Remote Monitoring and Data Analysis for Textile Machinery

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Abstract. Internet of Things - The common vision in smart systems, having sensors coupled with information and communication technologies. Intelligent monitoring and management of devices are achieved via sharing of data through networked embedded devices. The paper aims at designing a response-based machine monitoring system, by observing the vital parameters of the machine and by leveraging the Thing Speak platform. The machine parameters like the vibration and oil level and the environmental observances like the humidity and temperature are measured to enable the cooling/heating of devices or for long-term statistics. The statistics are stored on the cloud to get accessed by the needy applications and supplementary procedures. The uploaded data is shown on the webpage as graphs for easy interpretation. In addition to all this, the paper aims to provide a solution to the frequent occurrence of thread breaks in spinning machines by using image processing done using a camera and a simple mechanism to actuate the camera from one position to another position.

Keywords: IOT, Cloud storage, Machine monitoring, Thread break, Webpage, Image processing.

1 Introduction

Inadequate maintenance and poor monitoring of machines decay its efficiency. An efficient insight into the various parameters of the machine improves the quality of the final product. This demands the collection of key parameters such as temperature, humidity, oil level, and vibration, etc., and further analyzing the data for predictive maintenance as shown in [1], [2], and [3]. Hence a generic product – A machine monitoring system that can be used for analyzing the vital parameters in any type of machine is designed. As the study of parameters varies from machine to machine, the application focus is constrained towards the thread breakage monitoring in spinning machines. This functionality can be applied to any of the textile machinery, where the thread is processed and their breakage is a frequent occurrence. The product supports the interfacing of multiple sensors.

A spinning machine that has thousands of spindles on each side, with a thin strand of thread transferred from one spindle to the other at high speed is considered. Here, the thread breakage is inevitable. As a common scenario, the machine operators called Siders are to splice the thread with greater difficulty and the process is time-consuming. This leads to the decay in production efficiency. The current solution of employing the Electronic Yarn Clearer (EYC) and Splicer equipment add cost to the machine. Recent research to detect the thread

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breaks in yarn is shown by [6], [7] and [8]. All these systems use laser and optoelectronic technologies. However, the proposed product detects the thread breaks at a much lower

cost with improved accuracy by applying the image processing techniques. This data is also uploaded to the cloud for further processing. The results of this processing are used for the predictive maintenance of the machine. This data can be further analyzed by machine learning models to predict optimum working conditions of the machine.

2 Proposed Work

In the proposed model, the machine parameters such as core temperature, humidity, rpm of the gears, oil level, current flow in the wires, vibration data of the machine structure, etc. are periodically monitored using industry- grade sensors as clearly depicted in [3], [5], [7] and [8]. The sensor signals are processed by the Central Processing Unit (CPU) – Raspberry Pi 4 microcontroller. Note that any microcontroller with sufficient processing power can be used to process the data. The microcontroller used will also control the response systems such as the air conditioning unit, heater unit, and automatic oil refilling mechanism, etc. using electromagnetic switches. Threshold values, which are the maximum and the minimum values of a particular parameter, are programmed into the microcontroller. Whenever the corresponding sensor reads values below the threshold, the appropriate response system is activated until the values are stable inside the threshold condition. As an example, the temperature of the environment around a spinning machine must be X° C. Whenever, the sensor reads a value greater than X° C, the air conditioning system will be triggered by the microcontroller to stabilize the temperature value within X° C. This functionality is similar to the system shown by [4]. Additionally, all the data collected from the machine is logged periodically into the Thing Speak database through the Internet. The data is fetched from the database and plotted in the form of graphs. These graphs are imported in the form of API to a custom-built website. This is the end interface available to the machine owner for remote monitoring of the machine. This data can be further analyzed using machine learning and artificial intelligence tools to perform predictive maintenance of the machine.

For the thread break detection, we consider the same spinning machine. The normal / break condition of the thread is captured as an image with a camera that moves from one end of the machine to another end by using a screw rod rotating on a fixed axis. The stepper motor controls the movement of the rod and hence the camera. The stepper motor in turn is directly controlled by the microcontroller. This enables precise movement of the camera. The threads moving from top to bottom in a spinning machine are shown in Fig. 1.

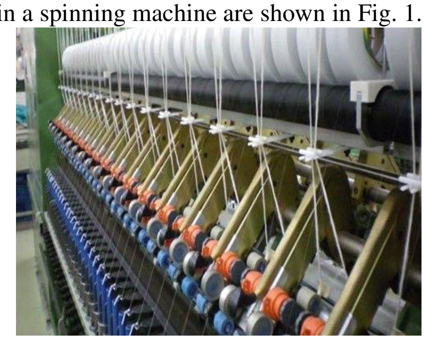

Fig. 1. Threads in a spinning machine.

