Baseline Signal of Crack Shaft Propeller With Acoustic Emission Technique

Novitha L. Th. THENU[1)], I Made ARIANA [2)], Achmad ZUBAYDI [3)], Dhany ARIFIANTO [4)]

1) Marine Engineering, Unpatti, Indonesia
2) Marine Engineering, ITS, Indonesia
3) Naval Architecture, ITS, Indonesia
4) Physics Engineering, ITS, Indonesia

e-mail: novithathenu@gmail.com

Abstract

It is common practice to detect crack on metal using direct contact technique such as vibrometer with an accelerometer attached to the object of interest. This paper presents a technique to develop acoustical signature baselines towards early detection of shaft propeller crack using its sound emission. The system consists of a microphone, analog-to-digital converter (ADC) and an electrical rotating machine with a shaft coupled to a mass to simulate propeller. We intentionally created a transverse crack to the shaft with two different carck depth, namely 0.25D and 0.5D where D is notation of diameter. The sound data acquisition was conducted in an anechoic chamber with the rotation speed varied from 500 rpm to 1000 rpm to intensify the magnitudo of acoustical cue of the crack. We compared the results to a normal shaft for validation. The results showed that a normal shaft may have a small fraction of spectrum amplitude compared to the shaft with crack that consistent with the accelerometer-based measurement. The cue was amplified significantly as the rotation speed, in rpm, increased. These findings suggest that the acoustic emission (AE) technique may be a suitable replacement to an accelerometer-based measurement.

Keywords: AE sensor, crack, depth crack, baseline signal

1. Introduction

The present of a crack in shaft propeller affectsthe dynamic response significantly. The changes of vibrationalcan be used to predict and/or detect crack in shaft rotating [1,2]. Experience in the field, we can observe changes in vibration by listening to the sound emitted change during system operation. By relying on human hearing alone, is not sufficient to detect damage in system. Moreover,the source ofsoundin thesurroundingarea of propulsion systems is verynoisyanddifficulttofinda damage. Thus we need a technique that can detect damage or failure of machinery by exploiting the emitted sound. Technologythat utilizessoundemittedbythe systemisAcoustic Emission (AE). With AE technique, Berkovits and Fang [3] have been study to investigated fatigue crack characteristic. The threshold stress intensity ranges were determined by combining AE tests and microscopic examination for crack initiation points. The AE technique revealed the crack closure process in smooth specimens, and crack-opening/closing stress was easily determined from the AE signature. Several published formulae for crack-opening stress were examined. During crack propagation, AE count rate and total counts, associated with the crack growth state, were stress and lifetime dependent. The results showed a nonlinear relation between the AE count rate and the crack propagation rate. Robert and Talebzadeh [4] monitoring of fatigue crack propagation in steel and welded steel compact tension and T-section girder test specimens, using an advanced acoustic emission system with accurate source location. The test results indicate that acoustic emission count rates, for small percentages of the applied load range close to the peak load, show reasonable correlation with crack propagation rates. Based on these correlations it may be possible to predict the remaining service life of fatigue damaged structures from the results of short term acoustic emission monitoring. Another parameter affecting crack rates is speed of shaft. AE technique has been success to monitoring slow speed machinery element [5,6,7,8].Internal crack, classification of cracking mode also presented using AE [9,10].These tests demonstrated the applicability of AE in detecting crack initiation and propagation on slow speed shafts whilst in operation.Mba and Rao [11] presented development of AE for condition monitoring of rotating machinery like bearings, pumps, gearboxes, engines and rotating structure. This paper, presented baseline signal of crack shaft propeller.laboratoryscaletestingdone insidea soundproof chambertominimizethe effectsof noisefrom the surrounding environment. Sensor AE used is single microphone cardiod type. Different fromotherstudies [3,4,6,7,8,10] AE sensor was attached on body of elements, in this studythe AEsensorplacedat a certain distancefromthe location ofthe crack. Its not different with placement of vibrometer or accelerometer. With this position, distortion due to vibration object can be avoided.

