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IOT Based Condition Monitoring and Fault Detection for Rotating Machine

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الملخص

مع تطور الاتصالات اللاسلكية وتكنولوجيا Micro Electro Mechanical Systems (MEMS)، أصبح من الأسهل مراقبة حالة الماكينات الدوارة من خلال تركيب مستشعر MEMS اللاسلكي المضغوط مباشرةً على الجهاز ، والذي لديه القدرة على توفير معلومات أكثر دقة حول الجهاز الدوار. في هذا البحث تم قياس درجة حرارة المروحة وإرسالها إلى السحابة عبر NODEMCU esp 8266 E12 والتي تحتوي على المعالجات الدقيقة واتصال Wi-Fi مما يوفر طريقة سهلة للتحكم في المستشعر. لتقييم أداء الطريقة تم جمع البيانات في ظل شرطين مختلفين وهما حالة صحية وخاطئة ثم تم تحليل البيانات المخزنة باستخدام MATLAB واستخدمت لمراقبة حالة الجهاز واكتشاف العيوب. تظهر النتائج التجريبية أن الطريقة المقترحة يمكن أن تشير بوضوح إلى الخطأ وبالتالي توفير طريقة موثوقة واقتصادية لمراقبة حالة الآلات والكشف عن الاعطال.

Abstract:

With recent development in wireless communication and Micro Electro Mechanical Systems (MEMS) technology, it becomes easier to monitor rotating machinery condition by mounting compact wireless MEMS sensor directly on the machine, which has the potential to provide accurate information about the rotating machine. MEMS sensors are optimal for wireless measurements and internet of things (IOT) applications, which makes them a good option for remote condition monitoring.

A cost-effective CM system is necessary to ensure that machines can work properly over long time of efficient operation with the required accuracy. Therefore, systems that use advanced technologies and techniques for predictive maintenance, such as IoT sensor communication are essential. In this paper, the temperature of fan was measured and sent to cloud via NODEMCU esp 8266 E12 bored that contain microprocessor and Wi-Fi connection providing an easy way to control the sensor. To evaluate the performance of the method, data was collected under two different conditions which are healthy and faulty condition. Then, the stored data was analyzed using MATLAB and used for machine condition monitoring and fault detection. The experimental results show that the proposed method can clearly indicate the fault, thus providing a reliable and economical method for machine condition monitoring and fault detection

Keywords: Wireless MEMS; IOT; Condition Monitoring; Rotating Machines.

Introduction

Condition based monitoring programs rely on data gathered from monitoring machine to inform maintenance activities. This approach seeks to eliminate unneeded maintenance, with activities only implemented where abnormal readings which may indicate a fault are found. Effective organization and implementation of Condition based Maintenance (CBM) can minimise maintenance costs, with fewer unneeded maintenance work being undertaken. Figure 1. shows a typical CBM procedure, including three essential steps, which are [1] [2]:

1- Data collection: acquiring parameters including vibration, noise level, spectrum, motor current and pressure, etc.

2- Data processing: information collected in step one is analyzed to provide an accurate description of the machine’s condition.

3- Fault diagnosis and decision making: recommending effective maintenance policies.

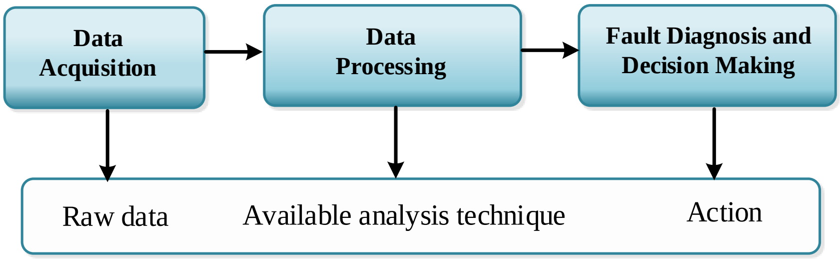

Figure 1. Condition based maintenance main steps [2].

Nowadays, the extensive and successful application of wired online condition monitoring techniques can be found in many industrial fields. However, the high cost of these systems has restricted their application for a wide range of critical industrial machines [3]. With the development of wireless transmission techniques, communications technologies, and electronics, it is becoming feasible and popular to use wireless sensors for machinery condition monitoring, to avoid wired online condition monitoring problems. As the cables used in wired condition monitoring can cost from £40 to £80 per foot, with a cost of up to £2000 per foot in dangerous, non-reachable and harsh environments [4], so the main benefit obtained by bringing in wireless technologies for condition monitoring is in reducing the cost. Besides, wireless sensors can be easily installed on machinery located in isolated environments, as well as allowing easier replacement and upgrading than wired condition monitoring.

