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An online condition monitoring system implemented an internet connectivity and FTP for low speed slew bearing

Wahyu Caesarendra
University of Wollongong, wc026@uowmail.edu.au

Buyung Kosasih
University of Wollongong, buyung@uow.edu.au

Tegoeh Tjahjowidodo
Nanyang Technological University

Mochammad Ariyanto
Diponegoro University

L Daryl
Nanyang Technological University

See next page for additional authors

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Abstract

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Disciplines

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Authors

Wahyu Caesarendra, Buyung Kosasih, Tegoeh Tjahjowidodo, Mochammad Ariyanto, L Daryl, and Daniel Pamungkas

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W Caesarendra[1,2*], **B Kosasih**[2], **T Tjahjowidodo**[3], **M Ariyanto**[1], **LWQ Daryl**[3], **D Pamungkas**[4]

[1]Department of Mechanical Engineering, Diponegoro University, Semarang, Indonesia

[2]School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Wollongong NSW, Australia

[3]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

[4]Electrical Engineering Department, Politeknik Negeri Batam, Indonesia

E-mail: *wc026@uowmail.edu.au

Abstract. Rapid and reliable information in slew bearing maintenance is not trivial issue. This paper presents the online monitoring system to assist maintenance engineer in order to monitor the bearing condition of low speed slew bearing in sheet metal company. The system is able to pass the vibration information from the place where the bearing and accelerometer sensors are attached to the data center; and from the data center it can be access by opening the online monitoring website from any place and by any person. The online monitoring system is built using some programming languages such as C language, MATLAB, PHP, HTML and CSS. Generally, the flow process is start with the automatic vibration data acquisition; then features are calculated from the acquired vibration data. These features are then sent to the data center; and form the data center, the vibration features can be seen through the online monitoring website. This online monitoring system has been successfully applied in School of Mechanical, Materials and Mechatronic Engineering, University of Wollongong.

1. Introduction

Slew bearings have been developed as new machine parts in the past 30 years. They were first used in excavators and cranes, and then applied to others machines such as loading and unloading machines, transporting machines and material processing machines. Slew bearings are almost the same as ball and roller bearings which have roller and rolling ring with the raceway. But compared with common roller bearings, they have many special features. They can be summarized in the following points: The size of slew bearing are great, diameter is generally between 0.4-10m. Slew bearings usually bear loads from different parts. They not only bear the axial and radial force but also endure tipping simultaneously. The speed of slew bearings is fairly low; usually ranging from 0.5 to 15 rpm. Slew bearing maintenance is relatively complicated, failure go unnoticed will result to breakdown maintenance and costly. Therefore the online condition monitoring of slew bearings has become necessary to provide the immediate information of bearing condition.

The industrial revolution has growth from Industry 3.0 which uses the automation system in the manufacturing process to Industry 4.0 which uses the advantages of cyber world into physical world of manufacturing which in return allows transmission and reception of data from and to anywhere on earth that connects to the internet.

2. A brief review on vibration online monitoring
There were many published articles used the word 'online' for their method [1-3]. Before going further, the definition of 'online' should be determined first. This paper defines the word 'online' as "the system that can provide the rapid and reliable information which convert the raw data into the useful information to support the decision making in maintenance work without any human interference". The example of recent article which put the word 'online' on their title is Loutas et.al [4]. The paper presented the on-line monitoring for three monitoring techniques: vibration, acoustic emission and oil debris using National Instrument. Even though the paper said the three monitoring are conducted by online but the post processing signal analysis methods such as PCA, DWT and ICA are calculated after the whole data from beginning until the catastrophic failure occurred are acquired. It can be said that this is an off-line analysis. Another paper was presented by Eric et.al. [5], the Authors developed the online remote monitoring for vibration and acoustic emission using National Instrument and LabVIEW. The monitoring system consists of data acquisition (DAQ) control, real-time analysis, off-line analysis, feature extraction and monitoring trending features. The signals are sampled at the DAQ card and saved in the PXI system. The PXI is connected to internet via local network with security function allowing access for user through internet.

