Preliminary Development of Real Time Usage-Phase Monitoring System for CNC Machine Tools with a Case Study on CNC Machine VMC 250

Herman Budi Harja¹², Tri Prakosa², Sri Raharno², Yatna Yuwana Martawirya², Indra Nurhadi², Alamsyah Setyo Nogroho²

¹Department of Manufacturing Engineering, Politeknik Manufaktur Bandung, St. Kanayakan No.21 Dago, Bandung, 40135, Indonesia.
²Department of Mechanical Engineering, Institut Teknologi Bandung, St. Ganesha No.10, Bandung, 40132, Indonesia.

Email : herman@polman-bandung.ac.id

Abstract. The production characteristic of job-shop industry at which products have wide variety but small amounts causes every machine tool will be shared to conduct production process with dynamic load. Its dynamic condition operation directly affects machine tools component reliability. Hence, determination of maintenance schedule for every component should be calculated based on actual usage of machine tools component. This paper describes study on development of monitoring system to obtaining information about each CNC machine tool component usage in real time approached by component grouping based on its operation phase. A special device has been developed for monitoring machine tool component usage by utilizing usage phase activity data taken from certain electronics components within CNC machine. The components are adaptor, servo driver and spindle driver, as well as some additional components such as microcontroller and relays. The obtained data are utilized for detecting machine utilization phases such as power on state, machine ready state or spindle running state. Experimental result have shown that the developed CNC machine tool monitoring system is capable of obtaining phase information of machine tool usage as well as its duration and displays the information at the user interface application.

1. Introduction
Flow-shop industry has different production characteristic compared to job-shop industry. The job-shop industry has characteristics of HVLV (High Variety Low Volume), where products have wide varieties but small amounts [1]. Customized product characteristic and limited capacity of workshop equipment induce negative impact on the utilization of production machine, that leads to dissimilar utilization of the machines and frequently result in utilization bottleneck at particular machines although production scheduling has been well planned. A machine with high intensity usage becomes a critical machine candidate which is prone to damage, eventually its quick reliability decreased will affect replacement frequency of machine component. The HVLV characteristics causes any machine tools to be shared and conducting a production process with the dynamic load. Reliability of machine tool will continuously
decrease with time usage but at certain condition it will quickly decrease when the machine tools continuously receives different operating conditions beyond its ideal operating condition [2, 3]. Generally, equipment reliability decrease is due to failure on machine component. It is measured by two factors, (1) life time and usage and (2) life time and number of failure. Maintenance activity for recovering reliability is machine component replacement at certain period, that causes the component is to be ‘as good new’ [4].

This paper studies a monitoring system which utilize CNC component actual usage as inputs for developing maintenance model especially in job-shop industry. This maintenance model applies the concept of Autonomous Distributed Manufacturing System (ADiMS) which emphasizes flexibility and autonomy of each production model element. Hence machine tool level from top until its component level will serve as maintenance object element whose ability and intelligence to define self-maintenance activities. The outcome of maintenance model is in the form of maintenance policy for maximizing production machine availability. One of maintenance policy is maintenance schedule whose activity scope such as cleaning, adjustment and age replacement policy of machine component. Time interval determination in maintenance schedule must consider real condition usage. Therefore the machine tools actual usage data are necessary for accuracy of maintenance model outcomes.

2. Research Problem
Currently, each of the CNC machine controllers such as Fanuc, Siemens, Mori Seiki and other CNC machine controllers have developed a machine monitoring system by their own software with different programming protocols. Therefore the monitoring data of machine utilization cannot be accessed to be taken and entered in maintenance model that is being developed. The examples are software Programming Tool PLC which developed by Siemens controller, and Fanuc controller uses Focas software for monitoring data diagnostic CNC machine. Hence, the focus of the study on this paper is development of a universal CNC machine monitoring system to obtain information about each CNC machine tool components usage in real time approached by component grouping based on its operation phase, and its system can used on various types of CNC machine controllers.

3. Materials and Method
The development study of machine monitoring system begins by studying the access ability factor of machine monitoring data on some CNC machines with different CNC controller. The review results indicate the monitoring data of each CNC machine controller can only be accessed by its own application software and access authority by theirs own maintenance machine maker technician. Hence, maintenance technician of machine tools user cannot access these data. Generally, the architecture and installation of control and feedback signals on CNC machines are similar. CNC controller is connected to several actuators such as servo motor axis or servo motor spindle through the servo driver interfacing, coolant and lubrication motor pump, lamps, alarm and some other actuators through relay interfacing. The CNC controller is also connected to the feedback sensor devices for accurate of actuator activation. In addition the CNC controller communicates data with computer either through wired or wireless communications [5, 6, 7].

The similarity of control architecture on CNC machine and availability factor of research object, then the experiment stages of study use object research machine is focused on a CNC vertical milling machine VMC 250 with Siemens 802C controller.
Figure 1. Research stages.

Figure 1 shows the research consists of four stages of research. The first is defining the machine utilization status, the second is the identification of the component pin which indicate each machine utilization status, the third is development of the hardware and GUI software as an interface, and the final stage is to perform the experiment to see the function of monitoring machine device.

