MONITORING AND INTEGRATION OF CNC MACHINES IN ADVANCED MANUFACTURING ENVIRONMENT FOR PREDICTIVE OPERATIONS.

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Abstract: One of the main problems that industrial organizations face today is to integrate their old but productive legacy equipment into digitized production management and control systems. This integration depends on gathering and monitoring critical variables and the ability to connect and communicate this data in networks capable of operating in industrial environments. The purpose of this article is to build a Cyber Physical System (CPS) capable of collecting data to monitor CNC machines during its manufacturing process. The proposed CPS is based on the review of state of the art of intelligent manufacturing workshops. The research results show monitoring CNC machines can be crucial to improve their efficiency and productivity that represents earnings for industry 4.0 model.

Keywords: Data acquisition; CNC; Industry 4.0

SENSORIAMENTO E INTEGRAÇÃO DE MÁQUINAS-FERRAMENTA CNC EM AMBIENTE DE MANUFATURA AVANÇADA COM VISTAS ÀS OPERAÇÕES PREDITIVAS.

Resumo: Um dos principais problemas que as organizações industriais hoje enfrentam é o de integrar seus equipamentos legados, isto é, antigos, mas produtivos, nos sistemas digitalizados de gestão e controle da produção. Esta integração depende de aquisição e sensoriamento das variáveis críticas e da habilidade de conexão e comunicação desses dados em redes capazes de operar nos ambientes industriais. O objetivo deste artigo é construir um sistema ciberfísico (CPS) capaz de coletar informações de máquinas CNC para seu monitoramento. O CPS proposto é baseado em uma revisão de estado da arte de sistemas industriais inteligentes. O resultado da pesquisa constata que monitorar CNC é crucial para melhorar seu desempenho e eficiência.

Palavras-chave: Aquisição de dados; CNC; Indústria 4.0;

1. INTRODUCTION

Since the first industry revolution, manufacturing has one purpose: produce more in less time with better quality. Productivity, efficiency and reducing costs are the keywords for the industry evolution which has been following the trend of maximizing the production of goods and services with increasing quality. In the beginning, the first advances in mechanization, followed by the organization of production lines, allowed for important gains in productivity and characterized what is now known as the first and second industrial revolutions [4]. Then industry 3.0 came to improve performance focusing on information technology and shop floor automation. Programmable Logic Controller (PLC) and Computer Numerical Control (CNC), which made it possible to increase the flexibility of operation, variety of products and better control of the machines involved [4]. As a consequence manual processes were gradually substituted by automated machines and processes.

Industry 4.0 (I4.0) is an emerging key concept that can enhance manufacturing capabilities to produce more, in less time, and with even better quality. I4.0 leads to the digitalization era, which the IoT (Internet of Things) and the CPS (Cyber Physical System) are the main technologies of this new industry revolution [1]. In this era, sensors, IT systems, internet, microcontroller, machines, workpieces will gradually be all connected and integrated to the production process [1]. The CPS are capable of controlling, monitoring and transferring data in real time.

But the implementation of the 4.0 concept in industries is complex and expensive. CNC machines are an important example of legacy, valuable and productive equipment that needs to be integrated into the I4.0 manufacturing model. Presently, CNC equipment has a limited monitoring system of data and low adaptability and extension, making it difficult to integrate to the 4.0 model [2]. Non-conformities can be detected late and an amount of information can be lost without a CPS [5]. Today, industries are using two types of maintenance on machines: corrective and preventive. These methods are defective because they have no scheduling planned or scheduling is based on inefficient aleatory facts or their maintenance occurs when the machine is already broken.

CNC milling machines can build personalized products by a numerical computer control. They can accurately and precisely cut any type of material in 2 or more directions in different angles or shapes. This equipment uses G-code, which is a programming language for computer-aided design and manufacturing (CAD/CAM) [4].