2. Test Procedures

Inthis study, propellershaftasa testmadeby 4rodswith a length of800mmdiameter14mm. In thetestshaftmadecertaincrackwithcrackdepth, respectively- eachwith acrackdepth of0%, 25% and 50% of thediameter of theshaft. Codenamingof shaftswith acrackdepth of0% nameduncrackshafts, 25% and50% diameteraxleshaftscalledcrack0.25D and 0.5D. Testshaftwill bemounted onatest modelthat resembles aship propulsion systemis simple, shown in Figure 1.

Determination ofcrackdepthwithdifferent percentagesonlytodistinguishthe level ofthe testshaftcrackingwhile cuttingtransverseshaftwitha certain depthaimstocreate theinitialcrack.

AEsensorused isa microphoneBehringerXM1800stype. The microphoneis placedat a distance of20mmperpendicularfrom test model. Microphone connectedto theM-AudioFast TrackUltrawithAdobeAudition Software. InAdobeAudition, duration ofthe recordingis 5seconds. 441100Hzsampling rate. Inthis test, theaccelerometermeasurementsare alsoperformedtovalidatethe measurement ofAE. What is different isthe accelerometercan not beplaced on thecrack location, but at theend of theelectric motorisapproaching thecracklocation. Variablesusedtestisthe testshaftwithdifferentlevels ofcrackedandthe enginerotational speedchanges. Rotational speedis setat a valueof 500, 600, 700, 800, 900and 1000rpmthroughan invertermounted on atest model. The value ofthe enginerotational speedequivalent to8.33Hz, 10Hz, 11.67Hz, 13.33Hz, 15Hzand16.67Hz.

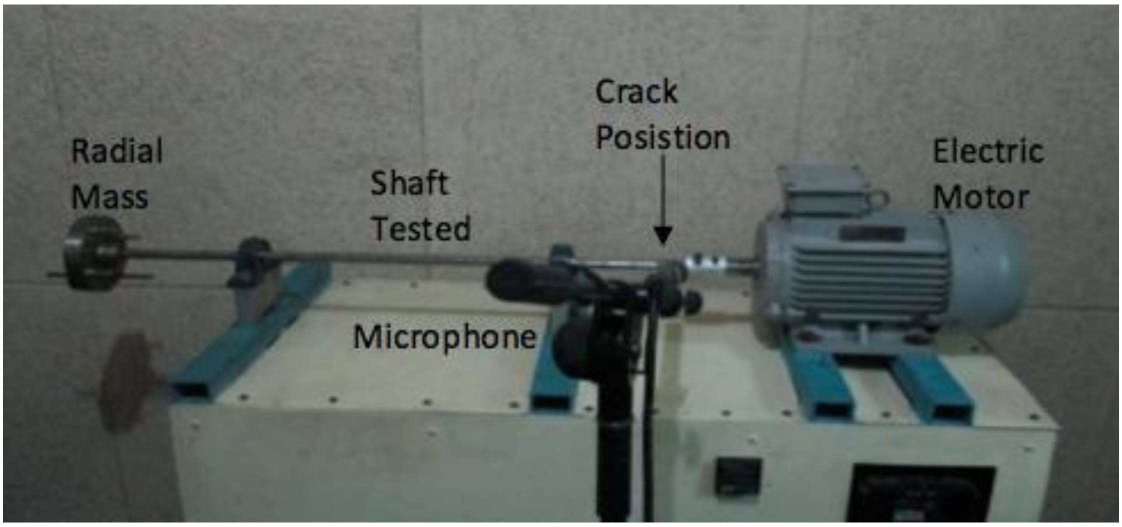

Figure 1. Experimental Set up

The firstphase oftesting; uncrackshaftmounted on thetest model. Motor is turned onatlow speedfor 30minutestoobtaina stable condition. Once consideredstable,speedincreased to500rpm. The microphoneis turned on, an accelerometerattached tothe motor. Recordingprogramis activatedin accordancewith thesetting. Onceready, recordingormeasurement can beperformedfor 5seconds. The second phase; testing is doneby increasing themotor speedup to600rpm. Thestepstestwas performed asthe first stage. This stageis doneup to1000 rpmrotational speed. Recordingis done3 timesforeach variable. The third stage; Any datais automatically recordedon each program.