Robust and complicated online monitoring systems have been developed by some vibration monitoring companies. Those systems are complicated and expensive but the quality is superior. In this project simple and low cost online monitoring system based C language, MATLAB executable, File Transfer Protocol (FTP) and Web design is proposed. This project is partially developed for PhD project in University of Wollongong.

3. Experimental setup
The slew bearing test-rig is operated continuously under controlled conditions. The bearing under test was run from the new condition to failure. Figure 1 shows the schematic of a slew bearing test-rig. The test-rig can be operated at speeds of 1 to 12 rpm. The test-rig was designed to simulate the actual working conditions of a steel manufacturing company. In this study, the test-rig is expected to run in reversible rotation at a speed of 1 rpm. The slew bearing type is an axial/radial bearing YRT260 supplied by China bearing manufacture with an inner and outer diameter of 260mm and 385mm. The constant load via hydraulic pressure was applied to bearing of 30 tonne.

Three types of sensors were installed on the bearing: accelerometer, temperature sensor and acoustic emissions (AE) sensor. We used four accelerometer and temperature sensors to maintain 4 symmetrical measurement area. These sensors were placed on the inner radial surface at 90 deg to each other as can be seen in figure 2. Two AE sensors are attached on the top axial surface at 180 deg to each other as presented in figure 2. The IMI608 A11 ICP type sensor is used in this study. The accelerometers were connected to high speed DAQ (PS3424) from Pico scope. To avoid noise interruption from laboratory environment, the vibration data was collected at midnight outside of working hours with 4880Hz sampling rates.

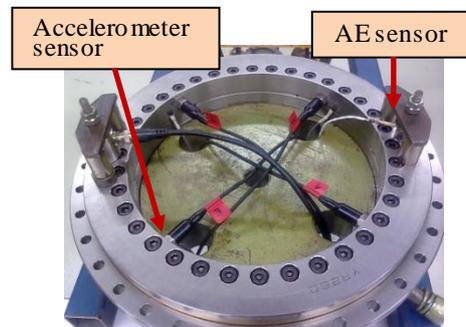**Figure 1.** Photo of slew bearing lab test rig [6].

Figure 2. Sensors location.

