Design of conveyor utilization monitoring system: a case study of powder coating line in sheet metal fabrication

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Abstract. Conveyor is a very useful equipment to replace manpower in transporting the goods. It highly influences the productivity, production capacity utilization and eventually the production cost. This paper proposes a system to monitor the utilization of conveyor at a low cost through a case study at powder coating process line in a sheet metal fabrication. Preliminary observation was conducted to identify the problems. The monitoring system was then built and executed. The system consists of two sub systems. First is sub system for collecting and transmitting the required data and the second is sub system for displaying the data. The system utilizes sensors, wireless data transfer and windows-based application. The test results showed that the whole system works properly. By this system, the productivity and status of the conveyor can be monitored in real time. This research enriches the development of conveyor monitoring system especially for implementation in small and medium enterprises.

1. Introduction

Conveyor is a technology which commonly used in industries with high speed and large volume of production. Conveyor has a function as material handling equipment to transport raw materials, work in process (WIP) materials or finished products from one station to another. It is very useful to replace manpower in transporting the goods. This technology was first popularized by Henry Ford in the era of second industrial revolution (beginning of 20th century) to support his automobile mass production. Basically, a conveyor system consists of belt or chain which is driven by rotating electric motors. The goods are put on the belt and move to particular location with a certain speed. Nowadays there are many conveyor systems available which are intended to meet various requirements of industrial process [1].

Conveyor systems are usually used in mass or continuous production systems. As explained in [2], those kind of production systems have several characteristics such as large volume of products, predetermined sequence of operations and higher rate of production with reduced cycle time. Those kind of production systems have risks related to the line balancing and the availability of the machines. If there is a problem in a certain workstation, it can immediately slow down the production speed or even stops the entire production line if a machine’s breakdown is occurred. As material handling equipment, conveyor can be considered as a machine also. Conveyor system will highly influences the productivity, production capacity utilization and eventually the production cost. That is the reason why conveyor system plays very important role in production performance.
In order to maintain or to improve the production performance, an accurate production monitoring system is required [3]. This prevails to any kind of production system including productions which utilize conveyor systems. There are some research which have been carried out to create conveyor monitoring systems. Design proposed by [4] aimed to monitor and detect the fault occurring in the coal conveyor using PLC (Programmable Logic Controller) and SCADA (Supervisory Control and Data Acquisition). It was intended to replace manual control which has many disadvantages such as being the major cause of frequent accidents. Another similar research was done by [5] using multivariate data analysis application for fault detection in belt conveyor drive unit. Those previously mentioned research focused only on the condition of the conveyor systems to avoid unexpected breaks in production but did not take into consideration the utilization of the conveyor system. Research by [6] proposed a model to predict and to evaluate the performance of conveyor system. It had a purpose to improve the flows of WIP materials and information with real time traceability and visibility. However, RFID (Radio Frequency Identification) technology has to be adopted to implement this model. Research by [7] resulted a system which was not only able to monitor but also to control the conveyor system. But the system was still in the prototype form and wasn’t yet proven to be implemented in real industry.

In order to enrich the development of conveyor monitoring system, this paper proposes a system to monitor the utilization of conveyor at a low cost especially for the conveyor which already existed in a production line. The components used were chosen in such a way as to reduce the investment cost but not eliminate the main function. Research was conducted through a case study at powder coating process line in a sheet metal fabrication owned by PT. ATMI Solo.

2. Research Method

Preliminary observation was conducted to identify the problems exist in the company by interviewing the related staffs. Important information such as production layout, input and output of the process, type of the conveyor system, mechanical construction, electrical control of the conveyor system and other related information were collected. All information gathered were then used to determine the system’s specification. The specification is taken from [8] which recommends guiding questions to build production monitoring system. Basically, those guiding questions are explained as follows: what data should be collected and how to collect them, how to save the data, how to connect and communicate the data and how to visualize the data. For the measurement function, direct method was used [9]. The method utilizes laser and proximity sensors which are capable of directly measuring the quantity of products. The signal processing method is taken from [10]. The signal generated by the sensor needs to be processed to produce a good quality of signal. The signal is then reprocessed with a specific descriptor feature so that the information contained can be understood by the user as intended. Examples of feature descriptor are root mean square, peak, mean, standard deviation, etc. The result of signal processing by descriptor is then displayed so that users can access and view information easily for analysis purposes.

