International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 01, January-2017

# Crack Detection on Rotating Shaft with Acoustic Emission Technique

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***Abstract*— Acoustic emission technique is one technique that utilizes condition monitoring engine during operation. The purpose of this study was to detect crack that occurs on a rotating shaft with Acoustic Emission technique that was placed at a certain distance. The model test consists of one unit of the electric motor as a driving source that connected to rotating shaft with a clutch. The test shaft supported by two ball bearings and the end of the shaft be assembled radial load that serves to replace the bending and torsion load. The test shaft is made in three conditions : the shaft without crack, depth crack of the shaft 25% and 50%. Shaft speeds for the tests varied from 500 to 1000 RPM. The results showed that the acoustic sensor capable of capturing high-amplitude acoustic signals. This capability is different from the accelerometers to determine the amplitude spectrum from high to low frequencies. Based on the measurements recorded, it can be concluded that the more badly cracked, the higher the amplitude and also, the greater the shaft speed, the higher the amplitude.**

***Keywords : Acoustic Emission; Condition Monitoring; Rotating Shaft; Crack***

## I. INTRODUCTION

Crack is one of the phenomena of fatigue failure. Early crack and crack growth in machine elements caused by repeated load for a long time. Rotating shaft as part of the transmission system in the machine given torsional load, tensile stress and plastic strain. If the rotating shaft is given repeated torque loads within a certain period, it can cause the plastic strain in stress concentration area. Plastic strain can be triggered via crack initiation and addition of tensile stress may accelerate the initial crack to the crack growth propagation and occurrence of failure. The presence of cracks in the rotating shaft significantly affects the dynamic response. Cracking occurs slowly but significant effect for the efficiency of the operating system. Cracks reduce the rigidity of the system and a shift to low speed resonance. This effect is magnified by depth of crack (Sawicki et al., 2003). Based on the geometry, the crack can be classified as a transverse crack and investigate effects transverse cracking (Sinou & Lees, 2005). AE technique used to monitoring condition of structural steel (Robert & Talebzadeh, 2003; Skorupa et al., 2005).

Changes of vibration can be used to predict and / or detecting a crack in a rotating shaft (Singh R., 2011; Tlaisi et al., 2011; Mohamed et al., 2011). Some researchers also have been used AE technique to monitoring condition of rotating machinery low speed (Holroyd, 2001), detect initiation crack and propagation at rotating shaft ( Elforjani & Mba, 2009), detect fatigue cracks at gearbox spline component (Ozevin et al., 2014). The ability of AE technique to detect early crack also increasingly developed (He et al, 2012, Roberth et al, 2003 ; Andreykiv et al., 2001; Yu et al., 2011; Antonaci et al., 2012; Rahman et al., 2009). In addition there are AE technique combination with other techniques that used as a comparison in terms of determining, identifying, predicting the failure of a mechanical system, such as spectrometry analysis of oil (Tan et al., 2007), monitor on-line oil debris (Loutas et al., 2011) and vibration analysis techniques (Lu & Chu, 2011). All of these techniques are then compared to the weaknesses, advantages and certain limitations of each measurement technique considered in more detail.

In this study, acoustic emission is defined as a temporary elastic waves emitted by a crack that occurs in the rotating shaft. Commonly, the AE sensor placement on a rotating machinery where the AE sensor attached to non-rotating part of the machine, such as at pinion gear and gearbox casing (Eftekharnejad et al., 2012). This study uses AE sensor in the form of a microphone placed at a certain distance from the axis of the test. This method is expected to minimize distortion poorly in testing and can also measure the rotating machine parts that can not be measured by the accelerometer.

## II. EXPERIMENT

Tests carried out on the test model. The scheme of experiment in this study is presented in Figure. 1. As shown in Figure. 1, the system consists of single microphone, analog-to-digital converter (ADC) and an electric motor as a prime mover or engine with radial shaft coupled to radial mass. The test model is connected to the inverter as a regulator of shaft speed. This inverter is equipped with the up and down buttons to adjust the shaft rotation frequency in Hz units. Shaft speed is set at a frequency of 8.33 Hz, 10 Hz, 11.67 Hz, 13.33 Hz, 15 Hz and 16.67 Hz equivalent to 500 rpm, 600 rpm, 700 rpm, 800 rpm, 900 rpm and 1000 rpm. Model tests are designed as hard as possible and cut the shaft is one way to simulate and initialize a crack at the test shaft.