4. Online monitoring based feature extraction

The objective of this system design is to facilitate online monitoring to the currently used slew experiment. The resulted software is expected to be able to send the data automatically from one location, to the data centre and then accessed from any other site using web browser. The locations involved in this online monitoring system are divided into 3 main locations: WORKSHOP, DATA CENTRE/SERVER and CLIENT. The illustration is shown in figure 3.
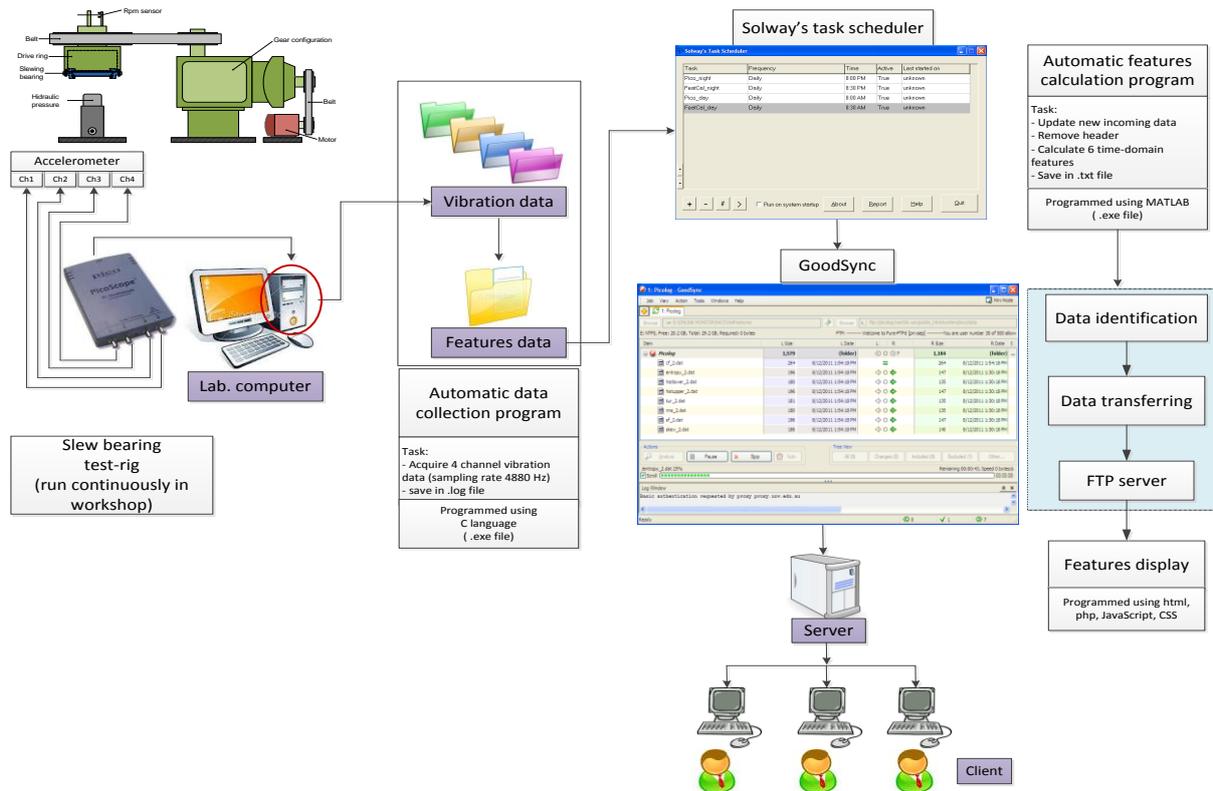
Figure 3. Online monitoring framework based FTP protocol.

4.1. Workshop

Since the vibration data is generated in the machine located in workshop, the control of data format should be done here. Disregarding the process of how the result is yielded, the end resulted data should be in form of simple human readable file, to be precise is TXT or DAT format. Each file will be produced every particular period of time, and each file will contain the readings of the bearing conditions by the machine at that time. Two automatic data acquisition will be conducted at day and night. This is will be done by doing two things. First, the executable data acquisition program is written in C language and saves in the EXE format. This is the advantage of PICO DAQ that it can be used not only for human interface but also for automatic way. Second, the automatic data acquisition will be used by running the executable file using Solway's task scheduler shown in figure 4. The vibration data are saving in desktop computer where the filename contain the information about date, month and year when the readings are taken.

Initial online monitoring process used free hosting. There is limited data transfer for free hosting. Therefore the huge file of vibration data should be transform into less capacity by calculating the useful information. This information is usually called features. In this work, six time domain features are used: root mean square (RMS), shape factor (SF), skewness, kurtosis, crest factor (CF), entropy, histogram lower and histogram upper [7]. The executable MATLAB program is created to do the six feature calculation. This program also runs automatically using Solway's task scheduler approximately every 30 minutes after the automatic data acquisition as shown in figure 4. The illustration of automatic data acquisition, automatic feature calculation and online monitoring process are shown in figure 3.

