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The Analysis and Implementation of Remote Production Monitoring System in Manufacturing Industries

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Abstract

The emergence of the fourth industrial revolution (IR4.0) turns manufacturing process into digital environment. In this transition, new technology especially the Internet of Things (IoT) play an important part in the global market rivalry. In order to shift manufacturing companies to the Internet of Things, it is crucial to connect their activities to the digital world using smart sensor systems. To overcome with this problem, this project presents a remote monitoring system for shop-floor and based on the IoT standard. This project is also about analyzing and developing a Remote Production Manufacturing System (PMS) framework and online tool condition monitoring system according to the Internet of things requirements (IR 4.0). The system is designed to establish a data acquisition and monitor the production shop floor remotely. For further processing, visualization and analyses, the monitored data are transferred to a cloud server using MDC-MAX solution. The developed system follows the IoT model to connect physical manufacturing with the cyber world and offer integration capabilities with existing industrial manual systems. Monitoring device installation is validated using a CNC milling machine on an industrial laboratory shop floor.

Keywords: Remote Monitoring System, Production Monitoring System, CNC Milling Machine, MDC-Max solution

I. INTRODUCTION

Computer Numerical Control (CNC) machine tools are now progressing into high-precision high-speed and complex practical machining. According to Kunpeng Zhu and Yu Zhang[1], machining monitoring system is critical for intelligent machining process control to produce complex geometric features and precision components.

Production is the basic focus of the manufacturing industry. The miniaturization of machine tools will lead to better space usage, reduced cost of production and lower energy consumption according to Rasidi et.al [2]. Since this drives value and profit, it is crucial to have a proper check and control over it by having it monitored. Absence or ignorance in the same leads to issue, problems, and losses. Despite the fact that production is the key function of the business, only a few companies keep a regular check and constantly monitor in-situ activities on their shop floors.

The problem in manufacturing to the manufacturer is the speed at which they can comply with system service in case of failure. Normal practice, this generally meant a real failure, resulting in days of downtime, discarded parts and delayed order . For after-sales support, the consumer expects to be solved with limited delay when too many service calls entail high prices and time-consuming on-site visits. Support teams send off and parts are repaired/replaced, but all this causes delay and extended time. To foresee the need for maintenance, conventional programmes required using the machines historical details, or merely setting maintenance plans, whether or not they were applied. Industry 4.0 software offers analytical instruments that help OEMs grasp the technical causes and environmental circumstances that contribute to system failures, as stated by Rasidi et.al[2]. Whether it is vibration, temperature, pressure or other performance indicators, MDC-Max solution will use this programme to evaluate computer data from their IoT-enabled computers for predictive maintenance.

Indeed the unique selling proposal that MDC-Max solution and other equipment providers can provide their customers using remote machine control, allowed by industrial IoT, is part of the post-sale service kit. One of the advantages of remote monitoring is by reducing downtime, as it is an important part of keeping manufacturing levels up and costs down. Remote computer monitoring will capture data on any unit's activities and send the data back through the cloud, allowing the device to have peak service response time.

The service will entail a long and expensive on-site visit and potential inquiry into the problems being encountered. A maintenance team could not immediately detect at a glance which pieces failed, resulting in a manual method of inspecting each part. Instead a remote monitoring system allows the system to access issues from anywhere via data. The smallest change in a tool path can be achieved easily and effectively.

Beyond operation, the answer is the ability to predict and even avoid breakdowns that have a significant effect on the manufacturing cycle by evaluating and analyzing the data generated. Predictive maintenance that can recognise any exceptions or historical trends and service the machines until a problem occurs, restrict the effect, and the equipment can review the available data. It also means that the manufacturer does not need to maintain a substantial inventory of the replacement components, but rather to operate on a just-in-time basis.

According to Willem[3], data can be used by the service departments to gain insight into the readiness and condition of customer equipment, identify maintenance opportunities with analytics and reporting, predict and provide early warning of possible equipment failures, highlight high risk areas leading to machine downtime, or even take proactive measures until the problem affects the machine of a customer.

Most of the existing CNC monitoring system performs one-way communication functions, either on system parameters or on process measurements, due to lack of interaction and data acquisition of the computer. As reported by Altintas et al. [4], the custom-developed specific machine tool monitoring system lacks the adaptation and reconfiguration of the machining process. The acquisition and evaluation of one-way data leads to a less intelligent machining system[5],[6].