3. Results and Discussions

Based on result, this paper present 3 case. Case 1 describe amplitude frequency each speed of shaft. Case 2 describe changes amplitude value increased speed of shaft and case 3 describe change amplitude on test shaft with different depth crack. Crack on test shaft located at the end of spi groove . Cutting transverse on cross section of shaft with certain depth to create crack initiation. Concentration stress maximum on spi groove.

3.1. Case 1

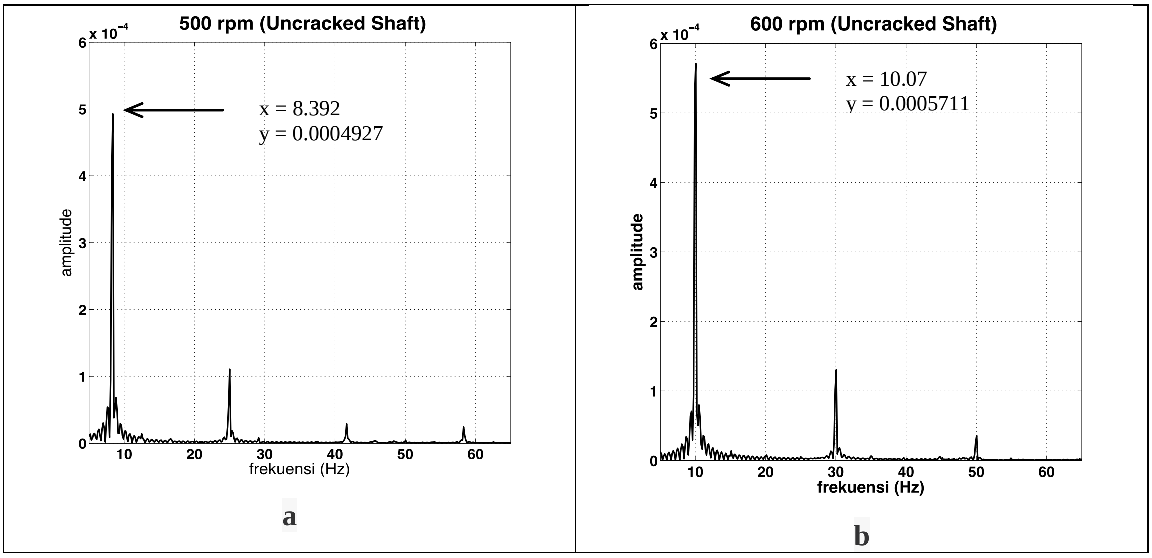

Figure 2. FFT of Baseline Signal Uncracked Shaft at : (a). 500 rpm and (b) 600 rpm

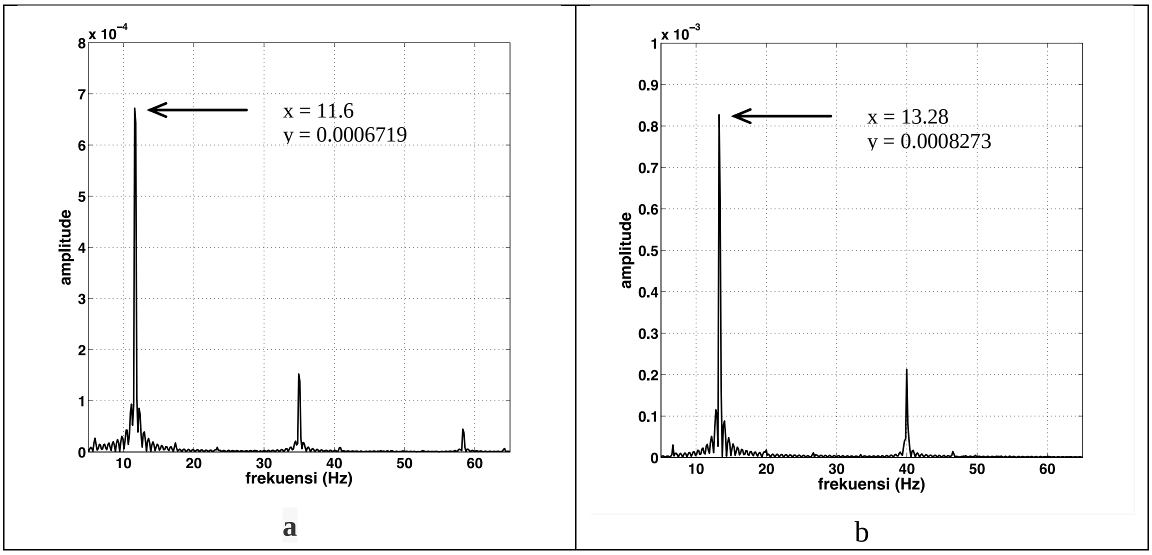

Figure 3. FFT of Baseline Signal Uncracked Shaft at : (a). 700 rpm and (b) 800 rpm