- The captured image is sent to the microcontroller where image processing algorithms are applied to identify the break-in threads. If a thread break is detected in any image, the microcontroller alerts the machine worker to

repair the thread breakage. This system thus speeds up the detection process to ramp up production efficiency. This data is also uploaded in the Thing Speak Cloud. This is similar to the system shown in [2], [3], [4], and [5]. This data is used to find the frequency of the thread breaks on a particular spindle and to calculate the production efficiency. Fig. 2 depicts the hardware model of the proposed system.

- *Thread breakage detection mechanism for spinning machine*

The camera employed to capture the images covers five spindles or threads per frame. The camera moves in the horizontal axis on the screw rod from one end to another end of the machine, capturing images on the way. Thus, the camera moves in such a way that five different threads can be captured in each frame. It moves from one end to the other in this manner and captures the images on both the trips, from start to end and from end to start of the machine. Fig. 3 depicts the detection mechanism.

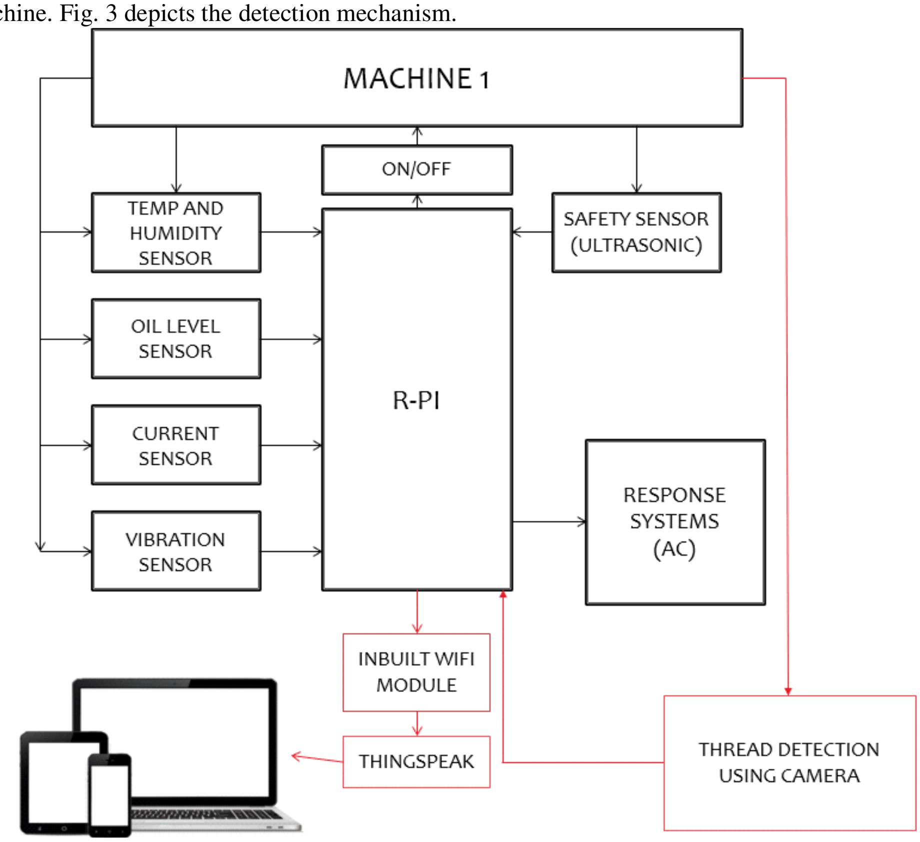

Fig. 2. Proposed hardware model.

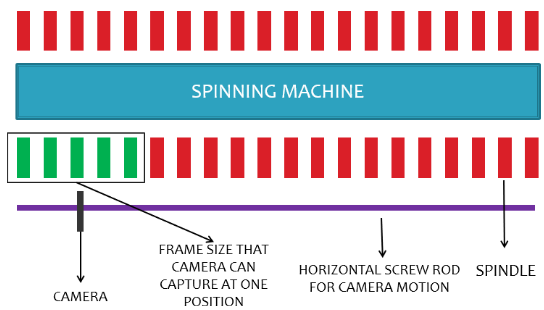

Fig. 3. Thread detection mechanism.