There is limited CNC machining monitoring in the applications. On the contrary, due to the advancement of the modern CNC system and sensing technologies, the method produces a large number of heterogeneous "big data" such as process parameters, measurements and operating history.

With the method advancement, the "big data" grows exponentially, which makes it impossible to manage the current data processing algorithms and can not reliably predict the cutting state and optimize the machining process. It is therefore important to research the Big Data-driven monitoring system for machining and to use various information sources to improve machining accuracy and improve production intelligence.

The Cyber-Physical Systems (CPS), according to Monostori [6], combines and communicates strongly in the network environment with computational units and physical objects and understands the convergence of information and physical systems and has a unique advantage for big data analysis and intelligent process monitoring. The CPS approaches for condition monitoring were applied to many areas such as manufactured of electric vehicle 8], [9] and manufacturing systems [10], [6]. It has been studied in smart factories as a cloud-based solution to automated factory maintenance and machining parameter selection. [11],[12].

According to Bagheri [13]. Cyber-physical systems have been defined as “the systems in which natural and human made systems (physical space) are integrated with computation, communication and control systems (cyber space)”. Sztipanovits stated that the framework seamlessly links the physical world to the virtual world of information technology and software. [14]. The system uses different types of accessible data, digital communication facilities and services. [15]. The evolution of science and technology in manufacturing leads to the adoption of CPS in industry, also known as cyber-physical systems of production [16]. Wang listed the planning of adaptive and collaborative processes using function blocks and the implementation of Web technologies [17]. Acording to Chen [18], the CPS modeling for production systems can adopt well-known system definition frameworks or expand existing frameworks such as the accounting of the EAST-ADL modeling language. The idea of cyber-physical production systems often applies as a low-level CPS modeling to resources. [19]. Despite the link with tangible resources, the CPS can be applied to social manufacturing with the use of social media in industry. [20]. A thorough analysis of the CPS in manufacturing from a quality of service perspective has been carried out [21].

The basis for decision-making and factory automation is shop-floor control and data collection during manufacturing operations. Under the IoT theory, the CPS model suggests the use of control systems that go beyond conventional methods for on-site data collection, processing and visualization. In Teti's work [22], the implementation to the use of real-time monitoring in production has been emphasized. There are a range of sensors that can be used in the sense of machine tool monitoring. (acoustic, vibration, force, and current). A less frequent form of sensing uses visual sensors to track the productivity of a production system. [23]. Electric current sensors, since they are cost-effective and non-intrusive in design, are encouraging candidates for measuring energy-related operating characteristics. For the purposes of preventive maintenance, remaining useful life assessment, and cutting tool reconditioning, among others, monitoring systems have been suggested in previous literature. [24, 25, 26, 27]. The use of monitoring devices on the shop floor to monitor the availability of machine tools, resulting in adaptive holistic scheduling, has been introduced, as reported by Mortzis [28]. Adaptive process preparation has also been enabled by analyzing the shop-floor situation via monitoring systems. [29].

The objectives of this paper are to develop a Remote Production Manufacturing System (PMS) framework and online tool condition monitoring system according to the Internet of things requirements (IR 4.0). The system is designed to record and monitor the production of CNC Machine at shop floor remotely. The research was conducted at Premach Laboratory UTHM through a case study.

II. LITERATURE REVIEW

Several types of research have been conducted to analyze and implement a production monitoring system. A study by G.D. Zhu et al [30] implemented an on-line monitoring and control system for steel ball production. The system used Wi-Fi technology and a displacement sensor. The proposed system provides a non-contact mode and intelligent control in real-time and with high precision, and it improves the production efficiency and the quality of steel ball. A few modern machines have incorporated features of data acquisition, utilization of monitoring and automatic data storage.

Other research that benefit from these attribute on developing Web-based Remote Machine Monitoring System for various brands and types of machine was done by Edrington et al [31]. The system provides the workshop manager with data accumulation, interpretation and machine event notification, so that the system comfortably increases the efficiency of the production process. In addition, via the internet network, the device can be remotely accessed. With a technology called MTConnect, any kind of machines used must be acceptable. It is a manufacturing communication protocol designed for the exchange of data between software applications and shop floor equipment and used for data analysis and monitoring.. However, the past version of machines without MTConnect technology unable to take advantage from the technology. Another system developed by T.F. Aydos et al [32] has a close design with our research. The system utilized wireless, plug-and-play technologies and RFID (Radio Frequency Identification Detection). The proposed system includes different RFID tags to track the transport of goods so that there are problems related to investment costs and the management of tags. Problem of designing automated output monitoring systems, according to Rasidi et al. [33], is a 'plug and play' approach that can be applied to most types of small and medium-sized enterprises. This is also stressed that the most critical criteria for any production monitoring system are that the system must be low-cost, precise and simple to set up on a production basis.

