Machine Process Condition Monitoring with 3MP

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Abstract Recently, machine process domain is archiving significant advancement in term of sensing technology. The technology has a powerful impact on enabling self -monitoring and results in high quality of final product. The aim of this paper is to propose a new method on machine process condition monitoring by 3MP. 3MP (Modern Machine Monitoring Process) works wirelessly to integrate between machine, computer and 6 type of sensory device.

Keywords-Machining process, Condition monitoring, WSN, sensor

I. INTRODUCTION

Manufacturing industries are drastically changing towards Industrial Revolution 4.0 (IR 4.0) since introduced in 2011. With this new revolution, manufacturing industries aim to produce a product model which is greatly flexible in-term of production and services [1]. Due to that reasons, communication in real time with surrounding, people, machine, device and products during production must be outstanding.

In manufacturing industries, conventional machining operations such as turning, milling, drilling and grinding are classified as the most common activities in production environment. With the rapid development of computer application and technology, the conventional machining had been extended to modern machining operation which supports agile manufacturing. Even though, a lot of advancement in term of machining ability had been implemented and the programming language used to do the machining process is still based on ISO 6936 namely called as G-code. G-code is a low level of programming language which delivers limited number of information and unable data feedback. CNC machine also blinds in term of machine movement. It will follow the programed input, even in appropriate machining parameter assigned. Future more, without any supervision, these scenarios will contribute to machine tool downtime. Machine downtime is defined as certain duration of time in which no machining operation could be done on workpiece and could be divided into two, avoidable and unavoidable [2]. Unavoidable occurred due to machine maintenance or any replacement on machine component and avoidable machine downtime occurred due disturbance during machine process which include over-loading of spindle torque, excessive cutting force, chatter, tool wear and other constraints [3]. The main issue at the machining process leads to major problem that is product quality deterioration [4], [5] Estimate that machine downtime due to

tool breakage is on average 6.8% meanwhile [6] closer to 20%. Those issues is solved by automating the current machining process condition monitoring [7]–[10]. This only can be achieved through the integration of machine, computer and sensor wirelessly. By integration on the current machining process system, such system promise has a large influence on production lines and also enable saving and increase productivity up to 40% and 50% respectively [2] and [11]. Currently, machine condition monitoring based on modern manufacturing industry had been successfully developed by [4], [12]–[14]. However there is still a room to improve the previously developed system.

This paper proposed, a new method on machine process condition monitoring known as 3MP. The idea of 3MP system works wirelessly between machine, computer and 6 type of sensory device and utilizes ISO 14649 data interface model instructions for milling machining operations. The 3MP will be applied on Denford Novamill ATC three axis CNC milling machine. Future, this paper is structured by review on machine condition monitoring, current and future machine condition monitoring methodology, proposed 3MP and conclusion.

II. REVIEW ON MACHINE CONDITION MONITORING

Machine condition monitoring system is the core element in assuring the reliability, safety, unmanned and adaptive machining [15]. The monitoring activity must be done real-time to enable control accurately. The first serious discussions and analyses of machine condition monitoring emerged during the year 1969 which was reported by [16]. The proposed system was based on graphic cathode ray tube terminals and significantly proposed first, to reduce flight test development time, second reduce certification time and third, reduce costs of data processing. Since that numerous research had been invented on condition monitoring system. Based on studies, the research can be divided into two, machine condition monitoring and machine process monitoring. Machine condition monitoring include monitoring on machine component that are gear, bearing, machine geometry error and other component while machine process monitoring include monitoring of cutting tool and workpiece. Both type of research aiming to realize adoption and adaption of fully automated machine monitoring system and as simplified in Figure 1. This proposed system is focus on machine process condition monitoring encompass IR4.0. Machine process condition monitoring can be modules to three that are tool condition monitoring, tool wear and chatter. Good tool condition may

result in high quality of product. Besides that, machining process can be done efficiently [17]. Tool condition monitoring focus on detecting the tool health or tool condition [12]. The tool with excessive wear and chatter may affect the final quality of product and may result in unexpected failure that might cause wastage. For that reason the tool condition monitoring need to consider as main for machine process monitoring. [18] define tool wear as shape of cutting edge which created due to gradual changes during machining process. The scholar mentioned, tool experience three stage of tool wear that are break-in, steady state and finally cause tool failure due to excessive tool wear. Besides that, different mode of wear based on the geometry and location can be classify into crater wear, flank wear, built-up edge, chipping, and breakage [18]. Hence to eliminate undesired failure of machined part, tool wear must be observed to be within desire limit and controlled during machining process. Other than tool wear, during machining process, a strong and self-excited vibration disturbance between cutting tool and workpiece may result in chatter [10], [19]. Choosing the right cutting parameter and timely observation during cutting process via automated monitoring system able to eliminated existence of chatter.
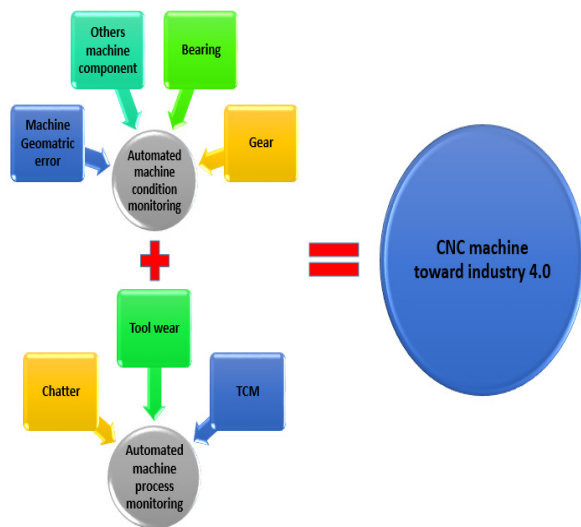