The microcontroller employs the image subtraction algorithm with a reference image, on the captured images to detect the thread break. The reason for employing the simple but powerful image subtraction algorithm is that the lighting, the shadow on every point of the machine will be the same and will not vary according to time or weather. When the thread breakage is detected in the image, the sector where the image is captured will be highlighted on an LCD screen. This eases the identification of the thread-cut zone/sector. Each thread break with the spindle number is uploaded to the cloud. The complete process of machine parameter monitoring and the thread breakage detection mechanism are illustrated in Fig. 4.

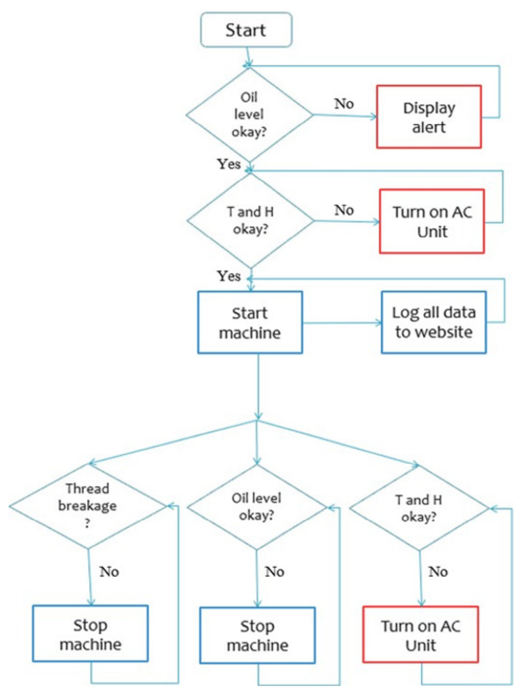

Fig. 4. The software model

3 Implementation

The prototype implements the hardware interface in Raspberry Pi 4 microcontroller, programmed using Python. Alternatively, any PC connected to the Internet through a WIFI can also be used. The system receives inputs from the temperature and humidity sensors, the vibration sensor, the oil level sensor (ultrasonic), the RPM sensor (infrared), the current sensor, and from a camera (raspberry pi camera) and additionally, a safety sensor (ultrasonic) to stop the machine in case of emergencies. The machine is allowed to start upon the satisfaction of two conditions:

- Under normal temperature and humidity values.
- The oil level should be above the minimum required value.

All the sensors are hardwired to the microcontroller. Industry grade sensors can be used to increase the efficiency of data sampling. Any number of sensors of the same or different types can be connected at various parts of the machine for maintaining optimum conditions. Further threshold values for individual sensors can be specified. As an example, the length of a spinning machine is very high such that the atmospheric temperature and humidity cannot be kept in check by using a single sensor. Thus, multiple temperature and humidity sensors are connected at various parts of the machine and they are all regulated by their respective threshold values.

The microcontroller collects the data from the sensors and uploads the same every 30 seconds to the Thing Speak cloud. Table 1 shows the assumed value of parameters for the sensors for testing the prototype.

TABLE I. PARAMETER VALUE CONSIDERED IN PROTOTYPE

Parameter	**Value**
Temperature	30^{o} C
Humidity	50%
Oil level	10 cm from the bottom of the tank
Vibration	20 kHz
Current	100mA
Safety sensor (Ultrasonic)	10 cm

For the thread detection part, the spinning machine is taken as a reference and the mechanism for moving the camera is constructed. Fig.5 shows the screw rod mechanism. The camera is mounted at the top of the screw rod mechanism

such that each frame of the camera contains exactly five threads. The camera is made to actuate linearly by rotating the screw rod. The rotation is taken care of by the stepper motor which is controlled by the microcontroller. The camera moves from one end of the rod to the other, thereby moving from one end of the machine to the other end. The camera captures images with exactly five threads in one frame which is processed by the image difference algorithm and the output is displayed on the LCD screen. The thread break status is indicated on the screen. Thus, the break is attended to immediately by the siders. This process saves time and is highly accurate since the lighting of the environment never changes.

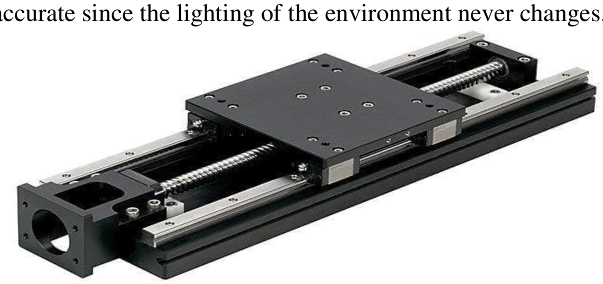

Fig. 5. Screw rod mechanism

The relative efficiency of the machine is calculated based on the time taken to convert the given raw material into the finished product in a machine regulated by the proposed system (tregulated) compared to the time taken to convert the given raw material into the finished product in a machine not regulated by the proposed system (tunregulated). This is shown in (1).

