iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: II Month of publication: February 2020

DOI: http://doi.org/10.22214/ijraset.2020.2038

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

Condition Monitoring of Marine Fuel Oil Separator System

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Abstract: Centrifugal Fuel oil separators are very important components in marine industry. Catastrophic failure of centrifugal fuel oil separators can have fatal consequences. The faults in fuel oil separators are hard to detect manually but can be identified by vibration and noise. In this research an approach for condition monitoring of the centrifugal fuel oil separators is presented using vibration analysis and noise analysis. Three axis MEMS accelerometer and piezo type microphone is interfaced with Arduino UNO microcontroller to collect the vibration and acoustic signals. The signals are analyzed with crest factor by a data analysis application developed in Microsoft Visual studio for predicting faults. The system is tested with data acquired in real time from a commercial centrifugal fuel oil separator and high fault detection efficiency is observed.
***Keywords**: Centrifugal fuel oil separator, condition monitoring, vibration analysis, preventive maintenance.*

I. INTRODUCTION

In ships fuel oil separators are used to separate dust particles from fuel. Fuel oil separators are of two types namely centrifugal and gravitational fuel oil separators. As evident from name in gravitational fuel oil separator the separation takes place by virtue of gravitational force, whereas in centrifugal fuel oil separators centrifugal force separates dust particles from oil. In marine industry centrifugal fuel oil separators are preferred over gravitational fuel oil separators due to higher efficiency.

Feed pump is used to feed the contaminated fuel to the separator bowl. The process of separation takes place in the solid wall bowl, which can operate on either clarification mode or purification mode. During separation massive forces are generated due to high kinetic energy. Desired vibrations occur in the system when it passes through the critical speed. Additionally, Undesired vibrations can occur due to many reasons such as unbalanced rotating parts. The undesired vibrations may lead to catastrophic failure of the machine. In extreme cases of vibrations such as ones caused by a bent bowl spindle, broken spring or damaged transmission, it is usually too late to prevent or reduce the damage incurred upon the system. This is because certain abnormalities in the system are not display on control panel and can be detected by noise or vibrations. Thus, predictive and preventive maintenance is crucial for early identification and rectification of undesired vibrations.

The purpose of this work is to provide efficiency-based maintenance for the oil separators through condition monitoring by vibration and sound signatures. One of the biggest challenges faced by ship managers is Maintenance controlling systems. The aim of this research is to fabricate vibration monitoring equipment using low cost sensors and microcontroller. The vibration data during operating condition is acquired with three axis accelerometers and sound data is collected through sound sensor. The collected data is passed to a PC for analysis to perform condition monitoring of the fuel oil separator

Fig 1: Centrifugal fuel oil seperators[1]

II. LITERATURE SURVEY

The practice of determining a machine's condition on the basis of periodically gathered data, and thus scheduling the maintenance is called Condition monitoring (CM)[2]. In condition monitoring data about various parameters which reflect the operating condition or health of machine is gathered. This may include lubrication oil temperature, vibration signature, debris contamination etc. Condition monitoring also aids in judging the reliability of machinery and gaining performance insights [3].Tang and etal[4] identified the excitation sources of engine by vibration and noise signals. Sanga and etal [5] demonstrated an approach for condition monitoring by identifying the change in colour characteristics of lubrication oil. Sun and etal[6] used health monitoring techniques on industrial robots.

Condition monitoring in offshore marine machinery is an evolving research field due to its immense importance . In marine industry high reliability is needed, especially for some components such as main engines, pump, crane etc. The high constraints on reliability make use of condition monitoring techniques essential in marine environment. Accurate diagnosis is also important in such circumstances due costly and complex equipment. A traditional approach of condition monitoring on ships is 'Watch Keeping'. In watch keeping the deviation from expected performance of machine is identified with help of some indications such as alerts, alarms, and gauge reading. The deck and engineering officers are responsible for this task in form of day to day schedule. However, the inability of the deck and engineering officers to evaluate a large number of discrete variables, such as trend analysis (TA), family analysis (FA), environment analysis, human reliability analysis (HRA), and design analysis (DA), has prompted questioning of the effectiveness of these routine CM activities. Additionally, this approach does not satisfy the industrial standards of flexibility and agility. This paves the requirement for customized condition monitoring approaches for sea.