WSN technology has recently begun to be applied in numerous commercial areas, including for example; environmental monitoring [5], construction health observation [6] and temperature monitoring in product distribution [7]. Nevertheless, the environment of industry and its applications cause further difficulties in the usage of wireless sensors for machine condition monitoring and fault detection, for example processing mixed sensor signals, provide higher sampling rates, required faster data transfer rates, and offer higher reliability [3].

Wireless Technology in Condition Monitoring

As mentioned earlier, wired online condition monitoring systems are successfully applied in many industrial settings. However, these systems rely on different types of cables for field applications, and installation, maintenance and cost become the major obstacles to their wider applications [8]. Providentially, there have been significant developments in wireless data communication technologies that can be used to transfer data instead of using communication cables.

Currently, wireless technologies are widely used and have gained great attention in industry for collecting and transferring data used for machinery condition monitoring due to their inherent advantages: for example, they are low cost, suitable for isolated environments, offer convenient installation and are easy to upgrade[9], [8], [10] [11]. In remote condition monitoring systems, a number of requirements should be considered in order to decide which wireless technology is most suitable for data transmission. Bandwidth, power consumption, bit error rate, length of data transmission, transmission speed, and security are some of these requirements [12].

Different standards have been designed for wireless communications to meet various application area requirements. The most widely-known protocols that have been employed in the Wireless Sensor Network (WSN) are Wi-Fi, ZigBee and Bluetooth, which correspond to the 802.11a/b/g, IEEE 802.15.4 and 802.15.1, standards, respectively [13], [14].
For wireless condition monitoring and fault diagnosis, very few researchers have used Wi-Fi to send data to the base station. Hashemian et al. (2011) used an 802.11g to send vibration signals acquired at the motor and fans, which are part of the reactor building ventilation system. To confirm the performance of the wireless system, a wired data acquisition system was used and compared with the wireless one and the results displayed good agreement between wired and wireless systems [15].

Also, it is possible to use ZigBee technologies across different industrial applications in medical equipment, intruder sensors, embedded sensor equipment, smoke alarms and automated features for buildings, among other applications. ZigBee networks offer extremely low energy consumption, meaning that a device could possible function for over a year on just one alkaline battery. Considering these characteristics of the IEEE 802.15.4/ZigBee, this technological solution is well-suited to condition monitoring and fault detection for industrial machinery using a wireless sensor network.
In wireless sensor network based fault diagnosis systems, many studies have used ZigBee as a wireless standard to send different measured parameters such as vibrations [16], current [17] and temperature [3] remotely to a host computer, to be used for condition monitoring/ detecting faults. One of the successful applications of ZigBee as a wireless protocol used for data transmission can be found in fault detection and diagnosis based on induction motor stator current and vibration signals in which stator open phase faults and one and two bearing imbalance faults were successfully identified [17].

Bluetooth is also a candidate to substitute for implementing WSN, but this protocol has paid less attention based in Bluetooth's complex nature and power parameters which are insufficient for sensor applications [18]. Bluetooth-Low-Energy (BLE) is a new version of the traditional Bluetooth developed by the Bluetooth Special Interest Group (SIG) [19]. The specification for BLE is included within that for Bluetooth, with its extremely low power requirements making it suitable for use in devices with minimal battery power. This wireless protocol has many features and advantages that make it different from the other standards. For instance, Bluetooth devices are widely available, their cost is quite cheap and they offer low power consumption [12]. Dementyev (2013) found that among different wireless standards, BLE achieved the lowest power consumption, followed by ZigBee[20]. These benefits make BLE a suitable wireless technology for many wireless

condition monitoring systems and maintenance applications, including that achieved in this research.
In recent years, many researchers have studied the feasibility of using wireless transmission technologies for machine condition monitoring. Raj et al. (2013) studied and demonstrated the importance of using vibration signals measured using a MEMS accelerometer in fault detection of a three-phase induction motor. Their experimental results show that misalignment and loose mounting produces additional amplitude and frequency modulations, providing an easy and cheap way to detect and characterize both mechanical and electrical faults in the induction motor [21]. Kumar et al. (2016) investigated and evaluated the usage of a wireless sensor inside an induction motor and sent data through IEEE 802.15.4 wireless radio communication [22]. Their findings show that the quality of the wireless link is relatively good and the effect of magnetic fields on wireless link quality is not noticeable.

