A predictive maintenance application for band saw machines

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ABSTRACT: Digitalization of production lines is the most important issue in the world in recent years. One of the most important issues of this digitalization for today's manufacturing enterprises is the need to update maintenance practices and maintenance work processes in production lines with technological developments. The fact that sawing machines are in the first part of the production lines shows that it is of critical importance. In this study, it is aimed to determine the necessary principles for digitizing sawing machines and integrating the predictive maintenance system into the machine. As a result of the evaluation, the necessity of real-time data collection, data analysis and artificial intelligence algorithms for predictive maintenance requirements has been determined.

KEY WORDS: *Manufacturing, Sawing Machines, Industry 4.0, Predictive Maintenance*

1. INTRODUCTION

Today's technological developments, increasing energy need, changing and developing competition conditions make maintenance and repair activities of enterprises even more important. In this direction, different maintenance strategies have been developed.

Maintenance is defined as ensuring that equipment and systems operate efficiently without malfunctions throughout their life cycle in order to maintain their functions with the best performance. Unexpected failures cause production losses and costly maintenance costs. In this direction, maintenance methods should be applied to ensure production and line efficiency. The fact that the saw machines are in the first part of the production lines shows that they are of critical importance.

Reactive maintenance occurs once a piece of machinery has already failed. In contrast to proactive maintenance, no analysis, tracking, or anticipation is required to carry it out. As the name implies, work is only completed in reaction to a breakdown, see Figure 1.

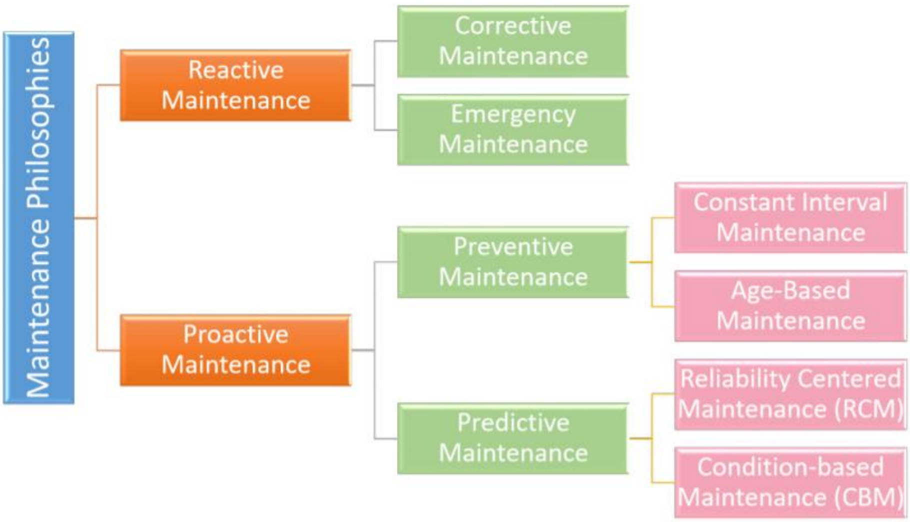

Fig 1. *Classification of Maintenance Philosophies [1]*

2. THE PREDICTIVE MAINTENANCE APPROACHES

In the predictive maintenance concept, a prerequisite for the condition of the system must be met to maintain the system. The aim is to keep the system at the highest level with the least number of maintenances required, thus reducing maintenance costs [2]. It consists of 2 main parts as Reliability Centred Maintenance (RCM) and Condition-Based Maintenance (CBM). RCM tries to improve the reliability and usability of the most crucial points in the system and minimize system failures and maintenance costs. The main aim is to find the optimum point where system reliability and profitability intersect with the number of maintenances [3]. CBM enables the maintenance decision to be performed in regard to the actual state of the equipment or system. CBM indicates that maintenance should be carried out when specific indications indicate the possibility of poor performance or unexpected failure. For a machine, these symptoms are detected by visual inspection, performance data, vibration data, and analysis of planned test results. A proper CBM plan reduce maintenance costs considerably as a result of avoiding unnecessary maintenance [4].

