Monitoring of Roller Bearings in the Context of Predictive Maintenance (RFID2007)

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***Abstract* – A prototype system capable of periodically monitoring the vibrations of roller bearings is presented. The collected data can be wirelessly transmitted to a hand-held unit during routine maintenance allowing for estimation of wear and planning of replacement.**

I. Introduction

Within the scope of industrial maintenance the field of condition-based maintenance has gained more and more importance in recent years. In order to identify wearings at an early stage and to replace damaged parts, the condition of industrial plants ought to be permanently monitored with sensors.

Specifically, the wear of roller-contact bearings can be estimated by monitoring the vibrations directly at the machine. Appropriate evaluation of these data allows for replacing the bearings only when the vibrations indicate incipient wear. Without this diagnosis device, the bearings must be replaced periodically just to be on the safe side representing a considerable cost factor.

II. State of the Art

In new established fabrication facilities wired condition monitoring systems can be installed easily. This systems can show you the whole history of the bearing, and dramatic changes can be reported automatically. But in existing plants this is very cost intensive. Up to now bearings have been changed after an estimated life time depending on the usage of the motor, transmission, etc. whether it is worn out or not, or handheld monitoring devices have been used to estimate the state of the wear of the bearing. These hand held devices require a skilled service technician who has to contact the test tip manually or with the help of a magnet for an expedient mechanical connection to the machine next to the bearing. He has also to interpret the measurement results and to decide if the bearing has to be changed or not. In some applications the device under test is inaccessible or in a dusty or soiled environment. Therefore fully wireless and low cost sensors that just have to be fixed once at the device of interest and need no maintenance for some years would be a good replacement.

III. Vision

A cost efficient system should be designed to monitor the condition of roller bearings. The sensor modules should be small and maintenance free. The method of choice is an envelope detection of the vibrations.

The ideal sensor system should be fully functional without being wired to a power supply or a data transmission. The module should be attached to a motor, a blower or a pump once and should not need any further maintenance.

Information regarding identification of the machine part and the used bearings is coded in the sensor, allowing for unambiguous context between measurement data and hardware. This functionality is common with standard passive RFID technology.

The sensor should periodically monitor the vibrations caused by the bearings and store these data for wireless transmission to a special PDA during an inspection tour.

The collected data then should be used for an automated decision whether a replacement of a bearing is necessary or not.

III. Envelope Analysis

For the extraction of hidden periodic low energy impacts of machine vibrations, envelope analysis is a common well known method [1]. It uses the fact that there are impact impulses appearing in the surrounding area of damages in the bearing surface or the rolling element every time when it is rolled over. It can be compared with a hammer knocking on a bell. Not the bells resonance frequency, the carrier frequency, is of interest, it is the frequency with which the hammer hits the bell. The resulting signal describes a simple amplitude modulation. To recapture the hammers original frequency it is necessary to rectify and filter the signal.

IV. Prototype

In order to analyze the conditions of rolling bearings first the mechanical vibrations have to be measured with an acceleration sensor. The next step is to form the envelope of the time-based signal and to store it at regular intervals. These stored measurements can be transferred to recording equipment via Bluetooth in the course of an inspection round in the industrial plant. The transformation into the frequency domain, which is necessary for the spectral analysis of the signal, is carried out by an evaluation software on a PC. With the help of this spectral analysis an evaluation of the condition of rolling bearings can finally be accomplished.

Supplying energy to the module is challenging. There are no energy harvesting techniques commercially available, that would power the electronics endlessly, even for extremely low power designs. For this reason the prototype system is powered by lithium cells.

Figure 1 shows a block diagram of the prototype [2]. A Microchip PIC 18F452 8-Bit microcontroller containing a 10-Bit A/D converter is the heart of the sensor. The whole system is powered down exempt from a series of four measurements once a day when it is activated by a low power consuming real time clock RN-8564-C2 from Microcrystal. The vibrations of the rotating bearings are gathered by a low cost Analog Devices ADXL210AE, 2 axis, ±10 g acceleration sensor and then conditioned for the A/D conversion by filtering and demodulating the sensor signal. The conversion frequency is 1 kHz, so due to the Nyquist criterion frequencies up to 500 Hz can be detected. The so collected data is stored at a 32 Mbit M25P32 Serial Flash from ST.

