7th Conference on Learning Factories, CLF 2017

Integrated Product / System Design and Planning for New Product Family in a Changeable Learning Factory

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The large product variety driven by customers' preferences and fluctuation in number of product variants produced annually impose manufacturing challenges. Changeable, reconfigurable, adaptable and smart manufacturing (Industry 4.0) paradigms aim at dealing with these challenges. The implementation of such paradigms presents many challenges to industry. Learning factories can be used as a research test bed and in educating engineering students and practitioners with the required knowledge and continuing professional development. This paper demonstrates the steps involved in introducing a new product family to an existing changeable learning factory characterized by changeability enablers including mobility, modularity, scalability and convertibility. A new product family of belt tensioners is introduced as a new product for the assembly learning factory, the iFactory, in the Intelligent Manufacturing Systems (IMS) Center, which initially assembled a family of desk sets with 265 variants. All required steps starting with the rationale of selecting the new product family, process planning, redesign of fixtures, pallets, and system re-configuration are discussed. The ability of the modular learning factory to change and adapt to the new product family, the involved experiential learning objectives and benefits and research projects along with the experience with the transition to new products family are discussed.

Keywords: Changeability; Reconfiguration; Manufacturing Systems; Integrated Product and System Design; Planning; Learning Factories, Systems Learning, research and education.

1. Introduction

In the recent years, there is a continuous shift in the job profiles and its correlated competence requirement driven by the new manufacturing paradigms [1]. Academic institutions and industrial are developing innovative learning environments capable of dealing with these challenges. Learning factories play a crucial role as a reality which simulates manufacturing environment for purposes of training, education and research by providing hands-on

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experience for students, trainees and practitioners. In addition, researchers use learning factories in testing and validating their research. Thus, the trend for using learning factories in industry and academia has been growing, particularly in Europe, and have taken many forms of facilities varying in size and sophistication aiming to enhance the learning experience of students in one or more areas of manufacturing engineering knowledge. ElMaraghy and ElMaraghy [2] and Wagner et al. [3] documented and classified these learning factories according to terminology, structural model, identified parameters and their values, definition of dependent variable, attributes of ideal learning factory and finally, testing classification and scheme.

The learning factories vary based on the required educational and research domains and objectives. For example, the learning factory in the institute of production management, technology and machine tools in Darmstadt (first implementers of process learning factories in 2007) consists of machining centers and it is responsible for providing training in industrial technologies as well as lean manufacturing methodologies in collaboration with McKinsey & Company [4]. Hummel et al. [5] presented a learning factory at Reutlingen University covering industrial production processes and logistics concepts. Goerke et al. [6] proposed a two-stage training to illustrate the advantages of Lean Production and Lean Administration methods through a learning factory at the Institute of Production Systems and Logistics (IFA), Leibniz University. Stoldt et al. [7] introduced a concept for resource networks to manage production through renewable energy resources and applied it on Fraunhofer IWU's E³-Research(learning) Factory in Chemnitz. Weidig et al. [8] developed a virtual learning factory at the Institute for Manufacturing Technology and Production Systems (FBK), University of Kaiserslautern in which software tools from a digital factory were applied for the purpose of factory planning. Erol et al. [9] suggested a scenario-based Industry 4.0 learning factory to be implemented as the first Industry 4.0 Pilot Factory in Austria. Kemeny et al. [10] proposed the architecture and design principles of the Smart Factory at the Fraunhofer Project Center at MTA SZTAKI in order to simplify the cyber-physical systems and Industry 4.0 concepts. The learning factory for advanced Industrial Engineering (aIE) at the Institute of Industrial Manufacturing and Management (IFF) (University of Stuttgart) focuses on integrating digital production planning and implementation of the physical models in the laboratory [11]. Standardized and mobile Plug and Play modules for assembly, coating, inspection, transportation and storage are utilized which permits re-configuration into different layouts.

2. Changeable Systems Learning Factory

Key transformative enablers and strategies for productivity in manufacturing, which can create significant competitive advantage for manufacturing enterprises of any size, include: flexile, reconfigurable and changeable manufacturing paradigms, intelligent manufacturing systems, customization and personalization of products, intelligent sensors and the internet of things, and personalized manufacturing. One of the main goals of industry 4.0 is to have a highly responsive system. For a system to be highly responsive, several characteristics should be included such as modularity, integrability, scalability and convertibility which are the main changeability enablers [12]. Therefore, it is essential to introduce engineering students to these concepts and tools and provide them with meaningful hands-on experience of their design, implementation and integration in manufacturing systems [2].

An integrated systems learning factory, the first of its kind in North America, was set-up at the Intelligent Manufacturing Systems (IMS) Center in 2011 [2]. It includes a modular and changeable assembly system (iFactory) which consists of robotic and manual assembly stations, computer vision inspection station, Automated Storage and Retrieval System (ASRS) and several material handling modules. Palletized fixtures with RFID are used to carry the product. Each module has sensors used for identifying its neighboring modules and sends topology feedback signals to the Siemens SCADA control system to automatically recognize the configuration. All modules are mobile allowing for quick and short time changes in the configuration. Fig. 1 shows the iFactory at the IMS center, University of Windsor, Canada. It is integrated with a design innovation studio (iDesign), process and productions planning tools (iPlan), 3-D printing facility and dimensional metrology CMM facility. Its structure is similar to that at University of Stuttgart, but with different foci including: i) developing enablers of change in manufacturing, ii) manufacturing systems learning which integrates products design with systems configuration design and co-evolution of products and systems development, and iii) products design, customization, personalization and prototyping. Hence, the