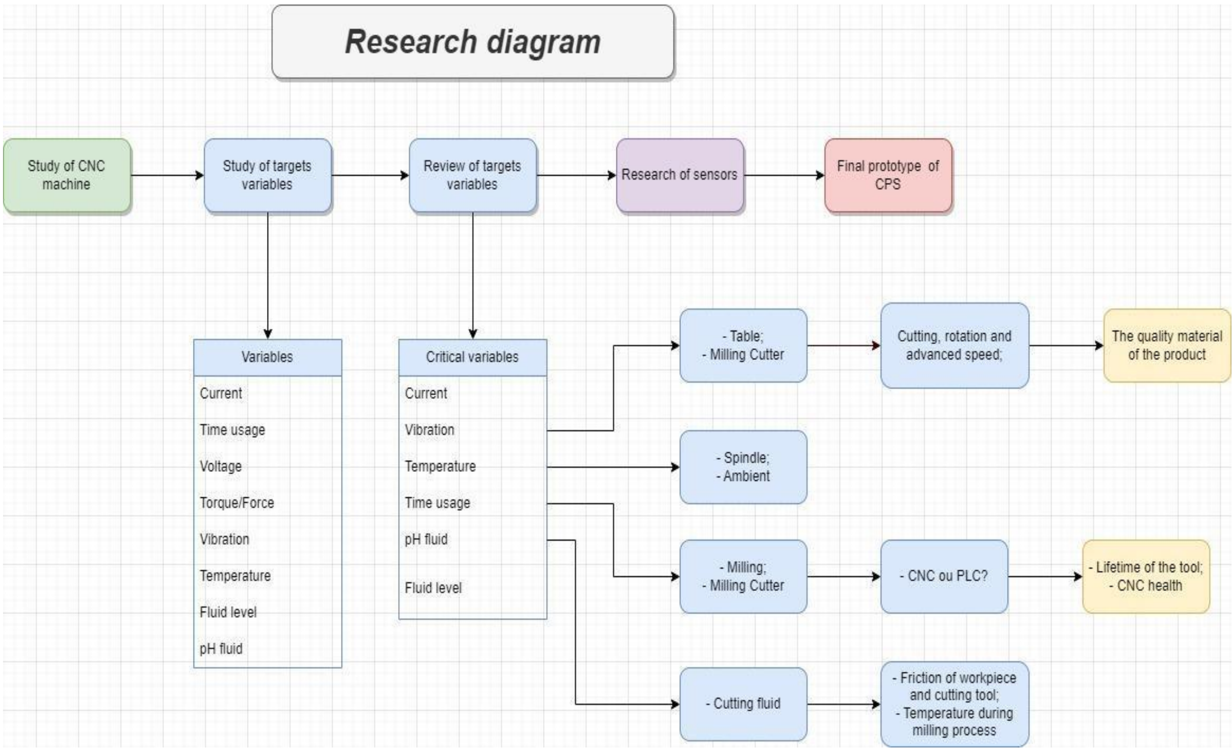
So, this article starts by a review of the state of the art of CPS applied to CNC machines in order to evaluate better solutions and propose a prototype of a CPS integrated in a CNC architecture for real-time data acquisition of the machine and its environment in the shop floor, gathering workshop information to connect with the cyberspace towards real-time monitoring and control of the production process.

2. METHODOLOGY

The methodology used is based on a diagram that describes each stage of the research. One of the main stages is to identify which CNC variables will be useful for data collection and analysis. Then, the final purpose is to build a CPS that can collect useful information from CNC machines to gather intelligence for predictive purposes.

Firstly, it is evaluated how the CNC machines work, use context and which information can be obtained by using the embedded equipment sensors (from encoders, PLC, engine). Next step of monitoring critical variables is divided into 2 parts: analysis of which variables can be collected from the equipment and which additional sensors are necessary to obtain useful information that have a significant impact in the manufacturing process. After that, an evaluation is made about how those data from sensors can be used as target variables. Finally, a prototype of a CPS will be developed to accomplish this objective. Figure 1 explains this whole process.