There are some works that need to be considered when building the monitoring system, which are mechanical design, electrical wiring and software programming. Afterwards, the system is deployed and tested. The tests consist of verification and validation. Verification means that all functions of the system are tested one by one. If the verification demonstrates proper results, then the system needs to be validated by the associated user. If there were any unsatisfied result related to the specified function, the system is then reviewed to find the solution. The validation results will determine whether the system solves the problem. If the overall test result is feasible then the proposed system can be recommended for implementation.
3. Results

3.1. Observation result and problems identification
Sheet metal fabrication at PT. ATMI Solo produces various type of office equipments such as chair, desk, drawer, filling cabinet and other similar products. The production begins from material cutting, punching, and bending process. The work in process parts are then hanged on the conveyor as shown in figure 1(a). The existing conveyor system is classified as open track-overhead chain conveyor [1]. The conveyor has length of 331.2 meters with maximum load capacity of 5 tons. The conveyor runs continuously at a certain low speed. The parts are then moved to the washing and drying facility. The parts need to be painted with specific colour according to the customer order. This process involves powder coating process which is done manually by the operator as shown in figure 1(b). Subsequently, the coated parts need to be heated by the oven facility in order to make the colour permanent. Finally the parts are ready to be assembled into finished products. There is a control panel which is used to turn on and to adjust the speed of the conveyor system. Related operators have an authority to control the conveyor through the control panel in accordance with the situation occurring in production. The productivity is monitored manually, in which an operator writes the number of processed parts on a paper. In the end of workday, the paper is delivered to the supervisor for data checking and validation.

There are three problems identified during the observation. First problem deals with the implementation of manual production monitoring system. The supervisor can only evaluate the productivity data at the end of workday so there is a delay for data collection and analysis. The conveyor system frequently stops because of several causes which are intentional or unintentional. The intentional causes usually come from the unavailability of the operator and the problems occurring on a certain production process. The related operator will deliberately stop the conveyor for a while. This intentional causes have a significant effect on the conveyor utilization.

![Figure 1](a) ![Figure 1](b)

Figure 1. The conveyor system: (a) parts are hanged on the chain, (b) work area for powder coating process.

Longer idle time of the conveyor means lower utilization which results to lower level of productivity. Unfortunately the supervisor is unable to always keep on eye to detect this condition and this is the second problem. The unintentional causes can emerge from the overloading or problems inside the conveyor system which force the system to shutdown by itself. If this happens, the operator should inform the supervisor who then call the maintenance unit to fix the problems. According to the maintenance unit, this condition can be prevented if there is information about the operating hours of the conveyor system. All this time, the operating hours data of the conveyor system are never recorded and that is the third problem.


3.2. System design

Considering the above conditions, it is necessary to design a system capable of monitoring the conveyor utilization automatically. First, we need to determine the system specification using the method proposed by [8]. Table 1 shows the specification. The data need to be collected are the number of processed parts, conveyor status, duration of status and total operating hours. Number of processed parts represents the level of productivity and are detected using proximity and laser sensor. Proximity sensor detects the hangers and laser sensor detects the parts. Conveyor status provides information whether the conveyor is currently at the status of running, idle or down. Duration of status informs the user the duration time of each status in a day. Total operating hours shows the accumulation of conveyor operating hours since the monitoring system is installed.