III. SYSTEMATIC PRODUCTION MONITORING SYSTEM

As stated by Haris Rachmat et al [34], in a common industries, manufacturing processes are assembled to form a manufacturing system to produce a desired of finished product. The manufacturing system takes specific inputs, add values and transforms the inputs into products for the customer. It is essential to distinguish between the production system which includes the manufacturing system and services.

A Systematic Production Monitoring System has the purpose of gathering and disseminating real-time data on activities on the shop floor.For decision-making, this knowledge must be valuable and understandable. Monitored data should help the production team to respond timely to the events that may influence the desired result. Such a system should also alarm and notify the respective department concerning all recognized faults. The Systematic Production Monitoring System is displaying boards that show production data which has an administration and reporting module. The stored data can be analyzed to detect projections, trends and estimations for knowledge-based decision making and production planning. Detected errors will proactively decrease downtime and improve overall equipment effectiveness.

A shop floor is the area of a machine shop or factory. where the space in a retail establishment where goods are sold to consumers and people work on machines, or. The shop floor is in charge of to produce an intermediate or a final product.

A. *Initial Observation*

The initial observation was piloted to the currently existing process at the Precision Machining Centre Lab. Based on the observation result, faulty and ineffective issues was identified. The further action to solve the problems is to design an automatic production monitoring system and the process flow is shown in Figure 1. In the initial step, the production procedure was observed to identify the overall process. Some of identified problem in the second step were such as quality problem on the high defect rate and poor quality output. Other problems was cost problem on the idle people and machines and bad working condition. Once the problem was identified, the designing of the Remote Production Monitoring System will be started. After the execution and the implementation of the designed system, the testing system will commence. Several process of system verification was conducted at the next step to ensure that the system meets its requirements and specification (such as throughput) that have been agreed with the users. Once the problem was solved, the final step was Final Acceptance Test. This was to confirm that the system meets the agreed-upon criteria by identifying and resolve disparity, if there are any. The Final Acceptance Test was to determine the readiness of the system for cut-over to live operations.

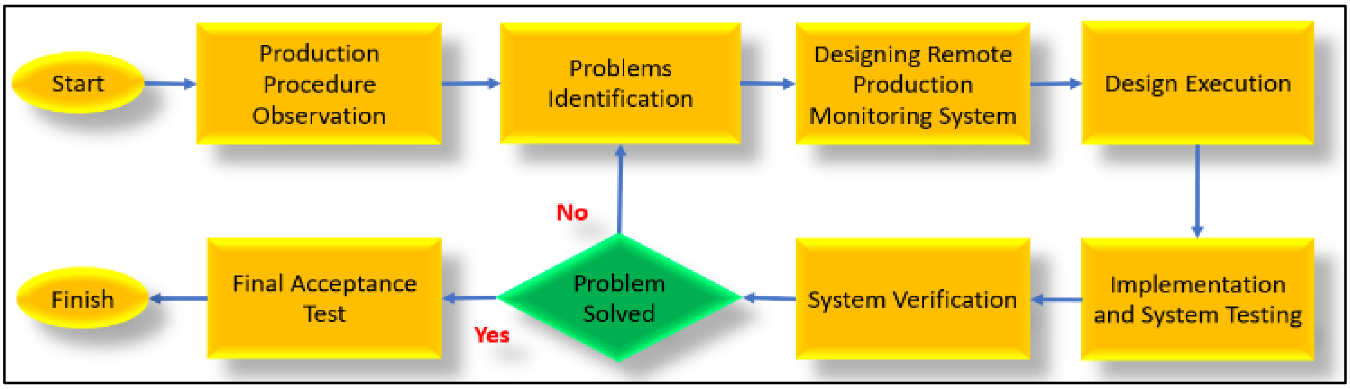

Figure 1. Process Flow of Analysis and Implementation of Remote Monitoring System

B. *Current Manual Process*

The fabrication process at Premach Lab is generally similar to other shop floor type of companies. An example of how a design was made at the Premach Lab was shown in (Figure 2).