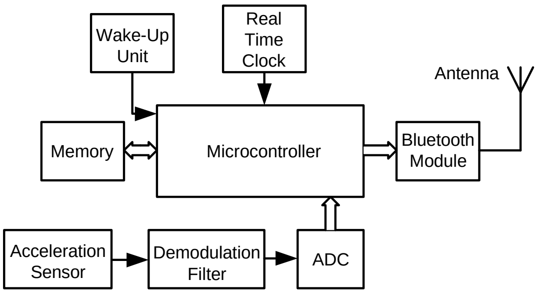

FIGURE 1 – BLOCK DIAGRAM OF THE ROLLER BEARING CONDITION MONITORING SYSTEM

Starting a data transfer via the Amber Wireless Bluetooth module based on the National Semiconductor LMX9820 needs a wake-up impulse by a laser pointer. The option of an optical wake-up realized with a simple phototransistor was chosen because in industrial environment sensors are often mounted at inaccessible points. The system prototype is depicted in figure 2 and has to be mounted by a polyester resin adhesive to the machine that has to be monitored.

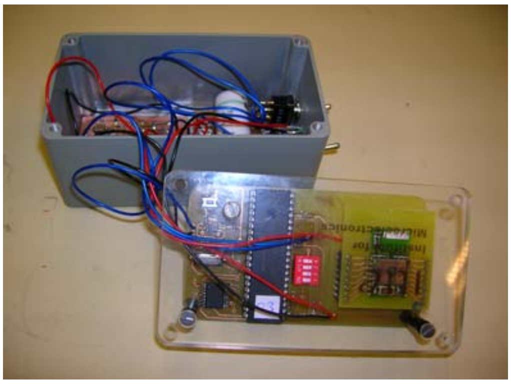

FIGURE 2 – PROTOTYPE, ROLLER BARING CONDITION MONITORING SYSTEM

For receiving the sensor data at the inspection tour an i.roc 420 personal digital assistant (PDA) is used. For a first on-site examination the gathered data is transformed into a frequency spectrum by an FFT and displayed. The data can then be transferred from the PDA to a PC. Using LabVIEW the condition of the roller bearings can be analyzed. For reduction of perturbation the series of four measurements is averaged. It is possible to display one reference spectrum with two measurements at the same time. The frequency of interest and three multiples can be identified by an adjustable cursor. A screenshot of possible measurement is shown in figure 3. The first yellow cursor shows the frequency and acceleration at a chosen point of the spectrum. The other three cursors show the second, third and fourth multiple of the frequency and the appropriate acceleration. Two measurements are displayed in red and in blue.

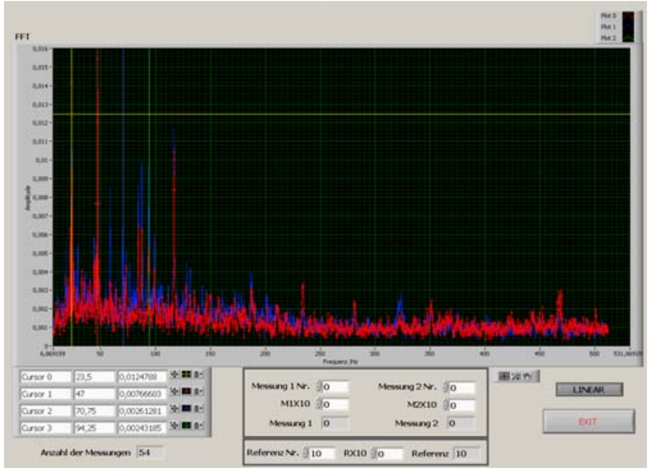

FIGURE 3 – GRAPHICAL PRESENTATION OF MEASUREMENT RESULTS AT THE PC

V. CONCLUSION AND OUTLOOK

A market analysis confirmed the demand for the proposed system for monitoring rolling-contact bearings. Subject to a decision to support the further development, production is planned to start in 2008.

The battery lifetime of the proposed sensor is about three years implementing a series of four daily measurements and a readout cycle of six months with the used 3700 mAh lithium-battery. A further improvement of the maintenance free operating time of the sensor could be realized by energy harvesting. An application of piezoelectric generators using the vibration of the device under test or Peltier-generators exploiting temperature differences is conceivable.

For extremely dirty environments the simple and cheap laser trigger for waking up the system would probably not be the best solution. A radio trigger is envisaged to be an alternative solution and will be investigated.

ACKNOWLEDGEMENTS

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