One of the most powerful tools for predictive or condition-based maintenance is 'Vibration Analysis'[7]. Vibration analysis is a reliable approach for identifying faults at an early stage and preventing unexpected Machine Downtime. In this approach data about a machine's signature is acquired by different sensors such as accelerometers and gyroscopes [8]. The advancement in Micro Electro and Mechanical Systems has facilitated the use of MEMS accelerometer sensors for vibration analysis. Vibration analysis using MEMS sensors is common in certain industrial condition monitoring. Anna and etal[9] performed vibration Analysis on two industrial gear hobbing machines. Dai and [10] demonstrated the use of vibration theory on a cold press rolling machine in an Aluminum factory for fault detection. The use of vibration analysis is yet to be explored in condition maintenance of marine machinery.

III. METHODOLOGY

A. *System Architecture*

The block diagram of system architecture is shown in Figure 2. The data acquisition unit consists of two sensors namely MEMS accelerometer MPU6050 and Piezo type microphone and microcontroller. The microcontroller used here is Arduino UNO. The data acquisition unit is shown in Figure 2. This unit is placed at MMB05 fuel oil separator. The accelerometer acquires vibration data from x, y and z axis and sends it to microcontroller. Similarly, microphone reads noise data and sends it to microcontroller. Microcontroller is connected to data analyzing unit which is computer. A vibration and noise monitoring application is deployed in the computer. The application is developed in Microsoft Visual studio .net framework .The details of the developed algorithm are mentioned in section 3.2.

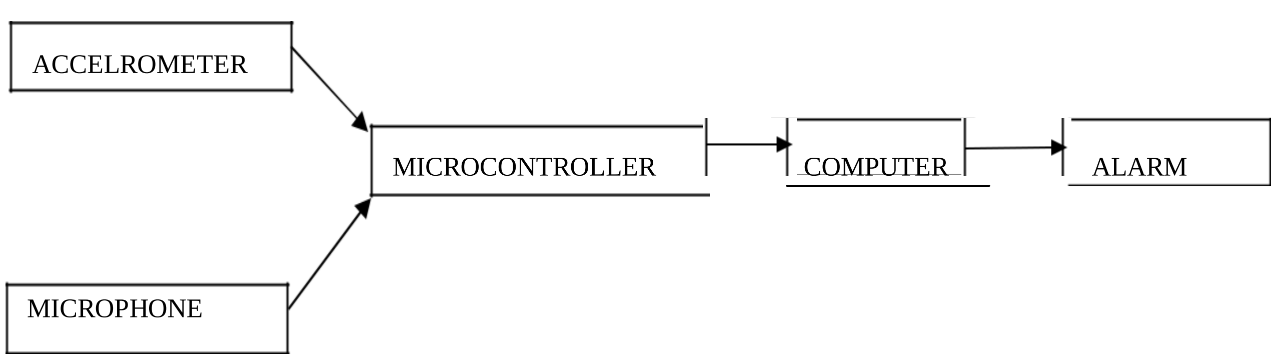

Fig 2 : Block Diagram of proposed system.

B. Proposed Methodology

The process flow of proposed methodology is shown in Figure 3.The Data Acquisition Unit is mounted on the MMB05 fuel oil separator and data is collected in real time. The acceleration data in the x, y and z axis is read by accelerometer . The Piezo type microphone acquires acoustic signals during machine operation. The microcontroller receives these signals and concatenates in order to form a single string. The string so formed represents the machine signature at a given condition as determined by the operating parameters.

The data transmitted by microcontroller is received at computer application. In the computer application, firstly data separation occurs and the single string is separated into four different vectors namely acceleration in x axis, acceleration in y axis, acceleration in z axis and acoustic data. After the data separation crest factor of all the four vectors is calculated.