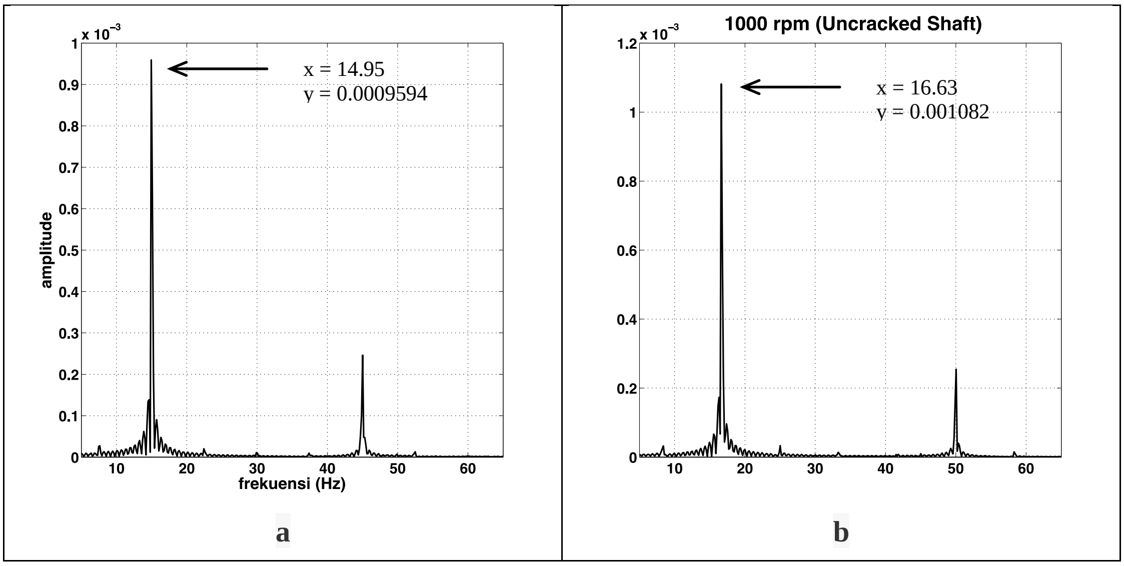

Figure 4. FFT of Baseline Signal Uncracked Shaft at : (a). 900 rpm and (b) 1000 rpm

Figure 2 - 4 shows FFT of baseline signal of uncracraked shaft at 500 rpm, 600 rpm, 700 rpm, 800 rpm, 900 rpm and 1000 rpm. Figure 2.a. shown that maximum amplitude located at frequency 8.392 Hz. Amplitude spectrum also appear at frequency 25.02 Hz , 41.66 Hz and 58.29 Hz. For this case, amplitude spectrum maximum will be concern because amplitude frequency isnearlyequal to thefrequencygeneratedbytheelectric motor 8.33 Hz equal to 500rpm. The same thing can be seen on figure 2.b., amplitude maximum located at frequency 10.07 Hz nearly equal to 10 Hz or 600 rpm. Figure 3.a. and 3.b. shown amplitude maximum located at frequency 11.6 Hz and 13.28 Hz. Amplitude maximum at 900 and 1000 rpm at frequency 14.95 and 16.63 Hz. The results shown on AE measurement for each speed of shaft, amplitude frequency nearly equal to frequency generated by electric motor. To confirm the results obtained, vibration analysis is also shown to validate the results of AE measurements. Figure 5.a. and 5.b. shows baseline signal measurement of uncracked shaft at 500 rpm and 600 rpm with accelerometer. Amplitude spectrumappears in figure 5.a. is at frquency 8.297 Hz, 12.36 Hz, 25.02 Hz and 50.09 Hz. Amplitude spectrum of closet to electric motor frequency at 500 rpm is 8.297 Hz.