3. AN APPLICATION FOR BAND SAW MACHINES

3.1 The Band Saw Machines

Band saw machines are saws that consist of a continuous metal band (called the band saw blade) that rides on two wheels rotating in the same plane. A band saw machine contains a round and serrated blade, and can be used to process metal materials. Depending upon the lateral flexibility and the width of the band, a band saw machine can be used for straight, irregular or curved shape cuts. In a band saw, work pieces are fed into the cutting edge of the machine. The band saw machine cuts by drawing a continuous metal band across the work piece. The band saw blade is supported and driven by a drive wheel and an idler wheel. A sample of the band sew machine was given in Figure 2.

Fig 2. *A Band Saw Machine [5]*

3.2 The Predictive Maintenance Application

3.2.1 Current and Linearity Analysis for Band Saw

Among several techniques to detect cutting force during cutting process, driver current and deviation control low cost and high efficiency methods. Cutting force directly affects surface roughness and surface steepness are Surface roughness and surface steepness are important outputs of the cut quality in sawing. These outputs can be controlled with the current drawn by the cutting tool and the inductive distance sensor to be placed on the cutting tool.

Many engine data can be received via the EtherCat protocol. EtherCAT (Ethernet for Control Automation Technology) is an Ethernet-based fieldbus system invented by Beckhoff Automation. The protocol is standardized in IEC 61158 and is suitable for both hard and soft real-time computing requirements in automation technology. The goal during development of EtherCAT was to apply Ethernet for automation applications requiring short data update times (≤ 100 μs) with low communication jitter (≤ 1 μs) and reduced hardware costs [6].

Motor current set value is set as 3 amperes. With the real-time current information to be obtained from the saw motor, the motor speed can be reduced automatically in case of strain.

In addition to the current data, it is aimed to make straight cuts by checking the perpendicularity with the deviation sensor placed on the cutting tool. With the inductive displacement sensor to be placed in front of the cutting tool, linearity control is performed in real time at the time of cutting. Since high precision cutting perpendicularity is aimed, perpendicularity limits are set as ± 0.2 mm and the sensor is positioned at a distance of 1.2 mm.

Omron ZX-EM02HT inductive displacement sensor is used for deviation detection. Linearity and measurement distance graphic of the sensor is given in the Figure 3.

The current graph of the motor driving the cutting tool was drawn with 100ms sampling (Figure 4).

The deviation graph of the cutting tool was drawn with 100ms sampling (Figure 5).