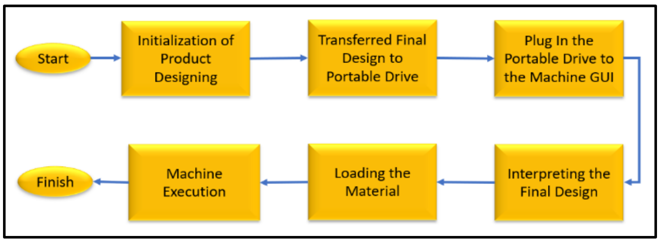

Fig 2. Current Manual Usage of the Milling Machine

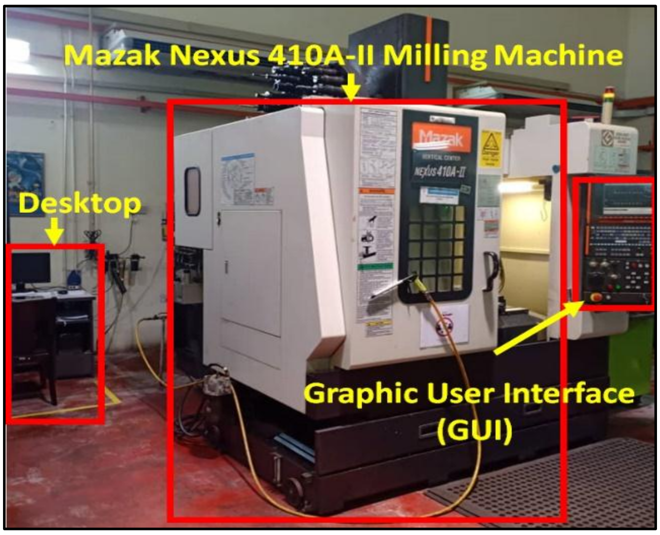

Fig 3. The Desktop and CNC Milling Machine at Premach Lab

There are potential risks in the existing flow shown in Figure 2. The major issue is the unavailability of real-time data to monitor the performance of the CNC machine. Others issue include the unavailability of direct LAN connection from the desktop to the machine and the machinist could not perform

direct execution after the design was made. Portable driver was used to transfer the drawing and to execute the design to

the machine. In terms of security, a portable USB may have a virus and will infect the machine operating system which results in greater damage to the machine. Other known issue referred to the inexperience of machinist in interpreting the drawing to the Graphic User Interface (GUI) to the CNC machine.

Based on those explained potential risk, there are some solutions to overcome the issue. The prime solution is to have an integrated Remote Production Monitoring System that will enable remote files transfer with monitoring capabilities through mobiles devices (Internet of Things). An automated data reporting and web-based monitoring using cloud computing is the next solution. Other solutions included the upgraded CNC machine with real-time data capturing on process actual output, hours spend, rejects and material consumptions and status monitoring of overall equipment effectiveness analysis. This will enable the optimization of operational cost while gradually monitoring production and making better decisions.

C. System Design Implementation

In view of the potential risks, it is imperative to design a device capable of automatically monitoring production remotely. Below is the architecture of the proposed automatic remote production monitoring system design. (Figure 4). There are 3 options to connect to the network switch.

i. Connection directly via the network cable

ii. Connection via MDC Adapter via RS232 cable with the wired connected one port.

iii. Connection via the Wireless Access Point (WAP)

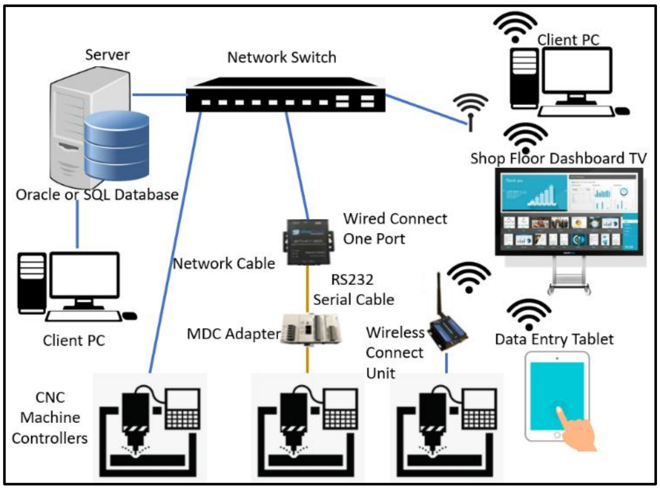

Fig 4. The proposed Automatic Remote Production Monitoring System

All data is sent to the router via LAN at the monitoring unit. Data is transmitted wireless or directly via the router to the local database on a PC located in the production control room. The management able to read the data through a windows-based application called CIMCO MDC-Max shown in Figure 5.