The readings as had been mentioned before are divided into four different channels (channel 1 to channel 4). In other words, each file will contain four values that represent the condition of bearing from four different accelerometer locations, separated by space. As automatic data acquisition will be carried out at two different times (day and night), the feature calculation filename will be consisting of

two data name as well. For example the kurtosis feature will be saved as 'kur_1.txt' for day and 'kur_2.txt' for night. Each file will consist of five column where the first column will be the date, month and year when the feature are calculated. Second columns to fifth column are the accelerometer channel 1 to accelerometer channel 4. The six different feature calculation data will be stored temporarily in the connected desktop computer. The illustration of data format is shown in figure 5. Once the data on figure 5 saved and collected in the main PC, the data is then transferred and sent to the web hosting through GoodSync as depicted in figure 6.
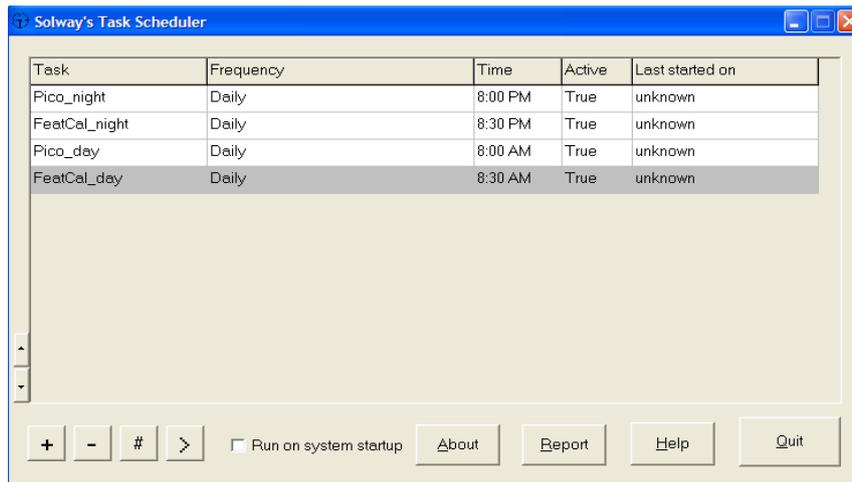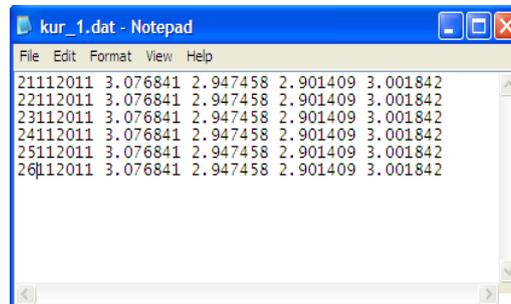

Figure 4. Solway's task scheduler.

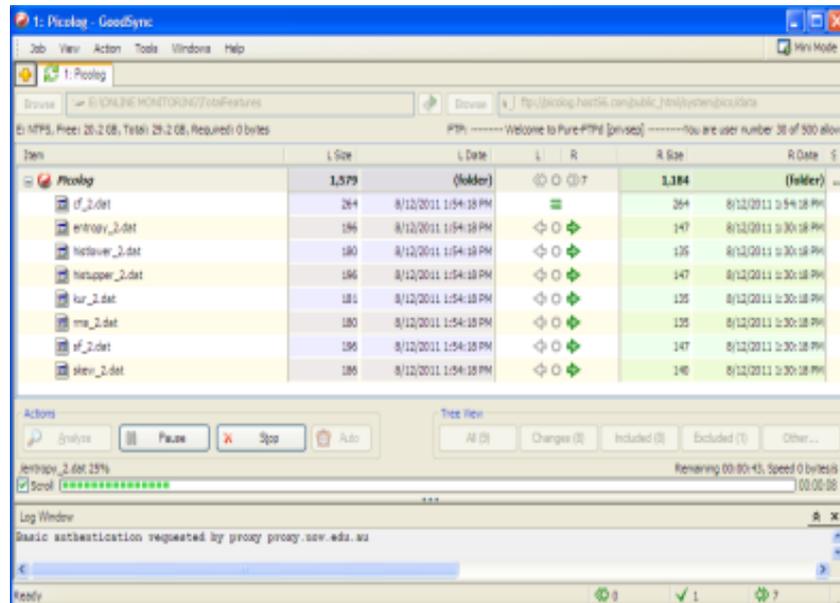**Figure 5.** Example of feature file format.

