An Extensive Review on the Use of Acoustic Emission Technique for Continuous Monitoring

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Abstract –
Modern society is characterized by an increasing attention for the environmental impact of newly developed machinery. Due to the interaction between humans and machines, vibration cause serious damage to the human health. Hence, it needs to be eradicated with proper controlling techniques. One of the environmental criteria gaining importance is the noise emission level produced by a new machine since the legal regulations more and more restrict the allowable noise levels. Acoustic emission monitoring refers to the detection of transient waves during the rapid release of energy from localized sources within a material. In this paper we have review the use of acoustic emission to find the fault localization and Structural Integrity Monitoring.

Key Words: *Acoustic Emission, Condition monitoring, Fault detection, Vibration control.*

1.INTRODUCTION

Rolling element bearing condition monitoring has received considerable attention for many years because the majority of problems in rotating machines are caused by faulty bearings. The acoustic emission (AE) method has attracted attention as a monitoring method for the friction and wear processes, as well as the lubricating conditions. If the lubricating grease in a rolling bearing contains contaminants, which may indicate inadequate or damaged sealing of the bearing housing. As a consequence of their importance and widespread use, bearing failure has become one of the foremost causes of breakdown in rotating machinery.
Modern society is characterized by an increasing attention for the environmental impact of newly developed machinery. One of the environmental criteria that are gaining importance is the noise emission level produced by a new machine since the legal regulations more and more restrict the allowable noise levels. Acoustic emission monitoring refers to the detection of transient waves during the rapid release of energy from localized sources within a material. This in-service test technique explores damage due to corrosion.

2. RELATED WORK

In 2009, Ziaur Rahman *et al*.[1] have described the acoustic emission (AE) technique it was applied to rolling contact fatigue tests. The test-rig was running under constant load and speed for detecting the incipient damage and damage location. The proposed technique incipiently-damaged roller was investigated in detail and monitored by further running to determine the damage severity and to understand the surface damage propagation process by applying the AE techniques. The conventional AE parameters and AE signal features were studied, and their relation with the AE source locator hit count rate were correlated. The results demonstrated the successful use of the AE measurement unit, which was principally, consists of the AE data analyzer and the AE source locator as a new system for detecting incipient damage produced by fatigue. Moreover, the system is able to forecast the position of the damage in the roller, capable of providing an indication of the severity of damage i.e. damage size, and thus it could allow the user to monitor the rate of further degradation of the rolling elements.
In 2010, Elforjani and Mba [2] have described the rolling element bearings are the most common cause of rotating machinery failure. Over the past 20 years, Acoustic Emission (AE) technology has evolved as a significant opportunity to monitor and diagnose the mechanical integrity of rolling element bearings. The proposed technique presents results of an investigation to assess the potential of the Acoustic Emission (AE) technology for detecting and locating natural defects in rolling element bearings. To undertake the proposed task a special purpose test-rig was built that allowed for accelerated natural degradation of a bearing race. It was concluded that sub-surface initiation and subsequent crack propagation can be detected using a range of data analysis techniques on AE's generated from natural degrading bearings. The proposed technique also investigates the source characterization of AE signals associated with a defective bearing whilst in operation. The proposed also attempted to identify the size of a natural defect on bearings using AE technology.

In 2012, Lakshmikanth *et al*.[3] have a detailed study on mechanics of vibration and acoustic noise in Permanent Magnet Synchronous Motors (PMSM) due to electromagnetic origins was presented. The proposed works reviews the various noise and vibrations reduction strategies from classical to state of art techniques. The recent research in development of wavelet controller, starting from brief review and the analytical analysis of acoustic noise and vibrations in Permanent magnet synchronous motor was presented. Application of wavelet transforms in the area of de-noising and filtering was explored.

Cyclostationarity was a relatively new technique that offers diagnostic advantages for analysis of vibrations from defective bearings. Similarly the Acoustic Emission (AE) technology has emerged as a viable tool for preventive maintenance of rotating machines. In 2011, Kilundu et al. [4] have presented an experimental study that characterizes the cyclo stationary aspect of Acoustic Emission signals recorded from a defective bearing. The cyclic spectral correlation, a tool dedicated to evidence the presence of cyclostationarity, was compared with a traditional technique, the envelope spectrum. The proposed technique comparison showed that the cyclic spectral correlation was most efficient for small defect identification on outer race defects though the success was not mirrored on inner race defects. An indicator, based on the proposed cyclostationary technique, has also been proposed. It was concluded that its offers better sensitivity to the continuous monitoring of defects compared to the use of traditional temporal indicators (RMS, Kurtosis, and Crest Factor).