3.1. Determination of the machine utilization status

The definition approach of real time or actual usage data of CNC machine component is by component grouping based on its operation phase, which is divided into several operation phases. In Figure 2. The Venn diagram shows three groups of machine utilization phases. Power on phase is the status at when the machine’s main switch is turned on, Machine ready phase is the status when the machine’s actuator system is ready to execute the commands such as setting zero point, machine start-up, or cutting process. And Spindle running phase is the status when the spindle component of CNC machine has been rotating either for start-up or cutting.

Figure 2. Venn diagram of machine usage status.

In the figure of Venn diagram shows that is:
- $C \subseteq B$ : C is subset or set of part B. It is mean that actual usage time for each component in Spindle running group is included as the actual usage time for each component in Machine ready group.
- $B \subseteq A$ : B is subset or set of part A. It is mean that actual usage time for each component in Machine ready group is included as the actual usage time for each component in Power on group.
- Because $C \subseteq B$ and $B \subseteq A$ then C is subset or set of part A. It is mean that the actual usage time for each component in Spindle running group is included as the actual usage time for each component in Power on group.
3.2. Identification of the component pin which indicate each machine utilization status

On this stage, Analysis and tracing of control signals on a CNC VMC 250 machine is performed to determine the pins of electronic components of CNC machine that represent the activation of each machine utilization status, such as the CNC controller, adapter and servo driver/spindle driver. Table 1. Shows the relation between component system and which component pin can be indicator of each machine utilization status.

| Machine Usage Phase | CNC Machine Component | Output Name/ Cable | Pin Number | Relay | Pin No. Micro Controller |
|---------------------|-----------------------|-------------------|------------|-------|--------------------------|
| Power On            | Power supply          | Volt 24V          | P24/ P24   | Relay Power | 30                        |
| Machine Ready       | Servo driver Axis-X   | Servo Ready 30/ 4116 | Relay Axis-x | 22           |
| Machine Ready       | Servo driver Axis-Y   | Servo Ready 30/ 4117 | Relay Axis-y | 24           |
| Machine Ready       | Servo driver Axis-Z   | Servo Ready 30/ 4118 | Relay Axis-z | 26           |
| Machine Ready       | Spindle Driver        | Spindle Ready 30/ 4108 | Relay Spindle Running | 28           |
| Spindle Running     | Controller 802C       | X7 Analog Input 4/ 209 & 37/ 208 | -          | A0 & GND          |

3.3. Development of the machine monitoring interface.

Monitoring machine device is consist of two interface that is hardware interfacing and software application as graphical user interface. Hardware monitoring device is build using microcontroller and several relays that schematic diagram of monitoring device and schematic of microcontroller algorithm circuit can be shown in Figure 3. And Figure 4.

**Figure 3.** Schematic of monitoring device.
4. Result and Discussion
Experimental result have shown that the developed CNC machine tool monitoring system is capable of obtaining phase information of machine tool usage as well as its duration and displays the information at the user interface application. Figure 6 shows display of interface when Power-on status is on.

Figure 6. GUI when Power on phase

Figure 7. GUI when Machine ready phase

Figure 7 shows GUI when Machine ready phase is on. The figure shows that time duration of Power on is longer than the time duration of Machine ready phase, because Power on phase has previously started since controller booting process.
Figure 8 shows GUI when Spindle running with time duration shorter than other operation phases, because its operation started after Machine ready phase is on.

![GUI when Spindle Running](image)

**Figure 8. GUI when Spindle Running**

5. Conclusion
CNC machine monitoring system based on real time usage-phase has been successfully developed and capable to convey operation phase information status, including its time duration and then displays the information in the user interface application.

Component pins for the machine usage status indicator are determined analyzing and tracing control and feedback signal on CNC machine. It uses signal status from power supply as Power on indicator, signal servo ready status from servo driver as machine ready indicator and spindle ready status from X7 output CNC controller to spindle driver as spindle running indicator.

This research should be continued by involving cutting operation phase as new components group, therefore actual usage for each component is based on real cutting operation phase, not on spindle running phase.

6. Reference

[1] Huang H and Irani S An enhanced systematic layout planning process for high-variety low-volume (HVLV) manufacturing facilities 2003 *Proc. Int. Conf. on Production Research* Virginia Polytechnic Institute and state University

[2] Borris S 2006 *Handbook on the Total Productive Maintenance*, (New York: McGraw Hill)

[3] Budi H, Prakosa T, and Yuwana Y 2015 Review and analysis: Maintenance on job shop industry. *J. Applied Mechanical and Material* ISSN 1662-7482 842 pp 365-372

[4] Chen M, Mizutani S, and Nakagawa T 2010 Random and age replacement policies *J. International Journal of Reliability, Quality and Safety Engineering* 17(1) pp 27–39.

[5] Siemens AG 2006 *Handbook on the Sinumerik 802C Baseline Start-Up* (Erlangen: Siemens-Aktiengesellschaft)

[6] Siemens AG 2003 *Handbook on the Simens Micromaster 440 Operating instruction* (Erlangen: Siemens-Aktiengesellschaft)

[7] Yaskawa Electric Corporation 2003 *Handbook on the Yaskawa ∑-II series SGMH/ SGDH user’s manual* (Saitama: Yaskawa Electric Coorporation)