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Development of Tools Utilization Monitoring System on Labor-Intensive Manufacturing Industries

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Abstract. Industry 4.0 implementation faces crucial problem when applied in labor-intensive manufacturing industries, which are common industries in Indonesia. The problem is that it requires a well-connected and transparent data among production elements. The purpose of this study was to solve the aforementioned problem by building a cyber-physical workstation system as bridges between the production elements in real world with object models in virtual world. The system acts as a tools monitoring system for obtaining real-time information of actual tools utilization, especially for hand tools which are mostly used in labor-intensive manufacturing industries. The utilization of cyber-physical workstation system model may be the best method for determining the actual utilization of production tool with simple architecture, affordable and minimum negative impact. Workstation monitoring system transforms attendance data tools in the work area and start-finish operation time event into actual tool utilization information. The major contribution of this paper is that the implementation of industry 4.0 on labor-intensive manufacturing industry has become enabled by using cyber-physical workstation system. It was shown that the usage time of each tool on each production operation can be monitored. Furthermore, the estimation of the actual duration of each tool utilization can be calculated. The resulted data will be further utilized as primary data input for building smart tools model.

INTRODUCTION

Tight competition among manufacturing industries currently, forces companies improving their production efficiency and effectiveness, products quality at affordable prices and appropriate delivery time, otherwise they will lose the competition. The must be greatly supported by reliable production equipment. Nevertheless, production equipment reliability will continuously decrease with time usage and at certain condition, it will quickly decrease when the production equipment continuously receives different operating conditions beyond its ideal operating condition [1]. Maintenance strategy for production equipment must be developed in order to prevent equipment failure during production operation and hence extend the equipment time usage. Maintenance schedule should also be decided based on actual time utilization. Referring to the development of the industrial revolution 4.0, Qin (2016) states that the application of CPS industrial 4.0 architecture, at the level of cognition can achieve predictive maintenance intelligence functions [2]. Production equipment have the intelligence to predict self-maintenance needs according to its lifetime and its actual usage, hence the replacement time can be correctly predicted. CPS is a system of collaborating

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computational entities which are in intensive connection with the surrounding physical world and its on-going processes, providing and using at the same time, data-accessing and data-processing services available on the internet [3]. A well-connected and transparency data among the production elements could be realized through the CPS. And the tool production elements in the real world could connected with object models in the virtual world. Cyber-physical system shall have major role in manufacturing industry in shaping the factories of the future during the 4th industrial revolution [4].

Some studies related to the implementation of CPS has been conducted, especially on manufacturing industry CPS object and its intelligent function for determination of maintenance and production decision. Monostori (2017) discuss the linkages between the development of computer science, communication and information technology, and technology and manufacturing science. It influences the current production system leads to Cyber Physical Production System (CPPS). CPPS is considered very promising but the realization requires a very significant effort and economic investment [5]. Liu and Xu (2017) propose a new generation of machine tools, i.e. Machine Tool 4.0, as a future development trend of machine tools. Machine Tool 4.0, otherwise known as Cyber-Physical Machine Tool (CPMT), is the integration of machine tool, machining processes, computation and networking, where embedded computers and networks can monitor and control the machining processes, with feedback loops in which machining processes can affect computations and vice versa [6]. Herman Budi (2018) developed the machine tool monitoring system as the connected level to build CPMT with simple architecture and affordable cost. It is oriented for obtaining real time information of actual component utilization, its actual utilization is approached by component grouping based on machine phase operation [7;8]. Qin propose combining the intelligence within the production system of automation levels which are machine, production process, and factory system to made hierarchical framework [2]. Zhong (2017) introduces an Internets of Thinks (IoT) enabled real-time machine status monitoring approach for the provision of resource availability. IoT technologies such as radio frequency identification (RFID) and wireless communication are used for capturing real-time machine statuses [9]. Konstantinov (2017) discuss Cyber-Physical e-machine Manufacturing System for monitoring an electric motor assembly unit. The electric motor assembly unit is replicated in the virtual system, hence the activity that occurs in the real assembly unit can be simulated and monitored through a virtual system. The system designed is only for the electric motor assembly unit. Its paper focuses on getting and applying the real time location information as positioning, tracking and monitoring work in progress (WIP) in the manufacturing workshop [10].

