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An information model to support reconfiguration of manufacturing systems

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Abstract: Reconfiguration has appeared as a paradigm that relies on a set of technologies and decision-making approaches to design, develop, monitor and control manufacturing systems in such a way to adapt to changes quickly, and with the exact required capacity and functionality. Existing research on reconfiguration of manufacturing systems puts more emphasis on enabling technologies and decision-making (mathematical modelling and reconfiguration algorithms), and less on the information models and tools that enable taking advantage of the flexibilities offered by such technologies and decision-making tools. Existing industrial information systems, such as Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES), offer limited support to manage configurations, and to capture decision makers' knowledge about when to use each configuration. In this article, we suggest an information model that supports decision-makers to reconfigure their manufacturing systems. The suggested model describes the configuration capabilities, performance, physical implementation (layout) on the shop floor, and situations in which each configuration can be used to overcome changes. We illustrate the proposed information model using an industrial case study.

Keywords: Information model, Reconfiguration, Manufacturing system.

1 INTRODUCTION

Reconfiguration has appeared as a paradigm that relies on a set of technologies and decision-making approaches to design, develop, monitor and control manufacturing systems in such a way to adapt to changes quickly, and with the exact required capacity and functionality (Koren et al. 1999). Reconfiguring manufacturing systems relies on different kinds of knowledge, requires and generates large streams of information, related to the description of product features, labour skills, manufacturing processes, production equipment, production management, planning and control, and production execution and performance. Indeed, researchers in this field have suggested approaches, methodologies and decision support tools to:

- Support collection of customer specifications, elicitation of needs, requirements engineering and subsequent automated design of reconfigurable manufacturing systems (Hirani et al. 2006), (Lohse et al. 2004), (Lohse et al. 2006), (Ratchev & Lohse 2004);
- Design configurations (Cavin & Lohse 2014), (Ferreira & Lohse 2012), (Liu et al. 2012), (Webbink & Hu 2005);
- Select suitable configurations based on multi-criteria decision-making (Ribeiro & Gonçalves 2010), (Landherr & Westkämper 2014);
- Move from one configuration to another in case of change and occurrence of unexpected events (Arai et al. 2002), (Cavin & Lohse 2014), (Travaini et al. 2002).

However, researchers have put more emphasis on enabling technologies and decision-making (mathematical modelling and reconfiguration algorithms), and less on the information models that would support taking advantage of the flexibilities offered by such technologies, and that would enable such decision-making. In fact, with respect to industrial information systems, the works in the literature focused on three aspects:

- Interoperability: propose architectures to allow an effective exchange and processing of information within or between enterprises, departments, and/or between different manufacturing software applications, e.g. CAD/CAM, simulation, scheduling, inventory, and logistics software (Bloomfield et al. 2012), (Harms et al. 2010), (Zhang et al. 2014);
- Product and process lifecycle management: suggest information and/or knowledge models to facilitate the product and process design, assembly, management of machine tool components and capabilities, and to support process planning, i.e. decide the suitable machining process to produce a specific part (Bruno et al. 2015), (Feng & Song 2003), (Guerra-Zubiaga & Young 2008), (Kjellberg et al. 2009), (Wang & Tong 2008), (Zhang et al. 2015);

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- Production execution and business intelligence: propose industrial information systems and architectures, such as ERP and MES, to support production management, planning, and control, to supervise production, to monitor operations execution, to insure traceability, and to monitor performance (Botta-Genoulaz et al. 2005; Naedele et al. 2015).

Only a few works suggest information models to support reconfiguration based on a monitoring and control point of view. For example, (Michalos et al. 2015) focused on the description of the assignment of resources and tools to stations. (Alsafi & Vyatkin 2010) suggested an ontology information model to reconfigure the manufacturing system using reconfiguration agents. The focus is on inferring the capability of a new machine based on the description of the capabilities of similar machines. The existing information systems and knowledge models offer limited support to manage configurations in terms of:

- Allowing and enabling creating new configurations;
- Describing configuration components and physical implementation (layout) on the shop floor;
- Describing the capabilities of each configuration;
- Capturing the knowledge of decision makers about when and how to use each configuration;
- Describing the performance of each configuration.

This article is intended to address these gaps by designing an information model to manage configurations and to support decision makers to manage their knowledge about configurations.

2 CONFIGURATION DESCRIPTION

This section introduces an industrial case study so that it can be used to illustrate the suggested information model. The selected case study is an assembly system that produces electro-submersible pumps of different sizes, power and usage. A sample assembly explosion is depicted in Figure 1.

