, image, video or audio. Data mining techniques can be applied to acquire the data from simulations, experiments or observations in various scientific domains. Various researchers define data mining as the process of discovering patterns in the data. This process can be automatic or semiautomatic [7]. Data mining can also be defined as the steps in the Knowledge Discovery in Database (KDD) process in which patterns are extracted from data. The extraction of patterns from the data increases opportunities and applicability in the field of scientific research. The pattern contains the information which can be useful for deriving significant results. In our study the patterns of sound have been taken into consideration.

2. CONDITION ASSESSMENT

The first document related to acoustic emission technology (AET) was reported by Balerston in 1969. Interestingly, this is probably one of the earliest applications related to condition monitoring. Since there has been increase in research of application-based studies in rotating structures. Balerston, Rogers, in 1979 utilized the sound technique for monitoring slow rotating antifriction slew bearings on cranes employed for gas production, and obtained some encouraging results compared to vibration monitoring techniques. Further, Yoshioka and Fujiwara, 1984, Hawman and Galinaitis, 1988 studied the diagnosis of defective bearings achieved through the modulation of high-frequency bursts at the outer race defects frequency by placing the receiving sensor directly onto the bearing out race. In addition, Bangoli in 1988 concluded that the sound intensity is less in case of non-defective rotating machine. In 1990 it was found by Tandon, 1990 that the peak amplitude was strongly related to recognize defects. Identification of defects in Rotating bearing on various sized bearings and rotational speeds ranging from 500 to 1500 rpm has been carried out by Choudhary and Tandon, in the year 2000. They found that counts were low for undamaged bearings and increased with increasing speed for damaged and undamaged bearings. An increase in load did not result in any significant changes in counts for both damaged and undamaged bearings. Kaewkongka, Au, 2001 studied the acoustic technique on a rotor dynamic system onto which multiple defects were seeded, including a seeded defects on one of the bearings. It has been shown that the technique offered high sensitivity, thereby allowing for discrimination of the multiple defects condition [2,4,8,9,15,16]. An essential electrical fault has been observed and detected by R. Bayer, (2008) using learning vector quantization neural network in serial wound starter motor through GUI software. Various diagnosis methods are available for condition assessment of electrical motors consists of different scientific techniques. Fault detection of electrical motors being implemented, which cannot meet all of the

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demands in fault detection [12]. Therefore there is a need to use an approach which may assess the condition of automobile rotating machine using data mining approach which has been presented in this paper. The presented condition assessment method can be applied without disassembling the machine. It reduces efforts and time required to assess the condition of rotating machine.

3. SCIENTIFIC DATA MINING TECHNIQUE

Data mining is the application of relatively novel data-driven approaches to find patterns in obtained data. The significance of data mining is to find patterns which are *not* predicted by established theories. The data mining techniques have been used to relate these unusual patterns to the operational condition of the equipment.

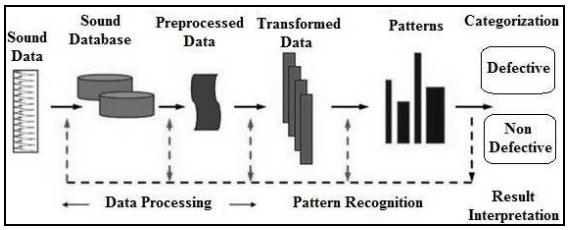

Figure 1: Adopted Scientific Data Mining approach for automobile machine health condition

Data mining provides an alternative to the traditional scientific method, where data analysis is highly developed and directed by hypothesis and theory [1, 14]. The traditional scientific data mining method has been adapted as shown in the given figure.

3.1 Data Acquisition

The study has been carried out on automobile rotating machine of passenger cars. The data acquisitions have been done from rotating machines. The proposed method adopted the signal-processing routines in information system as shown in figure 2.

The input power supply kept constant for all the rotating machines. During operation of the machine the emitted sound has been captured by the microphone using computer. Which, convert analog sound signals into digital data. The converted digital data save into the computer memory. To assess the condition of rotating machine, sound emitted by the machine has been considered. Transient is dynamic acoustic phenomena caused by friction and other events, can be detected through frequency analysis of emitted sound.