The state-of-the-art research in this area shows that researcher are striving to implement the CPS technology in manufacturing industry. All of these propose adding connectivity to automated production system including automated production equipment as CNC machine tools and other automated production equipment. The 4th Industrial Revolution is the global trend in the manufacturing industry, many countries in the world, including Indonesia have ambitious plans to adopt technologies and principle of the 4th industrial revolution to make this a reality [11]. But common manufacturing industries in Indonesia are labor-intensive industries which are in 2th industrial category. Labor intensive manufacturing industries involve a lot of human resources, minimum automation and using many manual tools in the production process. Therefore, implementation of CPS technology in labor-intensive manufacturing industries become a crucial issue for today. The development of CPS should consider its characteristics. CPS must be able to record every operation data of each production object completely, valid and up to date. The operation data is including data usage of hand tools on each operation. Hence the involvement of hand tools in each production operation can be known. Data actual usage of tools are used for primary data production equipment maintenance systems.

The aims of this study was to develop tools monitoring system for obtaining real-time information of actual tools utilization, especially for hand tools which been used regularly on labor-intensive manufacturing industries. The use of cyber-physical workstation system model could be the best method for determining the actual production tool utilization with simple architecture, affordable and minimum negative impact. Performance monitoring system is tested through verification using simulations with the manufacturing industries object of air conditioning factory.

METHODOLOGY

The research is conducted by several stages: determining cyber-physical workstation system, modeling production tools object and another related production object, developing a monitoring system and verification of monitoring system performance through simulation.

Cyber-physical workstation system. The research case study was conducted on labor intensive manufacturing industry producing air conditioning. The workshop factory is divided into several area or workstation, based on the type of production activities. Those are warehouse workstation, minor assembly cutting, minor assembly pipe, minor assembly insulation and assembly-line workstations from 1st station until 5th station. Workstation in workshop factory is the work area where production operations are carried out involving production equipment, products and operators. Production process for each workstation is different to each other. Tools needed for each production process are different to each other. The tools utilized in production process at workstation are mainly hand tools. Hence, each workstation has its own different characteristic. Industry 4.0 concept states that each production element should have intelligence. It is physically very difficult to make production elements be smart, hence the intelligence is realized through the production elements model at virtual world. Figure 1shows the relation between production elements on physical word and the model of production elements on virtual world. Ideally, each production object should be equipped by a controller for connecting the physical object with the virtual object model. But fulfilling this requirement faces many constraints, such as comfortable factor, disruption of operation, dimension factor of tools and product, and cost. Hence, CPS is build based on workstation scope. The cyber-physical workstation system (CPWS) model could be the best method for determining the actual production tool utilization with simple architecture, affordable and minimum negative impact. CPWS shown in Figure 1 is an approach to build a cyber-physical system for each production entity in the work area, including production equipment.