LCD screen is mounted in front of the machine to display the status of the thread break in any spindle of the machine.

The thread break detection system is constructed using the screw rod mechanism and the camera is mounted on the top of the plate attached to the screw rod. Initial calibration of the system is required as well as the threshold values for all the parameters have to be manually entered initially. All the threshold values will be automatically updated by the microcontroller after it receives the result of the analysis carried out MATLAB scripts in the cloud. These threshold values change according to the production efficiency calculated. This is done in order to maintain the production efficiency at an optimum value. Note that the automatic update of the threshold value starts only when there is enough data in the cloud that can be analyzed. Naturally, the update will start only after the machine has been operated for a few days and there are at least 4 sets of data each giving one production efficiency. The efficiency for the first one is calculated by using the efficiency of a machine that is not using the proposed system. The subsequent production efficiencies are calculated based on the previous production efficiencies in to push the machine towards optimum production.

Fig. 6 shows the control panel for the machine and the response systems in the custom-built website. The values of the buttons that are ON or OFF are communicated to the machine using the Internet. Note that the system should be connected to a WiFi network with internet access for data update to the cloud. However, the system can also work in standalone mode without data update to the cloud in cases of Internet failure. All the programs used in the system are threaded to increase the degree of multiprogramming as well as provide independence to every other program running in the background.

$$\eta = (regulated/tunregulated) \times 100 \quad (1)$$

Finally, all the data uploaded to the cloud is visible to the machine owner. For ease of use, a custom-built website is developed which shows the real-time value of all the sensors thereby indicating the status of the machine. The data is fetched from the cloud and is shown as graphs on the website. Also, remote access to the machine is given to the machine owner who can directly switch on and off the machine using the buttons available on the website. Control to other response systems is also given on the website such as the air conditioning unit etc. As further response systems are added to the machine, the control for the same can be included in the website also. Furthermore, all the data collected is stored along with the timestamp for further analysis using MATLAB or using any machine learning or artificial intelligence models.

4 Experimental Evaluation

The prototype is tested using the LR G5/1 Ring Frame spinning machine. The raspberry pi microcontroller is isolated at a safe position from the machine. The sensors such as the temperature and the humidity sensor, the vibration sensor, the current sensor, etc. are placed at various strategic parts of the machine and connected to the microcontroller. All the sensor values are monitored through the terminal of the

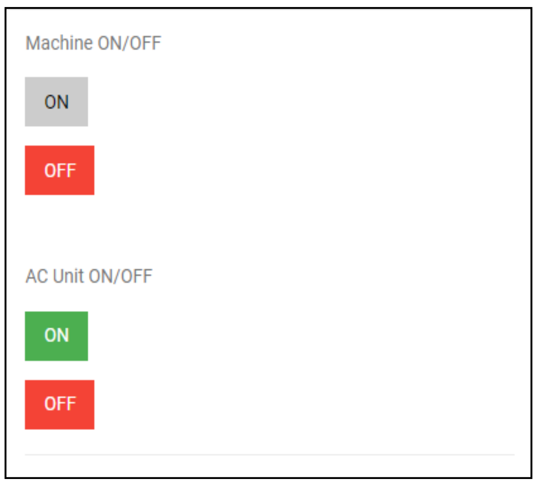

Fig. 6. The machine control panel in the custom-built website

Fig. 7 shows the output data graphs at the custom-built website. These graphs are imported as API (Application Program Interface) from the Thing Speak cloud. All these graphs are real-time based meaning that they are updated every time a new data record has been updated in the cloud database. The sample design of the custom-built website incorporates a left sidebar having START / STOP buttons for microcontroller as well as in the custom-built website. An machine control and response system (AC) control for manual operation. The graphs are displayed in the center. Individual graphs for each parameter are plotted to give better readability and provide efficient monitoring of the machine. Since the website is linked directly to the cloud and not to the localhost, that is the microcontroller itself, the website can be accessed through any system from anywhere in the world. Several accounts with privileges have been created to gain access to the website. Only the accounts with administrator access will be capable of controlling the machine remotely while the others will allow only to see the real-time parameters of the machine and learn about the production efficiency and other results of data analysis.