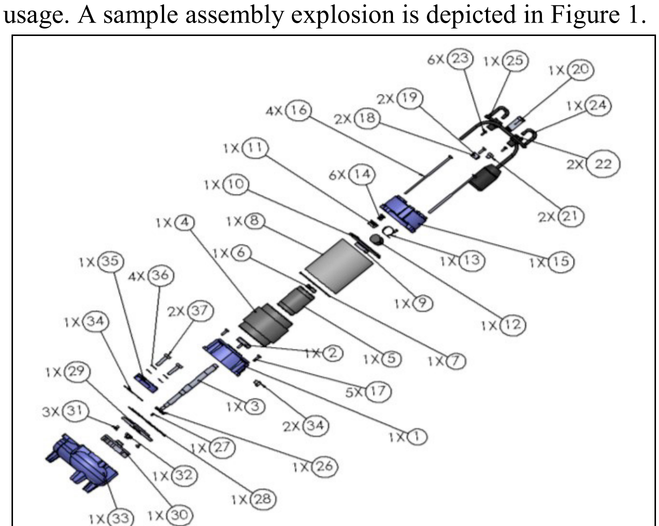

Figure 1.Electro-submersible pump assembly explosion.

Electro-submersible pumps are assembled in semi-automated assembly lines, which can be implemented according to several configurations. Each configuration is obtained from the association of multiple instances of a basic module (cf. Figure 2). Decision makers can reconfigure assembly lines by adding, removing and/or relocating basic modules during production execution, which enables quick and easy adaption of production capacity and functionality to changes (e.g. rush orders, machine failures, quality problems, etc.). A basic module is made of a *table*, a *roll conveyor,* and *mesh baskets* to store raw material parts, such as parts number 1, 8, 15, and 33 in Figure 1. The table has a working bench, and racks to carry small blue and red baskets. Blue baskets hold small assembly parts, such as parts number 7, 34, 36, and 37 in Figure 1, while red baskets hold tools, such as wrenches and screwdrivers. Each module requires one or more skilled workers to accomplish the assembly tasks.

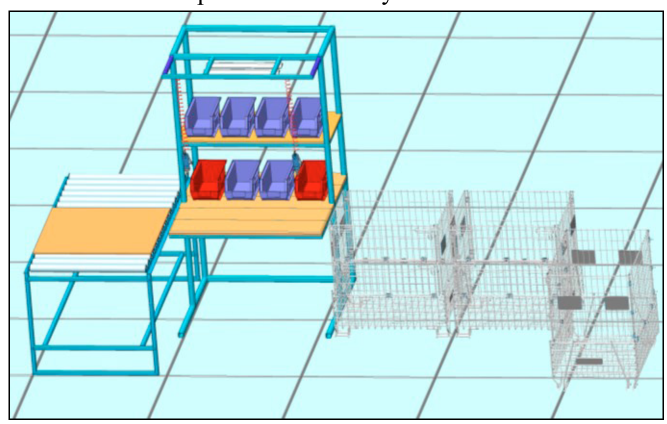

Figure 2. Basic Module.

Decision makers are able to provide general descriptions of the configurations they use in their manufacturing system. In this article, we are providing the description of two configurations for illustrative purposes.

The first configuration consists of two modules and one inspection station arranged in serial sequence (cf. Figure 3).

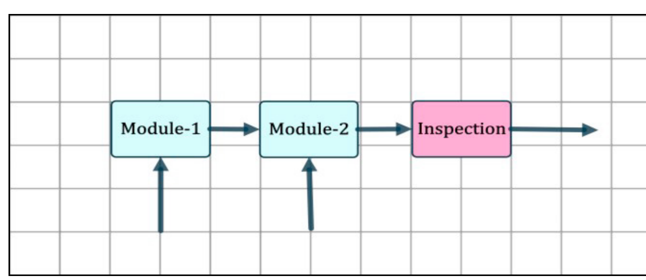

Figure 3. Layout of configuration-1.

In Figure 3, the motors (parts number 1 to 25 in Figure 1) are assembled on *Module-1*. Then, the motors are transferred on roll conveyors to *Module-2*, where the pump (parts number 26 to 37) is assembled on the motor to form a complete submersible pump. Next, the assembled submersible pump is transferred to an inspection station. After successful inspection, the assembled product leaves the assembly line for packing and delivery. Otherwise (non satisfactory inspection), the assembled product returns to one of the modules for rework. Figure 4 shows a CAD model of this configuration.