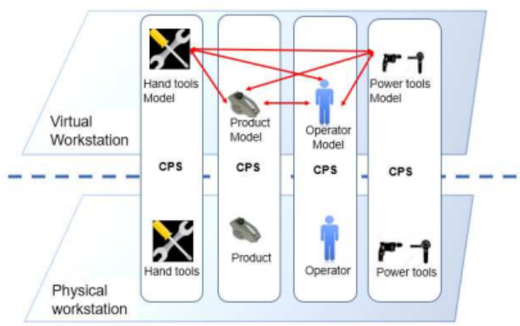

Figure 1. Cyber physical workstation system

Modelling production tools. The tools actual usage should be monitored on operation at the workshop. Hence, the tools production and other related physical production objects need to be configured into virtual system model. Those are consisting of workstation model, tool type model, product type model, operation model and production line model. Workstation model is representation of workstations object in workshop. Tool type model is the representation of tool properties needed in the production process. Tool type model has relation with product type model, its relation is tool needed information or which kind of tool type is needed on each production process. Product type model explains the product design need to be made, its model has product structure model, hierarchy model and process model. Production line model describe about the arrangement of the workstation which will be used by the production process. Operation model is representation of production activities that have time duration for each activity. Operation model is the transformation of process model into actual model. Operation model has several attributes such as materials, operator, tool, machine, workstation, scheduled start operation, scheduled finish operation, actual start operation, and actual finish operation.

Tool type model is combination of tool-need model, tool-list model, tool-operation model, and tool-on-workstation model. Tool-need model explain which kind of the needed tool type for each production process. Tool-list model is representation of real production tool that have been registered and have tool id number. Tool-on-workstation explain which tools have log-in and out on workstation. Tool-operation model is representation of which kinds of tool id that use on each operation.

Actual usage duration of each tool can be identified by monitoring which tool is used in each operation. Actual used tools can be known from tool-on-workstation, tool-need and time duration of actual usage can estimated from the attribute value of start-finish operation on each production operation.

Tools monitoring system. On CPWS, each workstation is equipped with an operation monitoring device as workstation controller which is used to record several data on database, such as log in-out of tool, operator and material at workstation, and actual start-finish of operation. Monitoring device is controlled using a Raspberry Pi and equipped with monitor and several sensors such as RFID sensor, barcode scanner. The system is programmed using python language. Controller connects with data base Microsoft Structured Query Language (MS SQL) Server. The status of tool utilization can be monitored online by web browser. The configuration of monitoring device is based on activities of production in each work area. If work area has printing operation for producing new object-ID as in warehouse area, its monitoring device is equipped printer unit. Printing operation of each new tool-ID is done when new tools have just been purchased. Hence each tool has different tool-ID even though the same tool type.

When any event occurs in a certain workstation, the device will renew the status of each model in virtual system according to its physical system represented. Monitoring data should be complete, valid and up to date. The concept of monitoring system is shown in Figure 2.

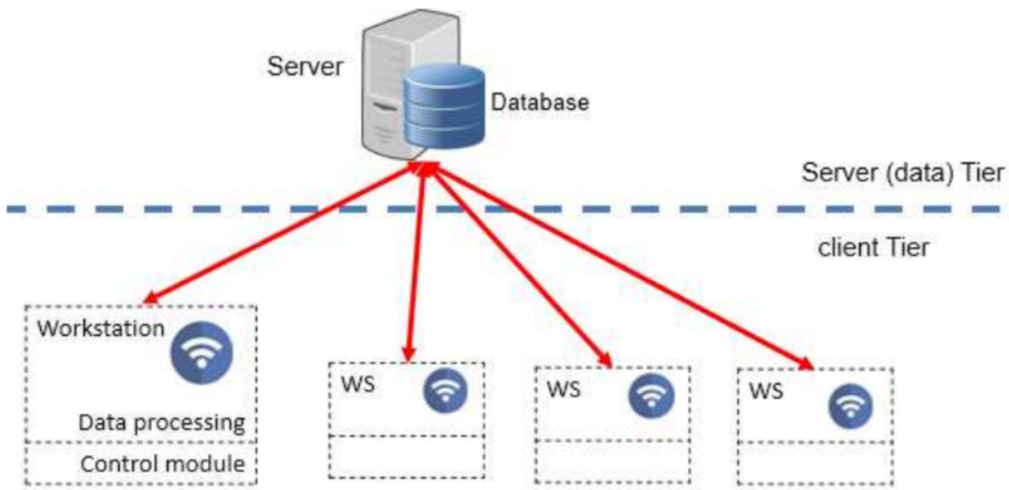

Figure 2. Monitoring system concept

The production operation is conducted at workstation. It involves production resources such as operator, material and tools. Operation of each workstation differs to each other, therefore, the tools utilized at each workstation will also be different types of equipment and time usage. The tool monitoring system functions will identify and record which tools and when to be used in each production operation at each workstation.