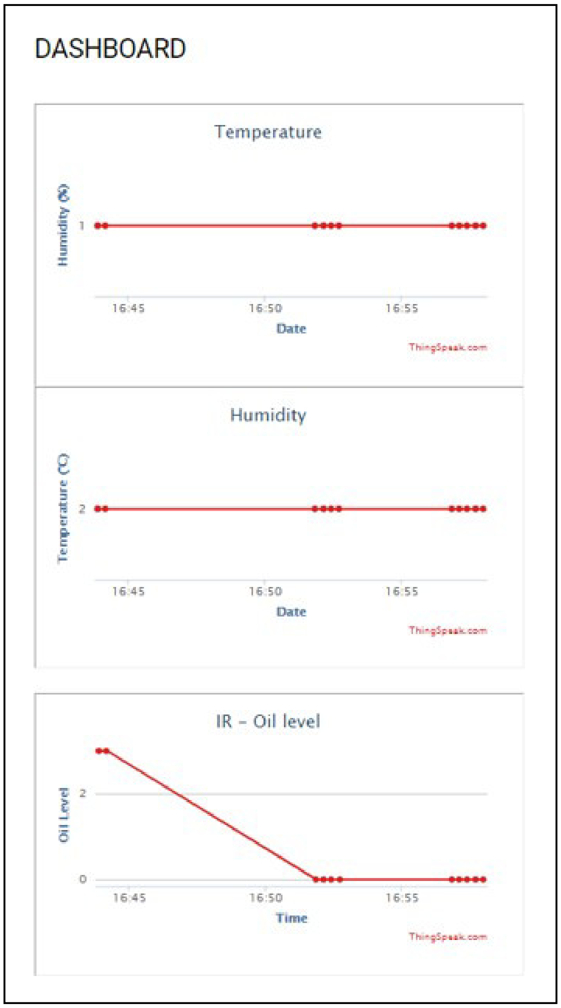

Fig.7. Custom built website with data graphs

Graphs can be analyzed further using MATLAB tools. Alerts are displayed on the website and the LCD screen simultaneously, for any deviation in parameters, demanding actions from the response systems. The sample alert messages obtained from the test results are depicted in Fig. 7.

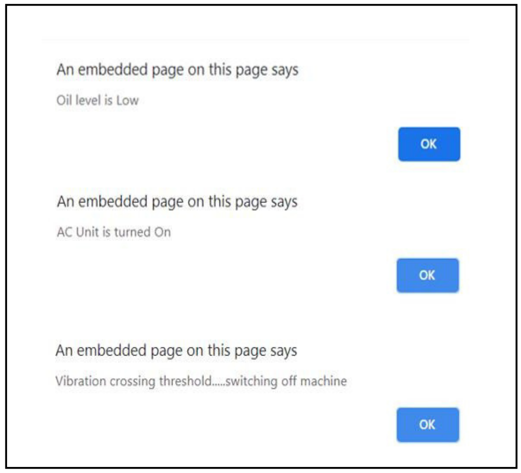

Fig.8. Alerts in website

The prototype is tested using the ring frame machine. The various sensors are placed in strategic portions of the machine. The temperature and humidity sensor is placed near the spindles where the thread is transferred from top to bottom. The oil level sensor is placed in the oil tank under the machine. The vibration sensor is placed on the panel enclosing the motors and the gear assembly. The current sensor is wired serially to the DC lines feeding the motors. For the prototype, only the line going to one of the motors is tested. The safety sensor (ultrasonic sensor) is placed on one of the panels of the machine. The brain of the prototype, the raspberry pi 4 was placed along with the safety sensor on the machine panel. The raspberry pi is provided with a WiFi network with Internet access for uploading the data. The thread break detection system is set up, as previously explained, with the help of a screw rod controlled by a stepper motor. Data is continuously sampled from the sensors and is analyzed using the python program to find new threshold values to find the optimum machine parameter values for efficient production. Thus, comparing with machines without this monitoring system, the prototype increases the production efficiency of the machine by 5%. This value can be further increased by using industry-grade sensors with a higher sampling rate, increasing the number of sensors used, using multicore processors for computation, and improving the algorithm used to calculate the threshold values. Usage of machine learning models can significantly ramp up the threshold calculation once a sufficient dataset has been collected. In addition to this, the thread break detection time was cut down to seconds compared with the manual checking which takes up to minutes depending on the workers' efficiency.

5 Conclusion

A response-based remote monitoring system to monitor and auto-control machines is implemented with a specific application for thread-break analysis of spinning machines. This product improves the production efficiency of the machine by monitoring its vital parameters, comparing with the benchmark statistics, and taking appropriate response actions. The periodic monitoring of key parameters indicates the sickness possibilities at early stages and hence the actions

to avoid a total shutdown of the machine. Moreover, it is a cost affordable system. The system design can be further enhanced by using machine learning / artificial intelligence techniques.

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