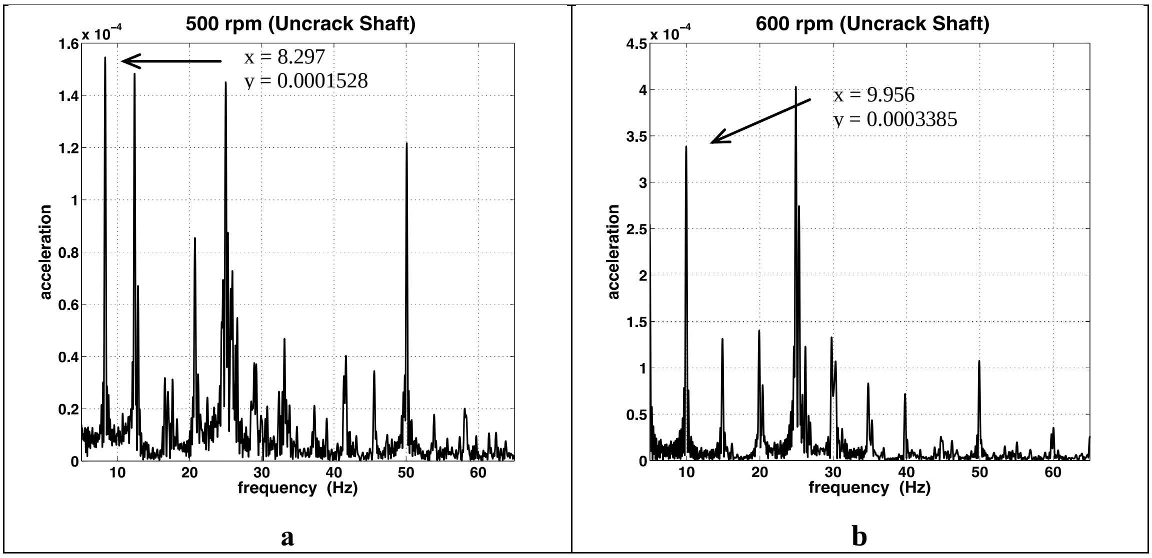

Figure 5. FFT of Baseline Signal Uncracked Shaft of Vibration Measurement at : (a). 500 rpm and (b) 600 rpm

3.2. Case 2

From figure 2 - 4 shown that amplitude change significantly.Maximum amplitude value on 500 rpm is 0.0004927 mV, showed in Figure 2.a. At speed of shaft 600 rpm, amplitudo value increase to 0.0005711 mV. For 700 - 1000 rpm, amplitude value, respectively is 0.0006719, 0.0008273, 0.0009594 and 0.001082 mV. If speed of shaft increased required greater energy for shaft rotate thus amplitude value will be increased.

3.3. Case 3

Amplitudevaluewill increasesharplyif thecrackdepthincreases. This canbe seen infigures6.a.and6.b.whichshows theamplitudevalueatcrackedshaft 0.5D. Amplitude value at 500 rpm is 0.06464 mV and 0.07851 mV at 600 rpm.Crack depth is keyword cause initiation crack and trigged growth crack. If crack depth increased, amplitude value increases shown in figure 7. Changes in the value amplitude is proportional to increase in depth crack.