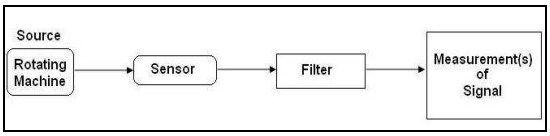

Figure 2: Principle of signal processing system

The presence of a noise in sound can make it difficult to analyze the data. This is especially true in the case of sound data if source of interest are occluded or not clearly separated from the background sound. In such cases, it may be difficult to remove noise from the sound. There are several specific domain algorithms available to reduce the noise in sound. This is because the noise in the data may be due to domain effects such as data acquisition sensor characteristics or external circumstances. Hence, the preprocessing techniques and algorithms have been applied to remove noise from the sound.

3.2 Sound Signal Analysis

The time waveform of the signal has been shown in figure 3 achieved from the developed information system. From these signals, we can compare the differences between the waveform. The waveform represents of new (a), old (b) and friction (c) of rotating machine. The friction occurs due to misalignment.

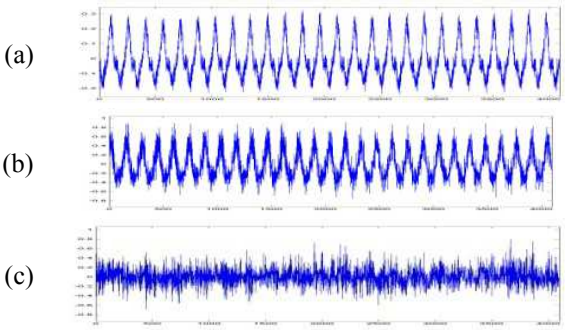

Figure 3: Sound Signal (a) New (b) Old (c) Friction

The signals are approximate sinusoidal waves with frequency of rotation speed. The sound characteristics of faulty rotating machine (old and friction) are sinusoidal with number of cycles per revolution. The signal also gives some indication of variations of machine behavior but it does not help much in condition assessment of a machine.

3.3 Transformation

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The components of this information system have various phases such as acquisition, quantization, coding, and preprocessing and feature extraction. The features can be extracted using frequency analysis. This method is most common and prominent to analyze the sound data. At first, transient part, DC offset and silence parts have been eliminated from the signal. Further, the data was normalized to zero-mean amplitude, then the system separate the whole data into various adjacent blocked into frames, each frame kept (X_n, ; where n=1,2..N) sequentially with an overlap between adjacent frames [6].

$$\omega_i = 0.54 - 0.46\ Cos\left(2\pi \frac{i}{N}\right) \quad ..(1)$$

$$x'_{ni} = x_{ni}\,\omega_i \quad i = 0,1,2 \ldots\ldots\ N-1$$

Each complete set of samples (X_n) considered in one frame, a pre-processing smoothing filter, the hamming window is used in subsequent Fast Fourier analysis. The cepstrum of a time domain signal is the Inverse Fourier Transform of the log-magnitude spectrum of the signal. The log-magnitude spectrum of a real signal is a real and even function, thus the cepstrum is normally computed via Discrete Cosine Transform which is equivalent with the Fourier transform in case of even functions.

A standard FFT algorithm is applied to each preprocessed frame.

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} nk} \quad .....(2)$$

$$k = 0,\ldots\ldots\ \ldots,\ N-1$$

The output/result component from the described information system is shown in figure 4 which is a set of 2000 FFT coefficients. These windows can be received through the system.

4. RESULTS

To achieve the desired results, FFT technique was used which is the most admired and reliable techniques in signal processing system.