Figure 2 shows the information flow of tool usage. Each tool in shop floor should be registered to the tool monitoring system. The system will generate and print unique bar code as a tool-ID number for each tool. Tools monitoring system record data log in and log out of each tool-ID of tool when tool is entering and exit on workstation. Its data will be saved to data base tool-on-workstation. System will define tool usage candidate when tool on workstation is needed on production process. Tools monitoring system processes and transforms attendance data tools in the workstation and start-finish operation time event into actual tool utilization information. This will enable the usage time of each tool on each production operation to be monitored. Furthermore, the estimation of the actual duration of each tool utilization can be calculated.

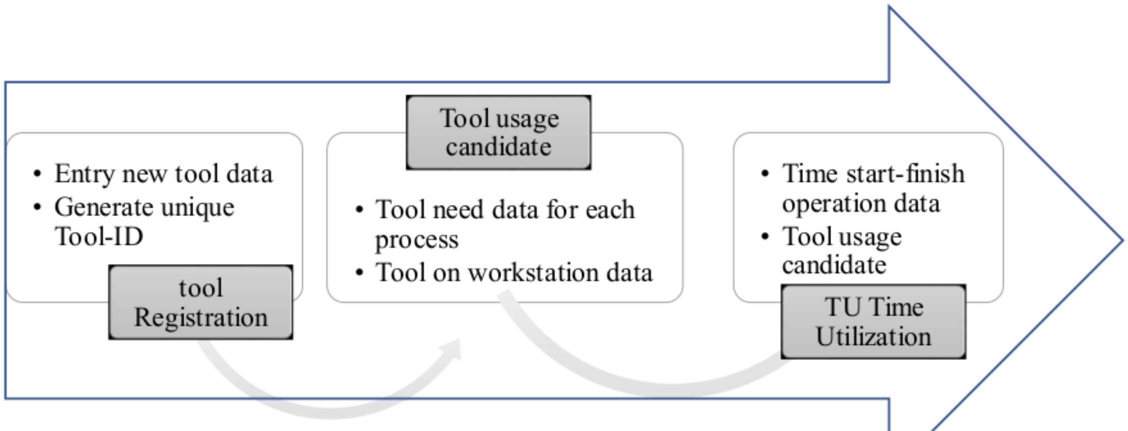

Figure 3. Information flow of tool usage

RESULT AND DISCUSSION

Monitoring device. Monitoring device comprises minicomputer, monitor and a several sensors. Minicomputer Raspberry serves as workstation controller, sensors are utilized for sensing log in and out of tool, material, and operator. Monitor shows the operation status which occur at the workstation. The status shown includes operators in the workstation, material in the workstation, and tool in the workstation. Tool which has to be provided for the current operation but not yet available, the latest operation that had been done, current operation, and next operation that need to do. An example of interface is shown in Figure 3.