Figure 6. GoodSync.

4.2. Server

The server is expected to handle a lot of storage and bandwidth size to access this site must be reasonable enough (if use paid hosting). Since the transaction including downloading the data from any client are done regularly, it is very important to choose a competent hosting site. Most likely, the best choice for this project is the unlimited storage and unlimited bandwidth. The costs are ranged between approximately 4 AUD per month, and greater than that. Moreover, the hosting site should satisfy the following needs:

a) Allow FTP connection to their site
b) Support PHP and MySQL just in Case
c) Again, unlimited storage and bandwidth is favourable.

Since the needed data for the client site is as the following:

a) Root mean square (RMS)   e) Crest factor (CF)
b) Shape factor (SF)   f) Entropy
c) Skewness   g) Histogram lower and
d) Kurtosis   h) Histogram upper.

Then the data must be prepared before fetched by the client site. The calculation for each variable will be done in 2 different triggers, automatically and an update button pressed. The first option should check the last time the webpage is accessed. As long as current timestamp and the previous timestamp fall under the same timeframe (frames are like sessions, depend on the FTP frequency) no pre-processor are executed, because definitely no additional raw data. In case the timeframe are different, then the calculations are needed, since we already have new data to be displayed. This way, we can achieve optimization as we do not waste unnecessary process. In case of manual update, this button will be provided, if and only if the user wishes to do so and not necessarily to do it. Just to reassure the user that the data can be updated at user's willed.

4.3. Client

Any computer with internet browser is considered as client. After simple verification the calculated data then displayed accordingly. The users are given several configurations option to choose what data preferred to be displayed by default. Nonetheless, as the user may see fit, users are allowed to download the data. May it be individually or in several at once. Furthermore, the data displayed is powered by JavaScript to make it more interactive and easy to deal with.

The expected configurations are:
   a) Display all data on start-up
   b) Download latest data on start-up
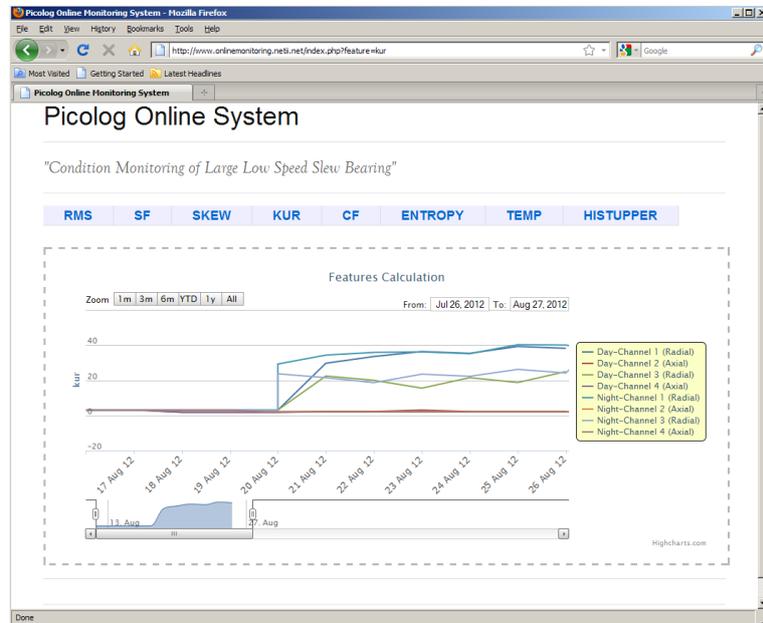   c) Only display last 3 days data

Figure 7. Kurtosis feature from online monitoring website.

5. Conclusions

Low cost, simple and easy to implement online monitoring system for low speed condition monitoring is presented. There are undergoing work to improve this system such as find the proper feature which indicates the bearing condition and embed the intelligent condition monitoring and prognosis algorithm to the online monitoring system.

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