Figure 1. Modern CNC Machine towards Industry 4.0

III. METHODOLOGY

A. Current Methodology

As the manufacturing industry experience several revolution from IR 1.0 to IR 4.0, the method on collecting monitored data from real machine condition also experience abundant of changes. These was based on research attempted by researchers year by year. Even though the method on getting the data changed, the current method on machine condition monitoring remain the same. This as illustrated in Figure 2 which include signal acquisition, signal filtering and condition detection. The first step on monitoring machine condition is signal acquisition. Different signal used for different purpose of monitoring system. It can be vibration signal, temperature signal, cutting force signal and others. Previously, milling process signal were collected based on wired system direct to personal computer. Rapid development on technology and IR 4.0 transition, the old technique is slowly changed into Wireless sensor network (WSN). Based on author reviews until date for milling operation, [12] was the first authors set up signal acquisition system based on WSN for milling machine since 2010.

The next steps after signal acquisition is Signal filtering process. While machine is rotating, machine itself produce different type noise. The noise might be come from different source. Due to that, the raw signal need to be filtered for feature extraction method. There are different method of signal filtering process which include time domain analysis, frequency domain analysis, wavelet analysis and others. Different signal needs for different filtration process. Detection or classification is applied to finally get the condition of the machining process. Previously, most condition detection were applying time domain, frequency domain, time-frequency domain and others. Through the passing of time and development of different software and computer application, most researchers applying machine learning algorithm to come out with the decision making approaches.
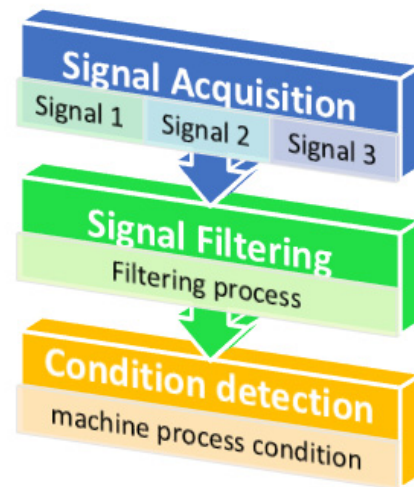

Figure 2. Current signal processing methodology

B. Future Methodology

The key on building a smart factories is by turning the traditional machine into modern machine. Figure 3, illustrate integration of 3S for future signal processing methodology. 3S (Sensing system, Decision system and Control system). IoT is applied into traditional machine to enable wireless signal collection for monitoring system. Signal filtration and signal processing methodology is based on machine learning algorithm. Machine learning enable signal to be process intelligently, robust and fast response. The final stage is to control the current bad condition of the machining process either to stop the machine process, fix the loose part/component or reset the cutting parameter to produce desired quality of product.
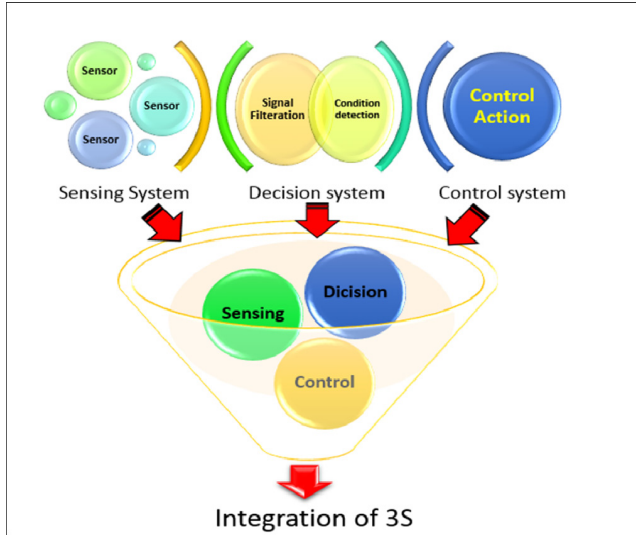
Figure 3. Future signal processing methodology

C. Proposed of the 3MP system

The architecture of the proposed system 3MP, were divided into 4 sub system. That include Sensing System, Decision System, Control system and finally result of machining parts as represent in Figure 4. The first sub system is sensing system. A total of 6 type of sensor employed on the CNC machine which are vibration sensor, temperature sensor, cutting force sensor, motor current sensor, vision sensor and smart label. This sensing system utilize Raspberry Pi B+ as microprocessor and integrated with transmitter and receiver to enable wireless sensor network between machine and computer. The computer is program to run and control the machining process by utilizing ISO 14649 data interface model instructions in LABVIEW software.

