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Dynamic Analysis of Intelligent Coil Leveling Machine for Cyber-Physical Systems Implementation

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Abstract

In manufacturing industry, wider range variants and personalized productions are becoming formidable challenges that needed to be for smart manufacturing. In smart manufacturing, machines are connected cooperatively to seamlessly and quickly adjust production setting to reach market requirements. Furthermore, real-time production data visualization and evaluation are the keys to increase manufacturing productivity, efficiency, and flexibility. This integrated research is aimed to develop an intelligent coil leveling machine through dynamic analysis of real-time machine sensors network for cyber-physical systems implementation in smart manufacturing. In this proposed intelligent coil leveling machine, intelligent sensors network is embedded in the machine to allow real-time monitoring of the machine through feedback controlled system and cloud network to ensure optimized production with optimal machine setting instantly. Intelligent sensors network of the proposed coil leveling machine such as leveling roller indentation, leveling force, and coil curvature has been completed. Preliminary real-time dynamic monitoring of the leveling rollers and coil curvature has been accomplished. Following, real-time dynamic analysis is performed to demonstrate the implementation of the cyber-physical systems where machine learning intelligence can be achieved. Lastly, real-time cloud network monitoring are implemented to allow users to collect manufacturing data online. Through this research, conventional leveling machine can be transformed in which machine setting configurations can be adjusted to the production line through virtual cyber-physical system. Production data can be visualized and evaluated in real-time with precise and intelligent production strategies to ensure customer's requirements and to enhance production efficiency and flexibility in smart manufacturing of sheet metal coil.

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Keywords: Keywords: Coil Leveling Machine; Real-Time Monitoring, Cyber-Physical System

1. Introduction

In a vision of future manufacturing, machines and products communicate with each other cooperatively. Machines are interconnected through cyber-physical systems (CPS) within the internet of things. The purpose is to transform current manufacturing industries into intelligent factories that have the ability to achieve highly flexible, individualized, and customizable mass production in order to fulfill the demand of increasing variants of personalized productions. The transformation of such manufacturing is called smart manufacturing, or intelligent manufacturing. To achieve intelligent manufacturing, the implementation of cyber-physical systems is the key. Cyber-physical system is the core of the future advance manufacturing vision that merges the physical world with the cyber world [1,3]. In other words, in cyber-physical systems, the physical world and cyber world are connected simultaneously through real-time monitoring and virtual simulations. Furthermore, system virtualization and visualization are the key approach in advancing the implementation of cyber-physical system in smart manufacturing. System virtualization and visualization are needed to improve manufacturing efficiency and flexibility to target the increasing demands of more personalized and customizable products [4,5].

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Likewise, the proposed coil leveling machine used in sheet metal manufacturing production line are needed to be transformed to meet the requirement of smart manufacturing. During sheet metal stamping forming process, various sheet metal defects can occur before the stamping process [6,7]. These sheet metal defects can be sheet metal coil set, crossbow, torsion, edge wave, and center buckles. Coil leveling machine is developed to utilized roller leveling process to remove sheet metal defects prior to stamping process [8,9]. Furthermore, the flattened sheet metal for stamping metal forming has been used in various applications such as automotive, aerospace, and electronics. Many leading manufacturers in precision coil leveling machine worldwide such as Arku and Oriimec had implemented advanced manufacturing technologies such as machine automation in coil leveling machines, as shown in Fig. 1 [10,11]. Furthermore, coil leveling machine needs to be an exceedingly customizable and flexible machine to fulfill the requirements of the users such as the various properties and dimensions of the sheet metal coil. Therefore, the implementation of cyber-physical system on conventional coil leveling machine is needed to adapt the various personalized market demands in smart manufacturing. The aim of this paper is to transform conventional coil leveling machine through cyber-physical system where production data can be visualized and evaluated in real-time. Dynamic analysis of the intelligent coil leveling machine are performed to achieve real-time production data monitoring and cloud network for smart manufacturing.

Fig. 1. Coil leveling machine from Oriimec

2. Cyber-Physical System Implementation

2.1. Cyber-Physical System in Coil Leveling Machine

The objective of this section is to address the implementation of cyber-physical system in coil leveling machine. The cyber-physical system comprises several technological components such as complex event processor, could computing, virtualization, internet of things, and data storage. These technological components allow machine to improve its efficiency and flexible to become intelligent. Fig. 2 shows the integration of cyber-physical system in the proposed intelligent coil leveling machine. The proposed system consists of three parts: algorithms, communications, and control systems. During leveling process, these three components communicate and compared interactively to ensure machine settings and maintain production quality. For algorithms, leveling algorithms are calculated from analytical, experimental, and real-time data. For communication, machine configuration data are been transmitted simultaneously from sensors to the system and data storage. Finally, control system utilized the data from the system to perform machine setting configurations. Above all, these part components interact with each other during leveling process to allow optimal leveling machine performance.

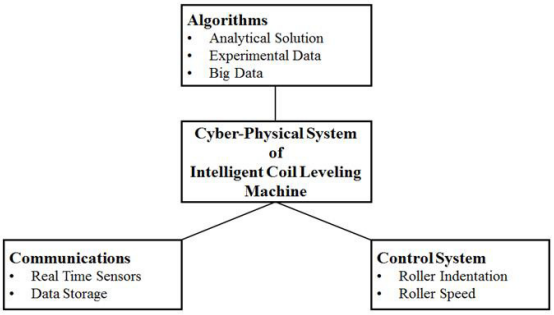

Fig. 2. Cyber-physical system of intelligent coil leveling machine

2.2. Real-Time Monitoring System

The proposed intelligent coil leveling machine is consisted of four main sensing systems for real-time data communications and they are: roller leveling indentation, roller leveling force, roller leveling speed, and coil curvature, as shown in fig. 3. The roller leveling indentation refers to the indentation of the roller, which varies with different initial material input. For roller leveling force, it shows the leveling force that is exerted on the sheet metal material during leveling process. This leveling force is crucial in intelligent coil leveling machine development since it can be transmitted to CPS to perform virtual simulation to ensure the quality of the sheet metal coil. Roller leveling speed refers to the speed of the rollers during leveling process, which is important in maintaining stability of the machine. Lastly, coil curvature is the final production data, it shows the final curvature of the sheet metal coil. Fig. 4 shows the schematic of real-time monitoring system of intelligent coil leveling machine. As shown in Fig. 4, real-time production data is also sent to cloud network for storage. Cloud network data storage is important in CPS due to its nature in mass collections of data for machine intelligent learning ability. CPS can learn the collections of data to improve leveling algorithms.

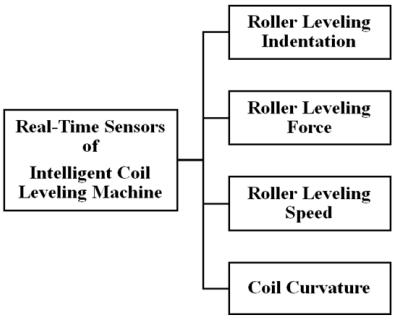

Fig. 3. Cyber-physical system of intelligent coil leveling machine