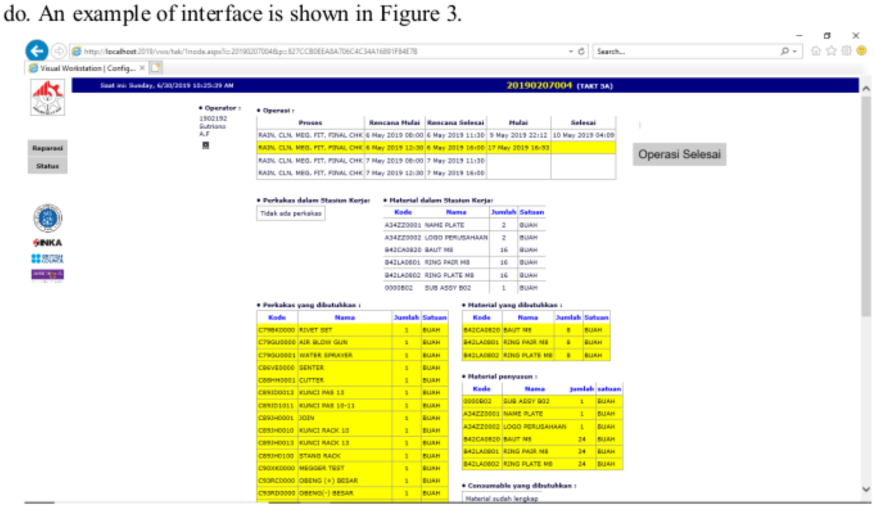

Figure 4. Interface of monitoring device

Simulation. The developed monitoring device needs to be tested by simulation before executing the actual operation. Simulation was conducted by scanning the barcode reader representing actual tool that enter the workstation. When a tool has been scanned in a certain workstation, the tool location can be recorded to new location in the database. The record of actual start operation is started when the operator presses the start operation button at the screen monitor. All production tools that been used for certain operation are also recorded. The actual finish operation is recorded when the operator presses the finish operation button at the screen monitor. When the finish operation button been pressed, the system will also record finish usage time of tools. Actual time usage of production tool can be calculated and shown in Figure 4. For example, the tool is rivet set which has 04190623053 as tool ID number. Actual time usage or time utilization is accumulation of all operation durations utilizing the related tool. Time utilization of its rivet set is 6024 hours

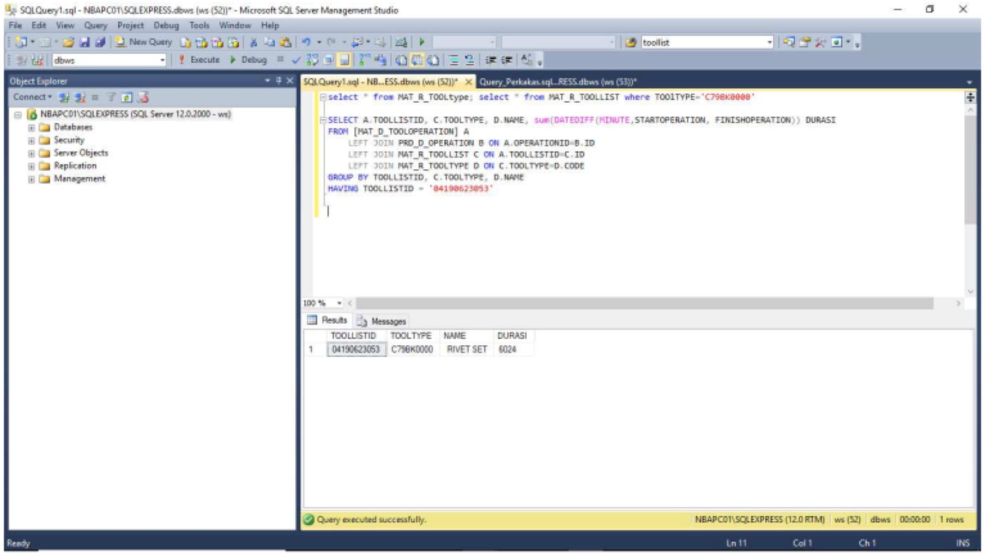

Figure 5. Actual usage time of tool production

CONCLUSION

The first implementation of industry 4.0 in labor-intensive manufacturing industry by using cyber-physical workstation system (CPWS) has been successfully conducted. CPWS has ability connecting the production elements in real world with the production elements object model in the virtual world. It could be implemented for manual tools objects even without automation effort. The actual usage time of each tool on each production operation could be monitored. The estimation of the actual duration of each tool utilization can be calculated.

Further research will be focused on building smart tools model from the previous obtained data.

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