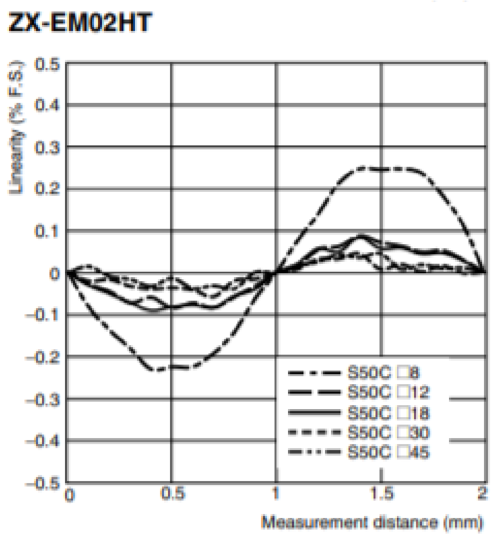

Fig 3. *ZX-EM02HT Linearity – Measurement Distance Graphic [7]*

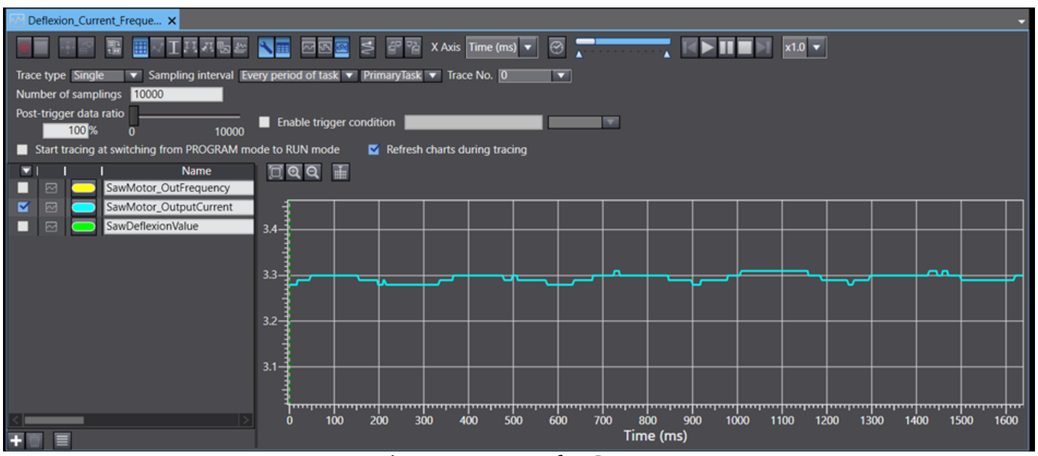

Fig 4. *Data Trace for Current*

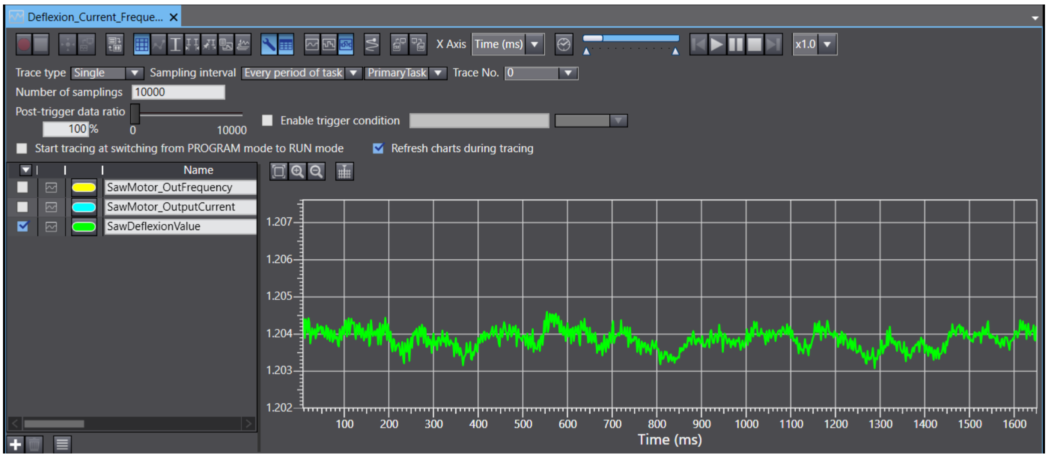

Fig 5. *Data Trace for Deviation*

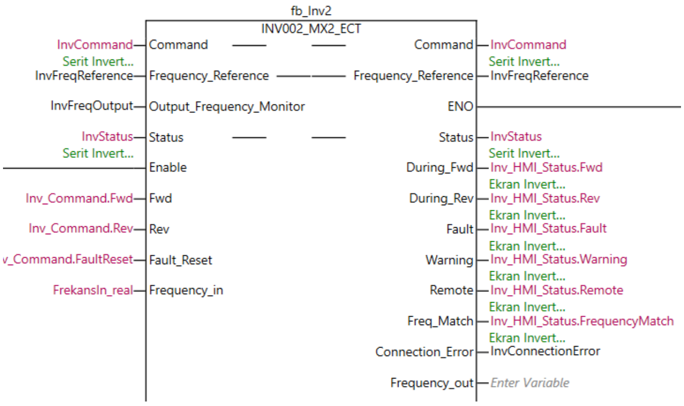

Fig 6. *Motor Driver Control Block*

3.2.2 Detection of Sensor Faults

Saw machines have many sensors to collect data. Conventional digital sensors produce zero or multiple signals for the situation. In order to design intelligent machines within the scope of Industry 4.0 transformation, it was felt that digital sensors should provide information to the user by creating additional data indicating the sensor operating status besides zero and one values [8]. For this reason, IO link sensors have started to be used frequently in the industry. IO-Link (IEC61131-9) is a point-to-point communication protocol that supports IO-Link and provides bidirectional exchange of data.