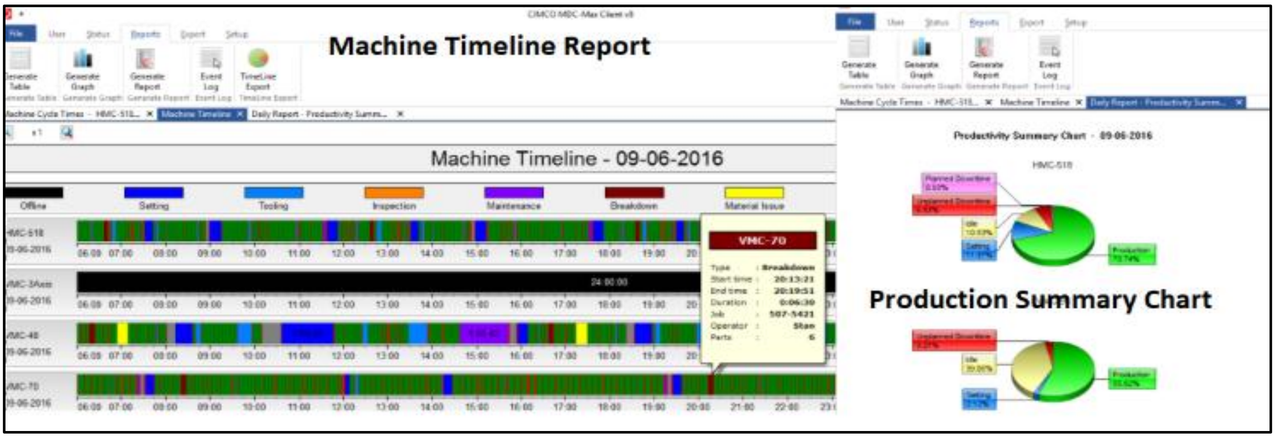

Figure 5. Machine utilization visualized as timeline

Device evaluation was done by checking and reviewing all of the functions and features that were developed using the Final Acceptance Test. This process has shown

ample and reasonable results. After that, the verification process was carried out by running the device in accordance with the actual conditions. The verification process included corresponding stakeholders who are technicians and supervisors. The test outcome features of the target

set system were shown in Table 1.

Table 1. System Verification Result

Goals	Verification	
	By	Result
Monitoring of technician output by offering value-added time data	Supervisor, Technician	Passed
Eradicate the queue timeline by automatically moving data from the Technician PC Workstation shop floor	Supervisor, Technician	Passed
Improving the Production Timeline	Supervisor, Technician	Passed

The developed system can be adequately implemented in the Premach Lab on the basis of the results of the verification. The key-in and analysis of manual data by the technician and supervisor are no longer required. This will avoid imprecision and the use of input data in such a way that the accuracy of the output data becomes accurate. The management can utilize the data from the system to make appropriate decision. The data on processing and machining time are practical for the supervisor to allow a clearer evaluation of the efficiency of the operator. Consequently, the monitoring of the usage history and capacity toward machines on the shop floor can be monitored by the supervisor. The supervisor able to determine the workload in the shop floor under his responsibility. Both stakeholders, such as managers, technicians or senior management personnel, are able to perform supervisory tasks wherever and whenever they are linked to the company's network.

IV. CONCLUSIONS

The automated remote production monitoring system for Premach Lab was developed in this paper. The monitoring system consists of a monitoring unit fitted with a human machine interface, a shop floor window-based program named CIMCO MDC-Max and a data communication system using LAN. The results of the validation showed that the device was operating legitimately. The results of the validation showed that the targets set to resolve the issue had been achieved. The issues resulting from the method of manual production can be solved. This research can be accepted with the production of new high specification and high strength materials is a new challenge for researchers and industries to manufacture molds, tools, jigs, dies, as reported by Rasidi et al[34]. Other related research was to develop the scientific relationship between all process performance, including instrument wear, surface roughness and rate of material removal and geometry/variables of tooling, and the instrumental implementation primarily involves the design of the vibration generation device and its control system as per Haris Rachmat et al[34] and can be used for production monitoring.

It can be concluded that it is practicable to incorporate this proposed method. There are some restrictions to this analysis, however. The developed system was achievable to be applied to other industries shop floor that have similar characteristics as in this research case study. Therefore, further research needs to be conducted for data monitoring and improving the efficiency of the production line for global industry.

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