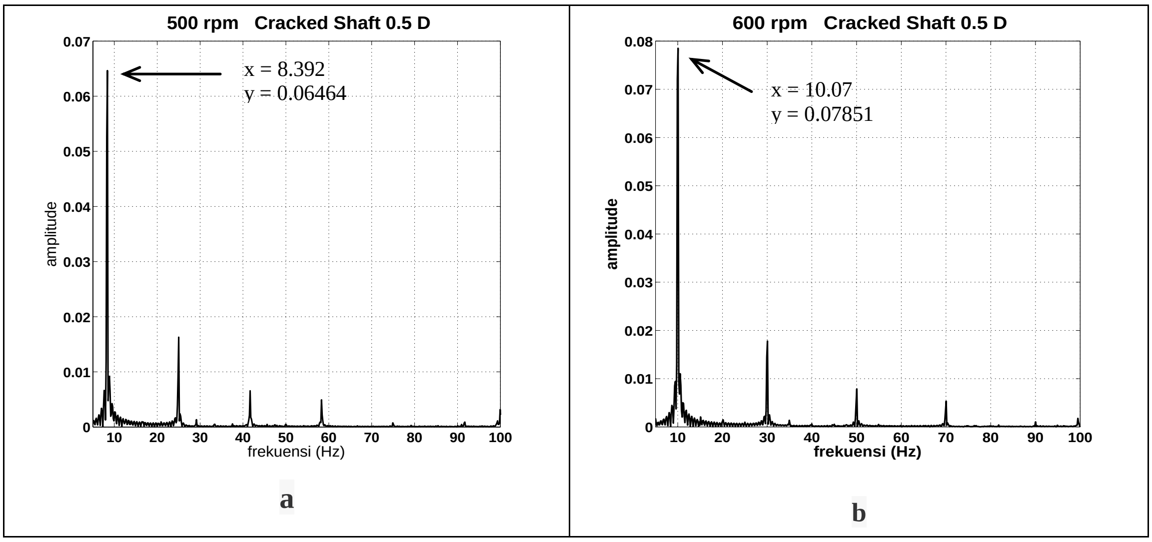

Figure 6. FFT of Baseline Signal Cracked Shaft 0.5D at : (a). 500 rpm and (b) 600 rpm

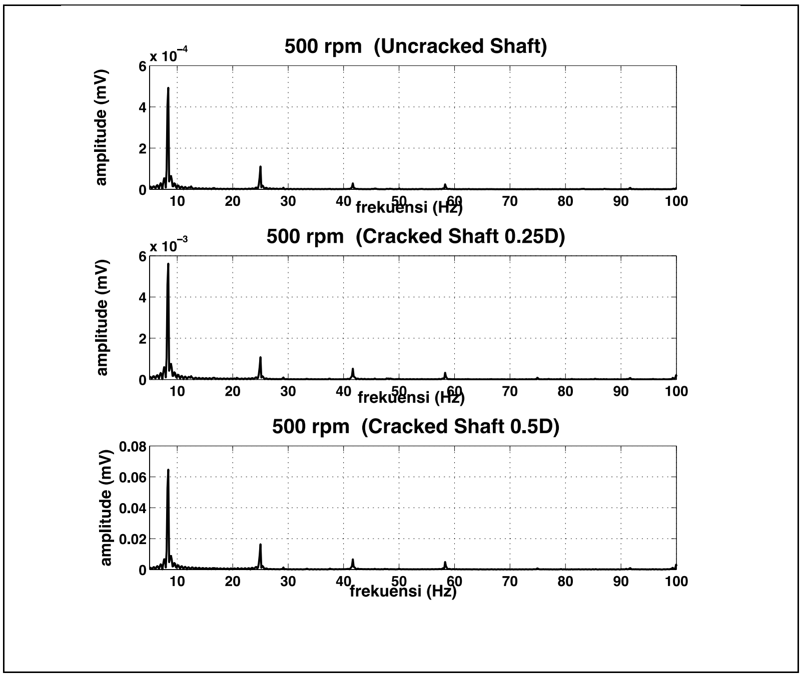

Figure 7. FFT of Baseline Signal uncracked shaft, cracked shaft 0.25D and 0.5D at 500 rpm

4. Conclusions

Thesetestinghasdemonstratedthe abilityandmicrophoneapplicationsasAEsensorstodetectcrackthat occurs inthe propellershaft. The advantagesgainedbyusing theAEtechniqueis the placement ofsensorsat a certain distance, suitable for measuringnoiseemittedbyrotating machinepart, the ability ofgeneratingamplitudespectrumathighfrequenciesso that theamplitudespectrumat low frequenciesremoved. This ability iswhat distinguishes it fromthe principle ofvibrationmeasurementby usingan accelerometerthatcangenerateamplitudespectrumatlow frequencyto high. The resultsobtainedfromthis testischangesshaftspeedanddepth crackis directly proportional tothe amplitudechanges.

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