Besides, In [9], a the performance of wireless sensor was investigated by installed a tiny accelerometer on a reciprocating compressor flywheel. There results show that the running status of the compressor can be remotely monitored, allowing different leakages and motor faults to be diagnosed. Sarkimaki et al. (2005) concentrated on the capability of different wireless technologies to collect and transfer data used for condition monitoring, and the requirements to be considered when choosing a suitable transmission protocol were discussed [12]. Medina et al. (2017) implemented a low cost, low power and highly reliable remote condition monitoring system for a three-phase squirrel cage motor. The wireless sensors measured various parameters, including vibrations, temperature and current consumption, providing an effective way for mechanical fault detection. The data was sent to a remote PC through a wireless sensor network based on the IEEE 802.15.4 standard for further signal analysis [23].

Experimental work

One of the most important application of IoT, which is sending the data from some sensors to another destination, is applied in this experimental work. Figure 2 presents a diagram of the hardware system used in this study. It mainly consists of fan with different speed and wireless sensor node fixed on the fan to measure the temperature which is easy to measure and straightforwardly affected by any change in the system. As shown in Figure 3, the surface fan temperature is measured and then send to cloud using the NODEMCU esp 8266 E12 bored that contain Wi-Fi connection and a microprocessor in one bored allowing to control the sensor and send the data to the cloud.

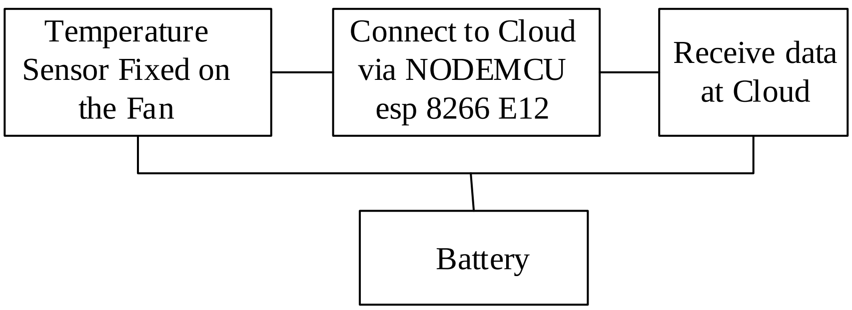

Figure 2 Block Diagram of the Practical System

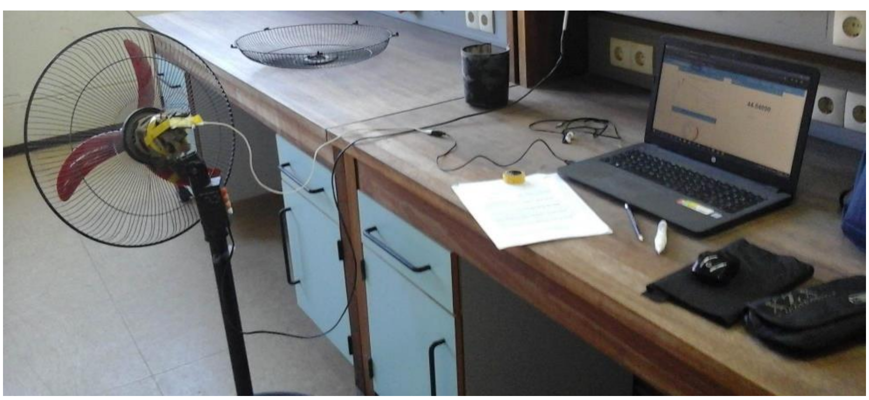

Figure 3 Sensor Installation

After all hardware were prepared and connected together to send data to cloud, the system was running at different speed and a table contain the temperature of the surface and the time of the measurement were stored in the cloud. The machine temperature information shouldn’t be recorded during the first 30 minutes as the fan is still unstable. So, after warming up the system temperature information was collected for the first speed. Thereafter, the fan speed was increased to the second level and data collected after five minutes to make sure that the system is stable after speed changing. The same procedure was repeated for the last speed level and all steps were done for healthy condition and faulty condition, which implemented by putting some loud on the fan.

Results and decisions:

Figure 4 displays the temperature sensor data that stored at the cloud. It can be seen that there is a large difference in the temperature value between the normal and the faulty conditions providing an easy and simple way to monitor machine condition through the IOT.