| Guidelines questions                                      | Results                                                                 | Technology                               |
|-----------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------|
| 1. Which data should be collected and how to collect the data?| a. Number of processed parts by detecting the existence of part.         | a. Proximity and laser sensor.           |
|                                                           | b. Conveyor status by detecting the electricity of conveyor control panel. | b. Relay.                               |
|                                                           | c. Duration of stand by and running by measuring the conveyor motor’s rpm (rotation per minute). | c. Tachometer measuring.                |
|                                                           | d. Duration of shut down by detecting the electricity of conveyor control panel. | d. Relay.                               |
|                                                           | e. Total operating hours                                                | e. Tachometer measuring.                |
| 2. How to save the data?                                  | a. Temporary at the work area                                           | a. SD card module                        |
|                                                           | b. Permanently, PC workstation at the management office               | b. MySQL                                |
| 3. How to connect and to communicate the data?            | a. Sensor node to transmitter                                           | a. Cable wire                           |
|                                                           | b. Transmitter to receiver wirelessly                                   | b. ZigBee protocol                      |
|                                                           | c. Receiver to PC workstation                                          | c. USB 2.0 cable                        |
| 4. How to visualize the data?                            | Windows based application                                               | Visual Studio 2013 and MySQL             |

The status and its duration data are measured by relay and tachometer circuits. If the conveyor was turned off, then the relay will give “OFF” signal and it will show the shut down status. Motor conveyor rotation is measured by tachometer and indicates that the conveyor is in running state. If the motor is not rotating but the conveyor system is still turned on, the tachometer will give no signal and the conveyor is considered in the idle state.

The data from the measurement instruments are stored temporary in a SD (Secure Digital) card module which then are transmitted wirelessly to a PC workstation and being saved permanently. The wireless communication utilizes ZigBee technology. It is an IEEE 802.15.4-standard for a communication protocols used to create personal area networks with small, low-power digital radios [11]. There is a windows-based application which is dedicated to visualize the data so that the user can make use of the data easily.
The proposed monitoring system is depicted in figure 2. It consists of two sub systems, data acquisition and data visualization. The data acquisition sub system has a function to acquire data by means of sensors and then transmit them to data visualization sub system. Relay and tachometer sensor are installed on the conveyor’s control panel. In particular, the proximity and laser sensor need to be mounted on a mechanical frame which is located next to the conveyor chain. The design of the sensor-mounting frame and its installation are shown in figure 3(a) and 3(b) respectively. All of the signals measured by the sensors are being the input for the transmitter circuit board which is an electronic circuit based on Arduino microcontroller.

The data visualization sub system has a function to receive the data transmitted by data acquisition sub system and then visualize them to the user. This sub system is located at the fabrication management office which is approximately 30 meters from the transmitter. The data are processed by means of a microcontroller circuit and a windows-based application. Figure 4(a) shows the screenshot of the monitoring system application’s main view. The application displays the information about recent date and time, total operating hours, recent status of the conveyor, number of processed products and duration of each status for a particular day. Through this monitoring system, the supervisor is now able to monitor the productivity in real time. He can easily supervise the status of the conveyor system remotely from his office without having to visit the shop floor. Information about total operating hours is useful for scheduling the maintenance activity. It can prevent any failure of the conveyor operation. The user can also retrace the data to any date and any time because the system records all status since it was firstly installed. There is an additional feature for the user to easily save a range of data at a certain date and time into spreadsheet form (MS Excel) as shown in figure 4(b).
Figure 4. Monitoring system application: (a) main view, (b) export to spreadsheet feature.

4. Conclusion

In this paper, we developed a conveyor utilization monitoring system for powder coating line in a sheet metal fabrication. The monitoring system consists of data acquisition sub system for collecting and transmitting the required data and data visualization sub system for displaying the data. The test results showed that the whole system works properly. Due to the implementation of the system, the productivity and status of the conveyor can be monitored in real time. Thus, conveyor utilization can be improved and actions can be taken immediately in response to any status of the production line. Information about total operating hours allows maintenance unit to reduce the level of conveyor’s down time. The data recording feature also enables user to retrace any data in the past period for any evaluation purposes. The hardware for this proposed system needed relatively low cost investment which was about $ 350. This research enriches the development of conveyor monitoring system especially for implementation in small and medium enterprises. By using more sophisticated sensors and signal processing algorithms, this system can be upgraded to detect and to prevent any fault of the conveyor system.

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