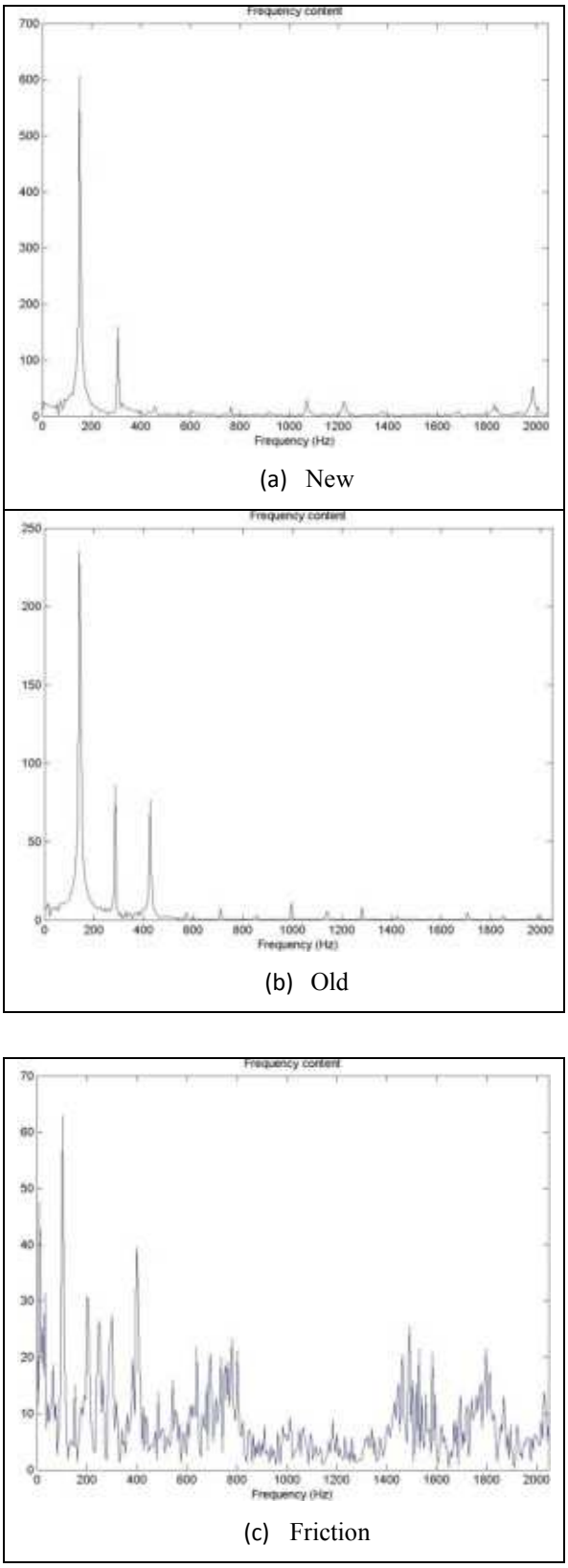

Figure 4: FFT for different condition

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The results of the sound analysis are described in this section. It illustrates the FFT plot for good condition/non- defective and bad condition/defective automobile rotating machine. Following figure represents the FFT of different conditions. The FFT of new rotating machine depicts smooth plot whereas for old, high frequencies are absent.

Table 1: FFT Observation

Machine condition	Amplitude Max (dB)	Spectral Mean (Hz)
New	600	440
Old	230	624
Friction	64	1059

Due to misalignment the output of such analysis received high level of noise characteristic frequencies which is one of the useful and valuable parameter for finding the health of condition assessment of automobile rotating machine, whereas for weak condition/old machine sound has missing frequencies compare to the new machine.

The RMS value of dB and frequency also been studied in this research but it doesn't have direct relation with performance of rotating machine.
The FFT observation table depicts the spectral mean values. These values are significant in identifying the defective non defective machine. The increase in spectral mean values is indication of initialization or occurrence of minor decay and defect in the machine.

5. CONCLUSION

In this paper, a non-destructive condition assessment approach has been proposed for automobile rotating machine using data mining technique through frequency domain analysis on acoustic signals. The useful information has been extracted using of the sound signals using data mining techniques. The extracted features are sensitive to condition assessment of rotating machine.

The salient feature of the study is as follows:

- The proposed information system can be used in condition assessment for automobile rotating machine without dissembling the unit.
- The proposed system is effective, compact, convenient, portable and economical. It has got real promising application. It can also be used in machine manufacturing plants for testing purpose for enhancing quality and reliability.
- It provides the benchmarking towards the condition of rotating machine.

Real test has been given to evaluate the proposed system performance. Three motors with different conditions have been presented as a test case. The results obtained by frequency analysis are in agreement with the results with the manual analysis. The major limitation of this study is the existence of noise in environment. The study can be revealed the appropriate results if and only if absences of noise exist but in this case the selection of filter becomes utmost importance.