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The test shafts consists of three shafts with depth crack of the different conditions, namely: uncracked shaft (0% of the diameter shaft), cracked shaft 0.25D (25% of the diameter shaft) and cracked shaft 0.5D (50% of the diameter shaft).

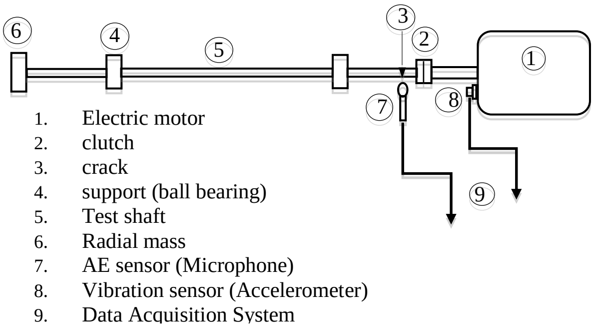


Fig.1. Scheme of Experiment

The length of shaft is 800 mm with 140 mm diameter. AE sensor used is a microphone cardiod. Behringer XM Microphone Type 1800 is connected to the M-Audio Fast Track Ultra and Adobe Audition Program. In Adobe Audition recording settings equipped with function buttons, such as play, record, pause. The parameters specified in the program Adobe Audition is recording duration for 5 seconds with sampling rate of 44100 Hz. Microphones as acoustic sensor placed at a distance of 20 mm from the location of the crack as shown in Figure 2. While the accelerometer attached at the end of the electric motor on axial direction. Accelerometer models PCB 352C33 connected with Lab View-NI program is also equipped with a function key. Parameters are set in Lab View program-Ni is a measurement of the duration of 5 seconds, g = 32.3 ft / s.

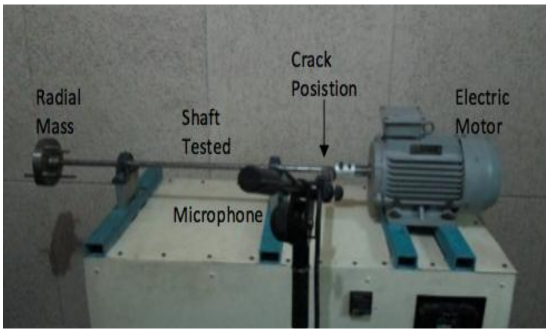


Fig. 2. Experiment Set Up

The main purpose of the vibration measuremnet simultaneously with AE measurement is to compare of the measurements result. During this time, the vibration sensor such as an accelerometer has ability to detect failures in the form of cracked shafts where accelerometer placement only on the part does not rotate. What distinguishes the use of AE sensors in this research is detect a crack on rotating shaft with AE sensor placement is not direct contact with the rotating shaft. So the AE sensor is not attached to the casing of the electric motor as long as this is done by attaching an accelerometer on non rotating parts. Microphone as the AE sensor is placed at a certain distance and directed to the location of cracks on the test shaft while rotating. It can not be done by accelerometer.

## III. RESULTS AND DISCUSSION

Retrieval of data, in this case the baseline signal recording made on three conditions that the uncrack shaft, cracked shaft 0.25D and 0.5D. Baseline signal recording process carried out simultaneously as shown in Figure 3. The variables that changes is the depth of the crack and shaft speed. In this study, acoustic and vibration measurements were first made on the uncrack shaft . It is intended to obtain reference data. In this section shows the acoustic emission and vibration FFT each shaft rotates at a speed of 1000 rpm. In Figure 3 to Figure 5 plotted graph can be observed in the form of a line (lvm) is the spectrum signals based on vibration measurements while the graphic in form of a dash with dot line (wav) is to plot graphs using acoustic emission measurements. The magnitude of the vibration method using the unit g (32.3 ft / s2) and acoustic emissions using the unit mV. In the method of vibration, a review is done on the axial direction because the position closest distance to the crack position. There are three reviews conducted in this case.