Crest factor is an important tool for detecting impulsiveness in the signal. Crest Factor is a waveform parameter and represents the ratio of peak value of waveform to RMS Average value of waveform. Crest Factor is a measure of the frequency of occurrence of peaks in the signal. The obtained crest factor is compared to the pre-defined threshold value. The threshold value is crest factor in the acceleration and noise signals which is allowable and safe during operation. If the crest factor exceeds the threshold a warning is flashed, otherwise next data set is acquired and analyzed. The sequence of operations is demonstrated in Figure 3. Here represents the crest factor in acceleration signal, represents the crest factor in noise signal. The threshold value of acceleration and noise signal is represented by $a^{t^{h}res^{h}old}$ and $n^{t^{h}res^{h}old}$ respectively.

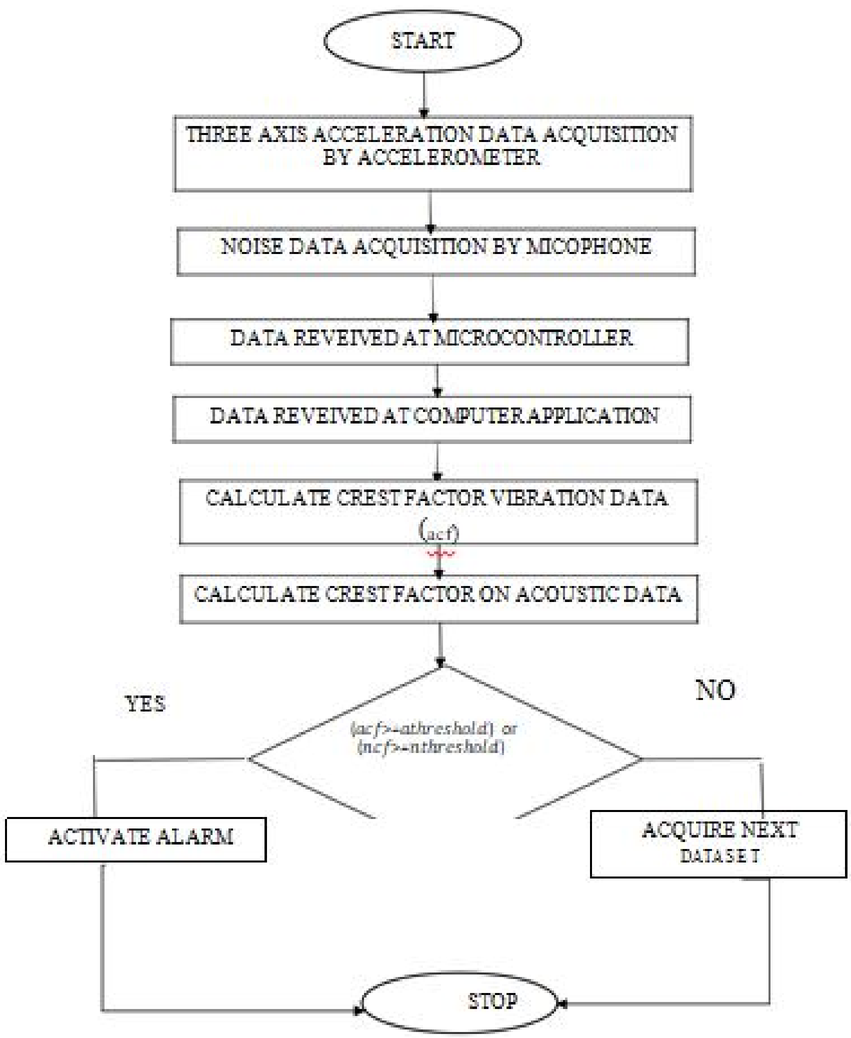

Fig 3 : Process Flow .

IV. RESULT

The fabricated data acquisition device is shown in Figure 4. The device was firstly placed on a correct working MMB05 Fuel Oil Separator in a ship . In this phase acceleration and acoustic signature for normal machine operation was acquired. The device was then placed on a furl oil separator which was on scheduled maintenance and acoustic and acceleration signatures were acquired for abnormal machine operation. The acquired datasets are split into test and train datasets.