In 2006, Abdullah M. Al-Ghamd *et al*. [5] have proposed the vibration monitoring of rolling element bearings was probably the most established diagnostic technique for rotating machinery. The application of acoustic emission (AE) for bearing diagnosis was gaining ground as a complementary diagnostic tool; however, limitations in the successful application of the AE technique have been partly due to the difficulty in processing, interpreting and classifying the acquired data. Furthermore, the extent of bearing damage has eluded the diagnostician. The experimental investigation reported in the proposed work centered on the application of the AE technique for identifying the presence and size of a defect on a radically loaded bearing. An experimental test rig was designed such that defects of varying sizes could be seeded onto the outer race of a test bearing. Comparisons between AE and vibration analysis over a range of speed and load conditions are presented. In addition, the primary source of AE activity from seeded defects is investigated. It was concluded that AE offers earlier fault detect ion and improved identification capabilities than vibration analysis. Furthermore, the AE technique also provided an indication of the defect size, allowing the user to monitor the rate of degradation on the bearing; unachievable with vibration analysis.

In 2007, Chee Keong Tan et al. 6] have proposed the technique on prognosis of gear life using the acoustic emission (AE) technique was relatively new in condition monitoring of rotating machinery. The proposed technique describes an experimental investigation on spur gears in which natural pitting was allowed to occur. Throughout the test period, AE, vibration and spectrometric oil samples were monitored continuously in order to correlate and compare these techniques to natural life degradation of the gears. It was observed that based on the analysis of root mean square (rms) levels only the AE technique was more sensitive in detecting and monitoring pitting than either the vibration or spectrometric oil analysis (SOA) techniques. It was concluded that as AE exhibited a direct relationship with pitting progression, it offers the opportunity for prognosis.

In 2008, N. Sawalhi *et al*. [7] have presented a combined dynamic model for gears and bearings, in which an extended fault in the inner/outer race of rolling element bearings can be studied in the presence of gear interaction. A combined gear/bearing model has been made to obtain a better understanding of the interaction of the two components. The essentials of the gear/bearing model and the results of simulating the vibration of localized faults in rolling element bearings in a gearbox environment have been discussed and illustrated in the first part of this paper (part I). The simulation model has now been modified to model extended faults of the type that do not necessarily produce high frequency impact responses, but do modulate the gear mesh signals. The proposed techniques compares the simulated and actual signals from the gear/bearing test rig for inner and outer race extended faults, and in particular demonstrates that they react similarly to existing diagnostic techniques.

In 2009, Saad Al-Dossary *et al*. [8] have discussed the investigation reported in centered on the application of the acoustic emissions (AE) technology for characterizing the defect sizes on a radically loaded bearing. An experimental test-rig was designed such that defects of varying sizes could be seeded onto the outer and inner races of a test bearing. The aim of the proposed investigation was to correlate defect size with specific AE parameters and to ascertain the relationship between the duration of AE transient bursts associated with seeded defects to the actual geometric size of the defect. In addition, the use of AE to detect inner race defects was explored particularly as the known to be fraught with difficulty. It was concluded that the geometric defect size of outer race defects can be determined from the AE waveform.

In 2009, Babak Eftekharnejad *et al*. [9] have proposed the Acoustic emission (AE) is one of many technologies for health monitoring and diagnosis of rotating machines such as gearboxes. Although significant research has been undertaken in understanding the potential of AE in monitoring gearboxes the proposed technique has been solely applied to spur gears. The proposed report presents an experimental investigation that assesses the effectiveness of AE in identifying seeded defects on helical gears; the first known attempt. Additionally vibration analysis has performed to study the effect of seeded defect on the vibration signature of the meshing gears.

In 2010, Khamis R. Al-Balushi *et al*. [10] have described that the application of Acoustic Emission (AE) technique to condition monitoring of gears and bearings was gaining significance as it can detect early symptoms of defects such as pitting, wear and flaking of surfaces. Such early detection of defects is of vital importance so as to avoid major failures with catastrophic consequences. The proposed article presents results on the Energy Index (EI) technique, used in detecting masked AE signatures associated with the loss of mechanical integrity in bearings. Both simulated and real experimentally generated AE signatures were used to investigate the efficiency and applicability of the technique at signal-to-noise ratios as low as 0.25. In conclusion it was shown that the EI technique was effective in detecting AE burst buried in random noise thereby offering a complementary tool for the diagnostician.

