The development of simulation model for self-reconfigurable manufacturing system considering sustainability factors

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1. Introduction

In order to achieve an effective sustainable production, environmental concerns and issues have become more important in the manufacturing industry. Many countries and companies are making great efforts to keep environmental regulations and eco-friendly manufacturing. The main environmental regulations include Waste Electrical and Electronic Equipment (WEEE), the Restriction of Hazardous Substances (RoHS), Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), and so on. Many countries try to keep these regulations to reduce harmful materials and saving energy consumptions. Hazardous chemicals, air pollution, waste disposal and energy efficiency regulations from European Union (EU) are worldwide trends. These regulations are as follows; i) expanding manufacturers’ duty of environment, ii) controlling import and export through mandatory environmental regulations, iii) expanding the scope of regulations to procure raw materials, manufacture and logistics in the production process, and iv) eco-friendly product standard. Also regulations will cover an entire production life-cycle[1-4]. In order to follow these regulations, innovative manufacturing systems appeared, such as fractal manufacturing system (FrMS), holonic manufacturing system (HMS), intelligent manufacturing system (IMS), and so on[5]. Manufacturing systems, which can adapt environmental regulations for sustainable production easily, have some features which are as follows; i) ability to distribute entities, ii) communication mechanism for cooperation between entities, iii) ability to use an inside/outside device or equipment for flexibility, iv) modularization design for reconfiguration, and v) integrated information management system for production and product[6]. Such manufacturing systems; FrMS, HMS, IMS and so on, have these five features to achieve sustainable production. In addition, these manufacturing systems can reconfigure manufacturing processes and structure by itself. However, up to now, there are not many studies yet discussing about the integration of sustainability into the self-reconfigurability. Therefore, in this paper, the relationship between self-reconfigurability and sustainability is investigated, especially when a manufacturing system changes its process based on its new-determined goal. This paper also provides an experiment result by using simulation model consider a process reconfiguration and sustainability factors. Through existing research results, the literature is reviewed in order to obtain the relationship between self-reconfigurability and sustainability. The appropriate sustainability factors for self-reconfigurability such as energy efficiency, resource efficiency, and so on, has been checked and selected by using AHP (Analytic hierarchy process). Then, the simulation model will be developed by considering the selected sustainability factors. To check and analyze how sustainability factors affect manufacturing processes and how sustainability factors, also change when manufacturing process are changed. The result of this paper can be a basis for the future research to increase sustainability in a self-reconfigurable manufacturing system.

2. Literature Review

2.1. Fractal manufacturing system (FrMS)

Two main features of Fractal concept are self-similarity and recursiveness. Tirpak et al.[5] proposed new methodology of modeling and controlling for flexible manufacturing system using fractal architecture and Warnecke[6] proposed fractal factory. Fractal manufacturing system (FrMS) is proposed by Ryu et al.[7, 8]. FrMS has three major characteristic which are self-similarity, self-organization, and goal-orientation[9, 10]. Self-similarity means that each fractal unit has similar physical structure as well as formulation and pursuit of goals. Self-organization is an application that is a suitable method for controlling processes and optimizing the composition of fractals in the system. And goal-orientation means that each fractal unit in the FrMS has specific individual goals to achieve systems goal. Therefore, each fractal unit decides its goals, which can be different with other fractal units. For instance, manufacturing system’s goal is minimization of cost. And some fractal unit’s goal can be minimization of time, or minimization of resource utilization, and so on. Fig. 1 illustrates conceptual structure of FrMS[9]. FrMS is based on the concept of autonomously cooperating multi-agents referred to as fractals. Basic unit of FrMS is a basic fractal unit (BFU) which consists of five functional modules and agents as illustrated in Fig. 2. Fractal agent consists of five functional modules, which are analyzer, organizer, observer, resolver, and reporter. Observer module gathers information or message from another fractal agent and environment. Then it delivers information to analyzer module and resolver module. Analyzer module takes information from observer module and analyzes information,
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