Figure 1. Diagram of the research methodology



Source: the authors

The main challenge is the research about which variables have a potential impact during the manufacturing in the shop floor, so the production process can be assessed in real-time, and which ones can be analyzed to determine the CNC health, so its operational condition can be optimized. After that diagnosis, some extra information can be extracted based on their causality relations that can measure some impacts in the process. Like, cutting speed of the spindle during the milling process causes vibration which is an important information that could predict when the equipment is overstressed or not. Then, monitoring the ambient temperature on a high precision milling process can be crucial to avoid problems with thermal expansion. The table 1 below presents the critical variables for this purpose.

Table 1. Critical variables of CNC

Variable	Equipment/Process	Result	Impact
Cutting, rotation and advanced speed; Current	Table; Milling Cutter	Vibration	The quality material of the product
Temperature	Spindle; Ambient	Thermal expansion	CNC health; Milling process
Time usage	Milling; Milling Cutter	Worn tools	Lifetime of the tool; CNC health
pH,Level	Cutting fluid	Refrigeration; Lubrication	Friction of workpiece and cutting tool; Temperature during milling process

Source: the authors

First, vibration during the milling process is important to analyze how the product quality material will be [3]. Second, it is important to monitor spindle temperatures in order to analyze CNC health. Then, time usage is crucial to calculate the tool life and also CNC health [4]. Finally, knowing the pH of the cutting fluid, it can be used to evaluate its quality and reduce friction between workpiece and milling cutter.

In conclusion, the prototype of a CPS integrated in a CNC architecture is to gather information about the machine in real-time, using it to monitor performance and health and plan predictive maintenance. Predictive maintenance allows the user to anticipate failures and plan in advance correct measures to act when is better for the process efficiency. After that, the production system will be able to make better decisions on the shop floor in an industry environment using digitized production management and control systems.

3. RESULTS AND DISCUSSION

Manufacturing has one purpose: produce more in less time with better quality. Nowadays, factories still have some problems transforming their old processes into new ones, adapted to the new I4.0 environment. Monitoring and integrating industry equipment is part of a process that eliminates the machines' islands, unpredictable problems and inefficient manual processes. Now, non-conformities can be detected fast and with an amount of information can be used to plan predictive maintenance and monitoring performance of the industries equipment in a more intelligent way. So, in this research, the main objective is to build a CPS that can maximize the CNC production, allowing legacy machines to lead to the Industry 4.0 digitized environment.

"The impacts of having this system are costs, quality, flexibility and time of response, which can influence the competitive advantages of industries in today's global economy [5]." The phase of Data requirements specification is crucial to the project: an overview of the state of the art on which variables are critical to be collected in a manufacturing environment. It defines how the CNC machine can build products faster and economically with the best performance. So, the investigation of the impact of the critical variables is key to measure the costs or complexity that can be associated with the production. In addition, analyzing the equipment health can be useful to plan its predictive maintenance and monitoring performance of each equipment considering its role in the manufacturing process.

So, sensing data from CNC is associated with reducing machining time, energy consumption and downtime losses. CPS is the main I4.0 technology that can help industries to make better decisions about their operations and especially, plan maintenance in order to not stop the chain production process. These advantages are valuable assuming the high competitiveness of the manufacturing market.

4. CONCLUSION

This is an ongoing research project that has three more final steps to achieve its purpose. The next step is to investigate what is the best way to collect all this data from CNC machines. The possibilities are available in the CNC system or in the PLC or by using sensors. The differences between the methods are complexity and cost. For example, pH and temperature are variables which can be only extracted from specific sensors. In addition, time usage, in most cases, can be collected from milling equipment. The second step is to investigate which sensors are better to extract specific data, according to the table mentioned at methodology. The last step is to find a way to connect and communicate in wireless connection to integrate the CNC machines into digitized production management and control systems. OPC-UA is used as a communication protocol that can be connected in an industrial management system to control multiple machines in a manufacturing environment. Finally, a developed CPS is to be integrated in a CNC machine of the Manufacturing Plant at Senai Cimatec University to demonstrate the potential of the solution.

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