IO links series photoelectric and inductive sensors are placed on the band saw machine. Thus, two-way communication with the sensors is provided. For example, when the sensor's performance is degraded due to contamination, the sensor can issue an alarm so that the situation can be corrected without stopping the machine. The ability to send new parameters to sensors is particularly useful for machines working with multiple products; because this feature eliminates the need for manual intervention during changes in many applications.

Thanks to the IO link protocol, the detection data of the photoelectric sensor can be received from the PD0, while stable operation, warning and alarm information can be obtained from the PD1.
Bits and assignments are shown in Figure 7.

3.2.3 Vibration Analysis for Ball Screw

The ball screw is a transmission device that converts linear motion into rotary motion or rotary motion into linear motion, and it has the advantages of high position accuracy, load capacity and fatigue life. Ball screw systems (see Figure 8) generate vibration signals when they are operated. when the system runs continuously the various frequency components of vibration signals represent different characteristics pertinent to each mechanical and the amplitude of frequency changes.

The vibration analysis method is the most applied and the fastest method among predictive maintenance methods. In this method, with the help of a receiver that converts the vibrations into an electrical signal. The measurement is taken on the machine and the electrical signal formed as a result of this measurement is transferred to a device that processes it. This information is transferred to the controller, analysed with the help of an analysis software, and a conclusion is reached about the machines [10].

4. CONCLUSION

Studies on predictive maintenance are topics that are on the agenda of today's machinery manufacturing industry and user-friendly solutions can be produced in many areas. These studies can generally be summarized as detecting and interpreting vibrations on the machine and taking the necessary precautions.
In this study, the necessary criteria for predictive maintenance integration into the band saw machine were determined. Field tests and analyses related to current and deviation for the cutting tool, field tests and error analyses on the sensors used to collect data were carried out.
It has been observed that surface roughness and perpendicularity outputs can be obtained with current and deflection control in particular for band saw cutting machines. Apart from this, it has been determined that manual intervention is prevented with IO link sensors.
The ball screw part, which was briefly introduced in the article, was left to the next stage of the work.

Byte0 (PD0)	Assignment	Details
7 6 5 4 3 2 1 0	Monitor output	The Sensing data are output as eight bits (0-255).

Byte1 (PD1)	Assignment	Details
0	Control Output1	0:OFF 1:ON
1	Control Output2	0:OFF 1:ON
2	Reserved	0
3	Instability Alarm(Non-Light Receiving)	0:Stable 1:Unstable
4	Instability Alarm(Light Receiving)	0:Stable 1:Unstable
5	Reserved	0
6	Warning	Diagnostic output when the sensor cannot continue operation due to a recoverable factor such as a load short-circuit or a service data error 0:Normal (OFF) 1:Error (ON)
7	Error	Diagnostic output when the sensor has an internal error such as the emitting circuit destruction and replacement is needed 0:Normal (OFF) 1:Error (ON)

Fig 7. *Process Data for Photoelectric Sensor [9]*

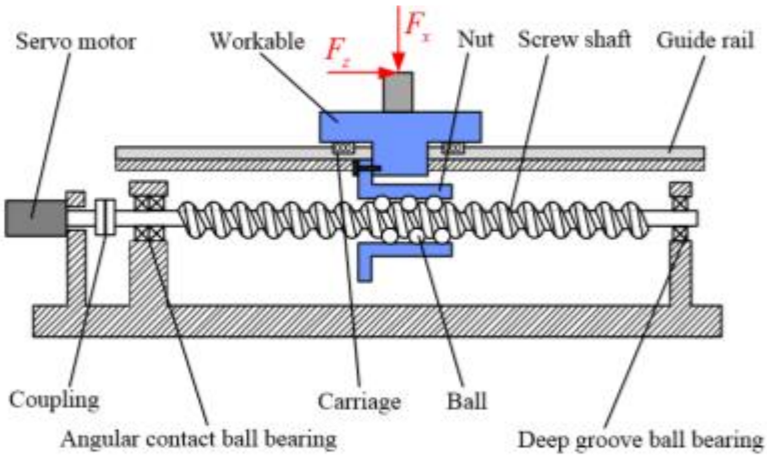

Fig 8. *Structure of Ball Screw Feed System [11]*

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