The second sub system is Decision system and the third sub system is Control system. Both of the sub system work together. If there is any undesired condition occurred during the machining process, the control system start working. All of the information sense by the six type of sensor is transmit wirelessly to Personal PC. Here the raw data is filter and decision on machine condition is made by using Fuzzy logic in MATLAB software. For Control system, there are two type of action control. First control action is taken by operator and second control action is done by the computerize system in LabVIEW. For the first control action, the operator is trigger. Operator is triggered only for major control condition such as remaining tool life, tool change or tool breakage purpose. In a
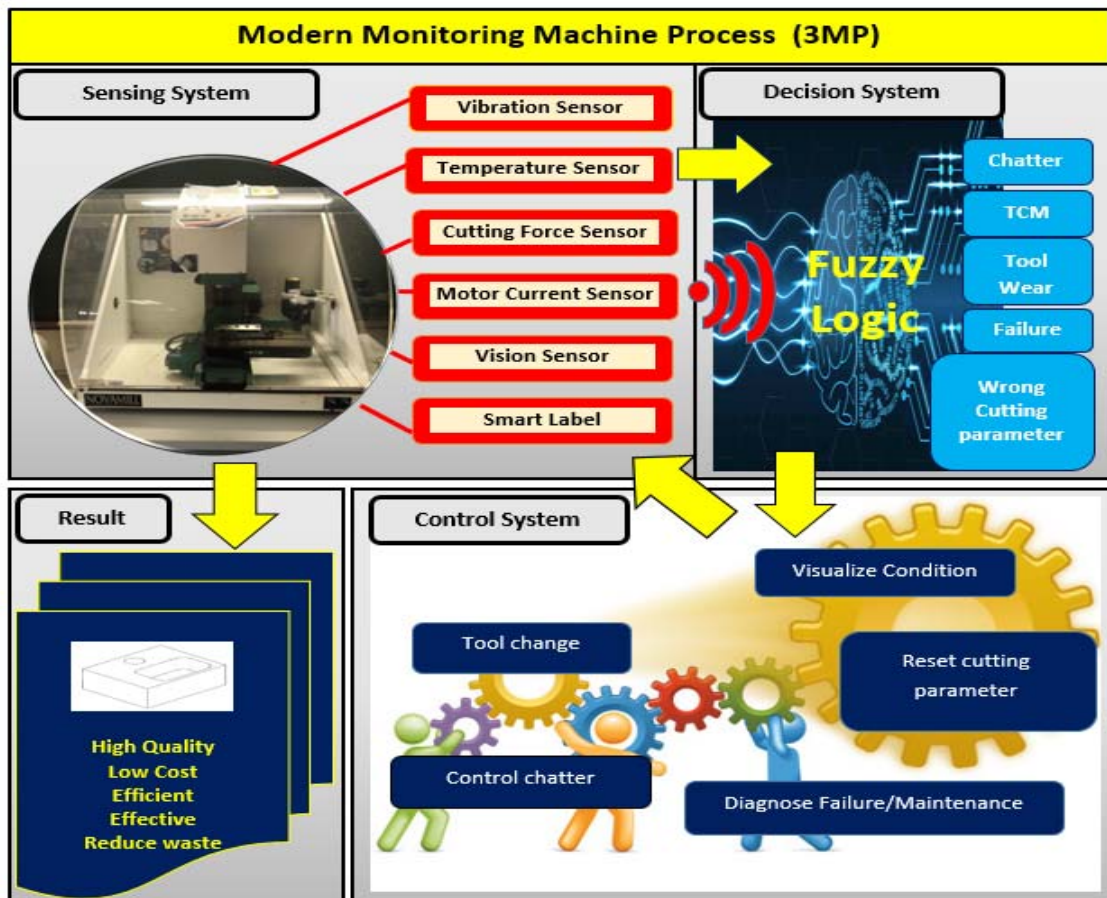

Figure 4. Modern monitoring machine process (3MP)

set of time, if there is no any action made by the operator, the machining system is stop automatically. For the second control action, the computerize LabVIEW system is control for any unsuitable parameter by self- monitoring and self-action based on the machining process condition. Finally, for the result sub system, computerized measurement of the machining parts is appear on the last interface of the developed system on computer.

IV. CONCLUSION

In this study a new approach for Machine process condition monitoring based on CNC machine for milling operation known as Modern Monitoring Machine Process (3MP) has been introduced. The 3MP system aims to integrate six type of sensor, CNC machine and computer. The computer is composed with various modules which are develop by LabVIEW functional block. The system is based on new ISO known as STEP-NC for machining programming and integrate MATLAB for decision and control purpose. The authors believe that 3MP will be able to fulfill the IR 4.0 needs for fully automated monitoring system and also enable to be integrated with any type of CNC machine system.

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