The crest factor of acceleration and acoustic waveforms present in the train samples is calculated and a threshold value is set appropriately. The developed data analysis application in Microsoft Visual Studio is shown in Figures 5 and 6. Figure 5 represents the waveform of normal working of fuel oil separators. Figure 6 represents the waveform of abnormal working of fuel oil separator in which the warning was flashed. The abnormal machine condition in Figure 6 represents due to improper cleaning of the separator bowl..

Fig.4 Fabricated Data Acquisition unit

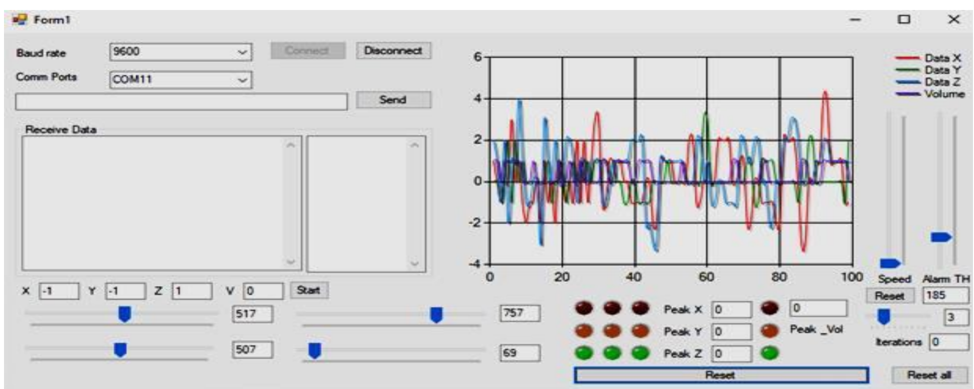

Fig.5 Acceleration and acoustic waveform during normal operation.

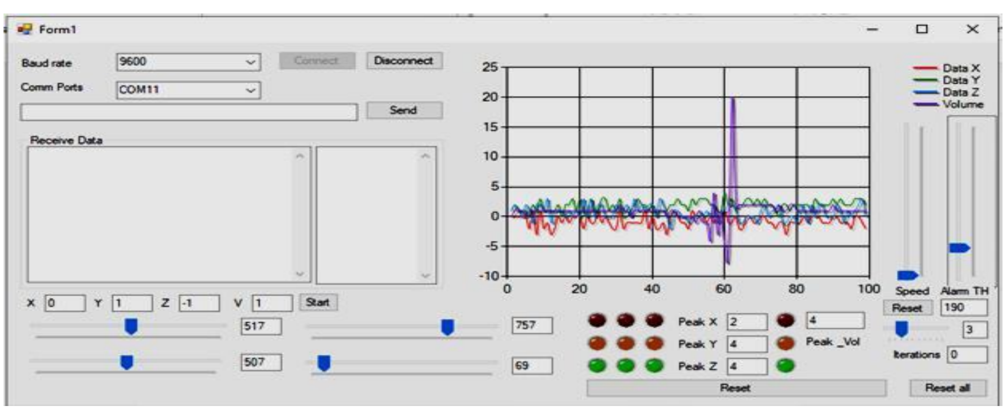

Fig.5 Acceleration and acoustic waveform during abnormal operation.

V. CONCLUSION

Vibration and noise analysis system for condition monitoring of a marine centrifugal fuel oil separator is developed. Three axis MEMS accelerometer and piezo type microphones are used for acquiring vibration and acoustic signals respectively. The developed approach uses crest factor to enhance the extremes present in the waveform. The developed approach is validated by data collected in real time during abnormal and normal operating conditions. The developed approach can identify various faults such as improper assembly , improper cleaning of separator bowl with an efficiency of 95 percent.

VI. FUTURE SCOPE

The proposed research has immense scope of future enhancement. The developed approach can be combined with machine learning techniques for improving the efficiency. The proposed approach can be linked with Industrial Internet of Things (IIOT) for continuous monitoring of all the fuel oil separators present on floor and thus shifting towards proactive maintenance. The warning system can be extended by applying algorithms of artificial intelligence to shut down the machine before the onset of failure in the proper way.