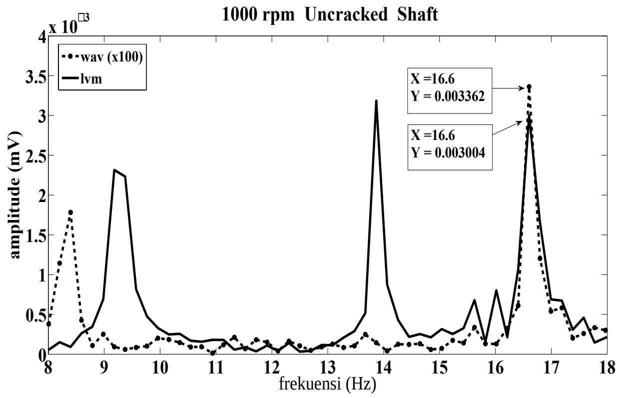


Fig. 3. Spectrum signal of vibration (lvm) and acoustic emission (wav) on the uncracked shaft

The first review, plot a graph based on the measurement of vibration and acoustic emissions showed the highest signal amplitude at a frequency of 16.6 Hz in every condition of the shaft. The frequency of 16.6 Hz amplitude is almost equal to the frequency generated by the electric motor 16.67 Hz / 1000 rpm as shown in Figure 3, 4 and 5. The results of similarity amplitude vibration and acoustic emission measurements indicate that the resulting vibration will cause sound changes (emissions acoustic). However, there is also a plot on a graph the spectrum of the vibration signal is raised beyond that which is at frequency of 9.18 Hz and 13.87 Hz. From the figures, it appears that the emergence of vibration spectrum on each shaft condition have the same pattern. There are three visible spectrum vibration signal clearly and at the same frequency. Likewise visible in the spectrum of an acoustic signal.

The second review carried out on plot graph showing changes in amplitude at each shaft condition. The amplitude of vibration measurements on uncracked shaft, cracked shaft 0.25D and cracked shaft 0.5D at 1000 rpm, respectively 0.003004, 0.003073, 0.003742, while the amplitude of acoustic emissions respectively, 0.003362, 0.003544, 0.004584. These results indicate that an additional depth of crack on the shaft will cause increasing amplitude.

The third review is acoustic emission and vibration signal increase shaft speed. This testing phase is done by following the previous tests on the cracked shaft with shaft speed varied. In Figure 6 and 7 shows the basic FFT signal acoustic emission and vibration with varying shaft speed. The magnitude of the signal of vibration and acoustic emission measurement shown in Table 1. This shows that amplitude changes at each increasing shaft speed resulting in an increase in the value of the signal of amplitude. It can be conclude that the rpm value is directly proportional to the increase in signal of amplitude.

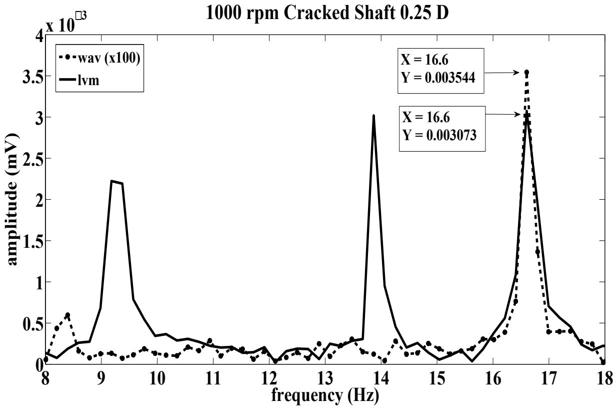


Fig. 4. Spectrum signal of vibration (lvm) and acoustic emission (wav) on the cracked shaft 0.25D