REFRENCES:

[1] A MOHRAIN, 2003, "Bearing Defect diagnosis and acoustic emission", *Institution of Mechanical Engineering, Journal of Engineering Tribology, Sage Publications* Vol. 217, No. 4, 257-272.

[2] AL-GHAMD, ABDULLAH. M, M. DAVID, 2006, "A Comparative experimental study on the use of acoustic emission and vibration analysis for bearing defect identification and estimation of defect size", *Mechanical systems and signal processing,* Vol 20, Issue 7, 1537-1571.

[3] EINOSHIN SUZUKI, 2006, "Data Mining Methods for Discovering Interesting Exceptions from an Unsupervised Table", *Journal of Universal Computer Science*, vol. 12, No. 6, 627-653.

[4] H. L. BALERSTON, 1969, "The Detection of Incipient Failure in Bearings", *Materials Evaluation*, Vol. 27, 121–128.

[5] H. TIAN, Y. BO-SUK, Y. ZHONG-JUN, 2007, "Feature-based fault diagnosis system of induction motors using vibration signal", *Journal of Quality and maintenance engineering*, vol. 13 No 2, 163-175 .

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[6] H. WU, M. SIEGEL, P. KHOSLA, 1999, "Vehicle sound signature recognition by frequency vector principal component analysis", *IEEE transactions on instrumentation and measurement*, vol. 48, No. 5.

[7] IAN H. WITTEN, EIBE FRANK, 2011 "Data Mining, Practical machine learning tools and techniques", 2nd Edition, *Elsevier Publications*, ISBN 13- 978-0123748560.

[8] L. M. ROGERS, 1979, "The Application of Vibration Analysis and Acoustic Emission Source Location to On-line Condition Monitoring of Anti-friction Bearings", *Tribology International*, Vol. 12, No. 2, 51–59.

[9] M. W. HAWMAN, W. S. GALINAITIS, 1988, "Acoustic Emission Monitoring of Rolling Element Bearings," *Proceedings of the IEEE Ultrasonics Symposium*, Chicago, IL, USA, 885–889.

[10] MOHAMMED AREF, 2012, "Detection of fault in Automobile rotating machine through computer sound acquisition system", International *Journal of Advances in Management, Technology & Engineering Sciences,* Vol. II, Issue 2-III, 158-162.

[11] MOHAMMED AREF, S. C. MEHROTRA, 2010, "Fault Detection in Automobile Rotating Machine using Sound Features" *International conference on Applied Mechanics, Material and Manufacturing (ICAMMM)* Muscat, Sultanate of Oman, December 13-15, ISSN 2220-3508.

[12] R. BAYER, 2008, "Condition monitoring and fault diagnosis of a serial wound starter motor with learning vector quantization network", *Journal of applied Sciences* 8(18):3148-3156.

[13] R. ISERMANN, 1993, Automatica ISSN 0005 - 098 *CODEN ATCAA9* , vol. 29, No. 4, pp. 815-835 (1 p.), Elsevier, oxford, ROYAUME-UNI.

[14] S. BAGNOLI, R. CAPITANI, P. CITTI, 1988, "Comparison of Accelerometer and Acoustic Emission Signals as Diagnostic Tools in Assessing Bearing," *Proceedings of the 2nd International Conference on Condition Monitoring,* London, UK, May, 117–125.

[15] T. KAEWKONGKA, Y. H. J. AU, 2001, "Application of Acoustic Emission to Condition Monitoring of Rolling Element Bearings," *Measurement and Control*, Vol. 34, No. 8, 254–247.

[16] T. YOSHIOKA, T. FUJIWARA, 1984, "Application of Acoustic Emission Technique to Detection of Rolling Bearing Failure," *American Society of Mechanical Engineers, Production Engineering Division Publication,* Vol. 14, 55–76.

[17] Y. WANG, L. GUAN, 2008 "Recognizing Human Emotional State from Audiovisual Signals" , *IEEE transactions on multimedia*, vol. 10, No. 4, pp 659-668.