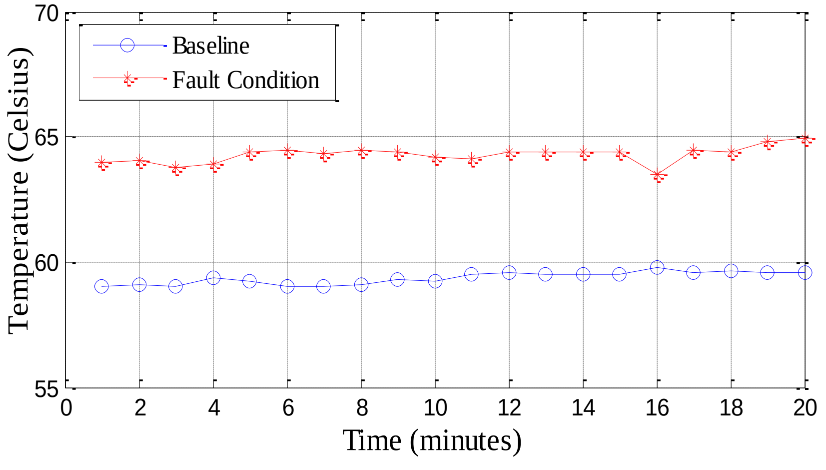

Figure 4. Fan temperature at maximum level 3

Also, it is clear that temperature value at specified time (minute 16) for the faulty condition is decreased which may occur due to some reasons such as drop in the internet connection or change in the sensor position.

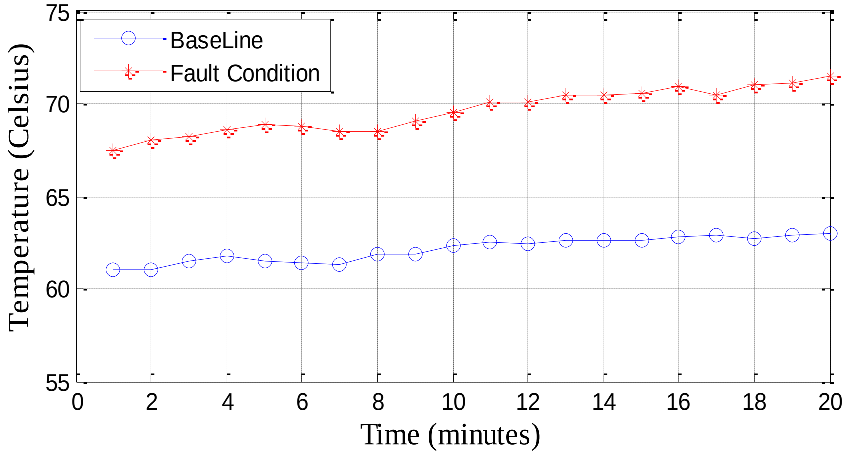

Figure 5. Fan temperature at maximum level 2

The temperature signals for the second and third speed are shown in Figure 5 and Figure 6. From these figures, it can be noticed that the temperature level of the fault condition is much higher than the normal condition making it easy to indicate the fault. As mentioned early, the temperature value at specified time is decreased which might be occurred due to Internet quality or sensor sensitivity.

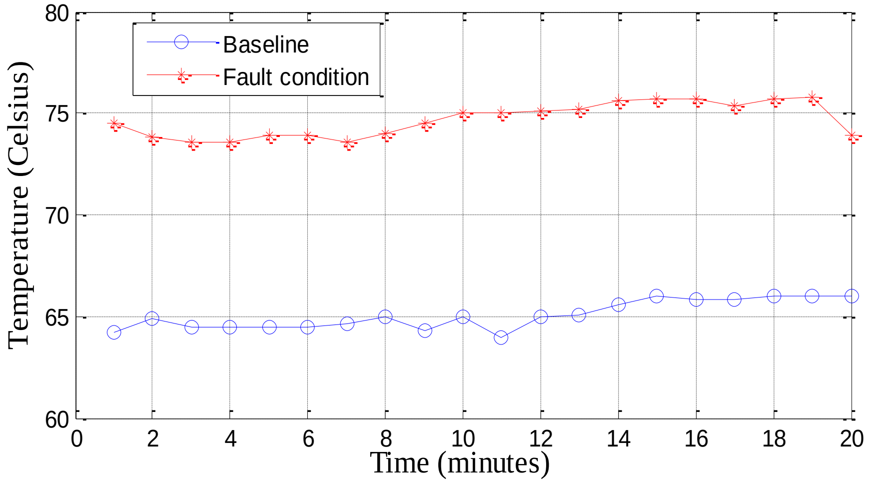

Figure 6. Fan temperature at maximum level 1

Conclusion:

In this paper, the temperature of two conditions at three different speed of a fan was measured and sent to cloud through Wi-Fi. The collected signals for healthy and faulty conditions were analyzed and used for machine condition monitoring and fault diagnosis. The experimental results show that the suggested method can clearly indicate the fault, therefore providing an easy and reliable economical way for machine condition monitoring and fault detection.

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