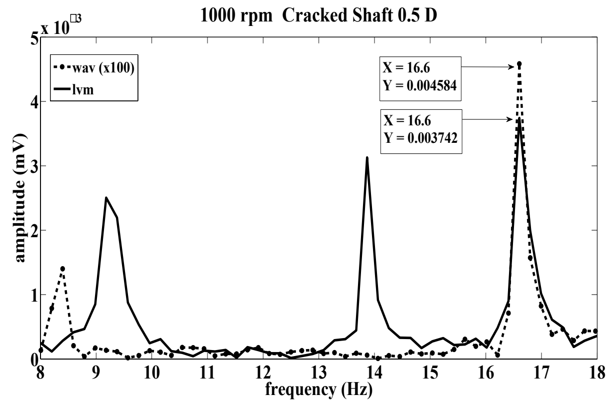


Fig. 5. Spectrum signal of vibration (lvm) and acoustic emission (wav) on the cracked shaft 0.5D

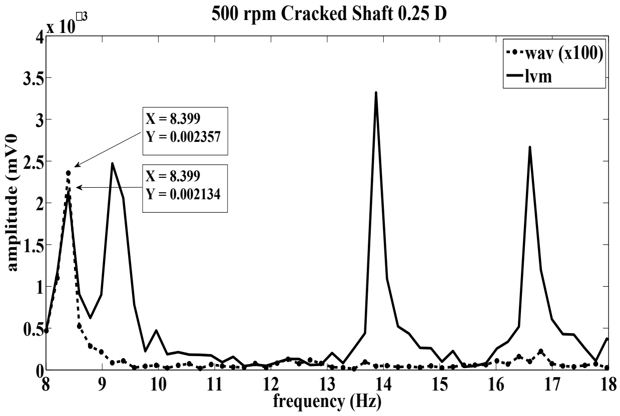


Fig. 6. FFT spectrum signal of vibration (lvm) and acoustic emission (wav) signal at 500 rpm / 8.33 Hz on The Cracked Shaft 0.25D

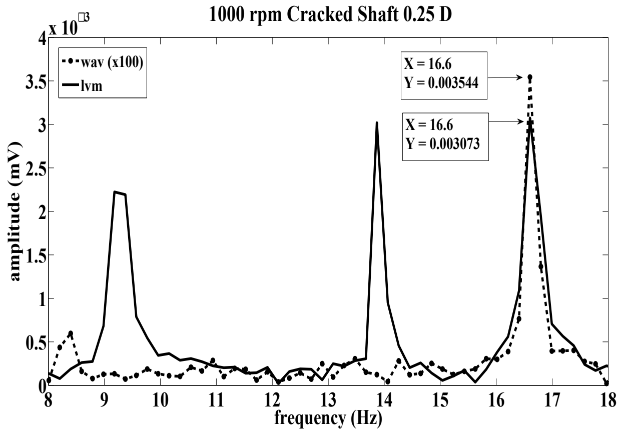


Fig. 7. FFT spectrum signal of vibration (lvm) and acoustic emission (wav) at 1000 rpm (10 Hz) on The Cracked Shaft 0.25D

Table 1 Magnitude of vibration and acoustic measurement on Cracked Shaft 0.25D

| Rotation of Shaft (rpm) | Frequency (Hz) | Magnitude | |
|---|---|---|---|
| | | vibration | acoustic |
| 500 | 8.33 | 0.002358 | 0.002357 |
| 600 | 10 | 0.002843 | 0.002733 |
| 700 | 11.67 | 0.002633 | 0.002865 |
| 800 | 13.33 | 0.003057 | 0.003132 |
| 900 | 15 | 0.003199 | 0.003069 |
| 1000 | 16.67 | 0.003073 | 0.003544 |

## IV. CONCLUSSION

Acoustic emission measurement technique with a single microphone at a certain distance has been done and is able to measure acoustic emissions from crack on a rotating shaft. Changes in crack depth and speed of the shaft significant impact test to changes in amplitude. The test results concluded that the increase in crack depth and speed of the shaft will cause an increase in the signal amplitude. Acoustic emission measurements validated by measuring the vibration has a value approach one another.

## ACKNOWLEDGMENT

Thanks to Dr. Dhany Arifianto as head of The Engineering and Building Physics Laboratory of ITS whisch has given permission to the aothor to use tke lab for all research activities.

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