The challenge in many production activities involving large mechanical devices like power transmissions consists in reducing the machine downtime, in managing repairs and in improving operating time. In 2010, Renaudin et al. [11] have proposed an alternative way of bearing condition monitoring based on the instantaneous angular speed measurement. By the help of a large experimental investigation on two different applications, they prove that localized faults like pitting in bearing generate small angular speed fluctuations which are measurable with optical or magnetic encoders. They also emphasize the benefits of measuring instantaneous angular speed with the pulse timing method through an implicit angular sampling which ensures insensitivity to speed fluctuation. A wide range of operating conditions have been tested for the two applications with varying speed, load, external excitations, gear ratio, etc. The tests performed on an automotive gearbox or on actual operating vehicle wheels also establish the robustness of the proposed methodology. Sideband effects are evidently seen when the fault was located on rotating parts of the bearing due to load modulation.

In 2011, Eftekharnejad *et al*. [12] have described the application of Acoustic Emission (AE) technology for machine health monitoring is gaining ground as power tool for health diagnostic of rolling element bearing. The proposed technique provides an investigation that compares the applicability of AE and vibration technologies in monitoring a naturally degraded roller bearing. The proposed research was the first known attempt investigating the comparative effectiveness of applying the Kurtogram to both vibration and AE data from a defective bearing.

Acoustic emission (AE) monitoring of engineering structures potentially provides a convenient, cost-effective means of performing structural health monitoring. Use of the technique is not widespread due to the lack of a simple and effective method for detecting abnormal activity levels: the sensitivity of AE sensor networks is such that events unrelated to damage are prevalent in most applications. In 2011, James Hensman *et al*.[13] have propose the monitor AE activity in a structure using a spatial scanning statistic, developed and used effectively in the field of epidemiology. The technique was demonstrated on an aerospace structure – an Airbus A320 main landing gear fitting – undergoing fatigue loading, and the method is compared to existing techniques. Despite its simplicity, the scanning statistic proves to be an extremely effective tool in detecting the onset of damage in the structure: it requires little to no user intervention or expertise was inexpensive to compute and has an easily interpretable output. Furthermore, the generic nature of the method allows the technique to be used in a variety of monitoring scenarios, to detect damage in a wide range of structures.

In 2012, Hamdi Taplak *et al*. [14] have discussed that the Rotating machinery was becoming faster and lightweight due to the advanced technologies made in engineering and materials sciences. The proposed technique was required them to run for longer periods of time. All of these factors mean that the detection, location and analysis of faults play a vital role in highly reliable operations. Using vibration analysis, the condition of a machine could periodically monitor. The proposed study, dynamic behavior of a direct coupled rotor-bearing system was investigated. Experimental vibration analyses in the vertical direction of the system are implemented. Vibration monitoring with trend analysis and spectrum graphs are employed to diagnose the excessive vibration source(s). It was seen that the rotating machineries can have one or more vibration sources. The vibration values obtained from each bearing show that the main excessive vibration sources in the system stem from mechanical looseness and misalignment.

In 2011, Amit R. Bhende *et al*.[15] have described that the dynamic performance of bearing was highly influential on performance of any machine. More specifically, the presence of bearing defects often results in reduced efficiency, or even severe damage of the machine under Consideration. Rolling element bearing find widespread domestic and industrial application. Different methods are used for detection and diagnosis of the bearing defects. The proposed technique was intended as a tutorial overview of bearing fault detection using vibration signal analysis. It reviews complete working of the condition monitoring system. Various signal collecting transducers, selection of transducers according to the applications are discussed. The signal processing techniques that are being used for the analysis are also discussed.

Ball bearings are among the most important and frequently encountered components in the vast majority of rotating machines, their carrying capacity and reliability being prominent for the overall machine performance. Fault detection and diagnosis in the early stages of damage was necessary to prevent their malfunctioning and failure during operation. In 2011, Manish Yadav *et al.* [16] has presented the fault detection of ball bearing using time domain features of vibration signals. The vibration signals are recorded at bearing housing of 5hp squirrel cage induction motor. These extracted features are used to train and test the neural network for four bearing conditions namely: Healthy, defective Outer race, defective Inner race and defective ball fault condition. The experimental observation shows that the proposed method was to detect the faulty condition with high accuracy.

3. CONCLUSION

In this review paper, an extensive technique work base on acoustic emission and vibration are reviewed thoroughly. Because the physical process of acoustic emission occurs in a wide variety of materials and under a large range of loading conditions, the technique offers great potential for use as a continuous monitoring technique. Due to its inherent advantages as compared to other techniques, it should always be considered when continuous detection is required. Thus, this review paves the path for the budding researchers to be acquainted with various techniques existing in this field.

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