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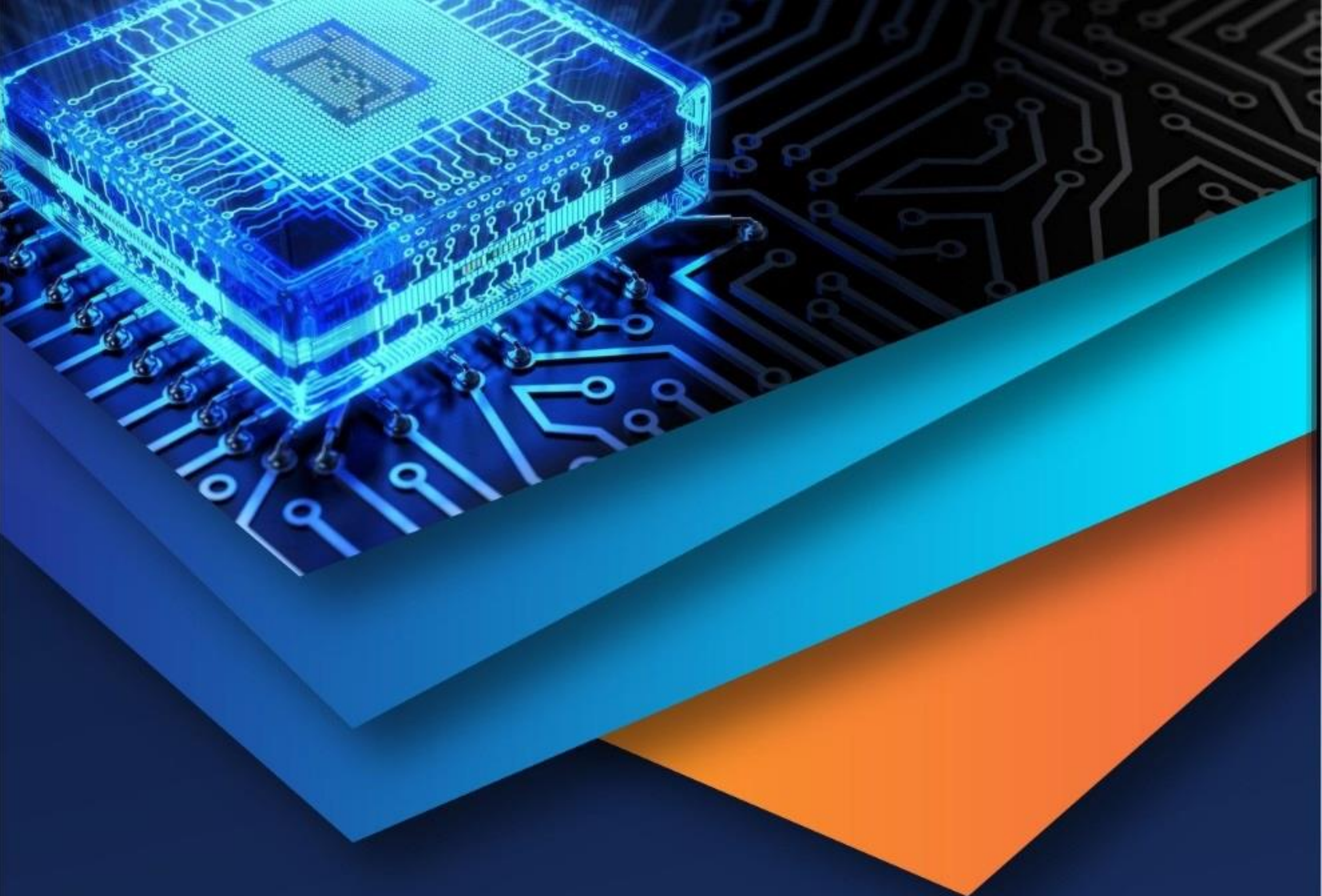

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