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Usage of a digital eco-factory for sustainable manufacturing

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ABSTRACT

This paper proposes sustainable manufacturing using a digital eco-factory. When a digital eco-factory is used, green performance is examined in addition to productivity and manufacturability at the same time. A digital eco-factory shows green performance with various granularities such as machine level, product level and factory level. A digital eco-factory is a virtual factory and IT platform for sustainable production planning. In a digital eco-factory, the production scenario is examined by simulating manufacturing processes. The digital eco-factory is configured on a digital factory. The digital factory is constructed by applying multi agent technology. In the digital factory, all factory elements such as machine tools and assembly machines are configured as software agents. A digital factory mirrors the structure of the actual factory. At the usage stage, the user of a digital eco-factory can easily customize the configuration of the factory, target production scenario, granularity of simulation parameters, etc. Furthermore, the digital eco-factory supports execution of planned sustainable production by providing reference data for monitoring and online control of the shop floor. In addition, to practically spread the use of a digital eco-factory, e-catalogue library of machines/devices is proposed.

Introduction

Recently, it has become inevasible for the manufacturing industry not only to optimize customer service but also to consider the sustainability of the global environment and the whole life cycle of a product. Methodologies for environmental sustainability are available from the international standard ISO 14000 series about environmental management. (e.g. [1–3].) Now, there are various kinds of CADE (CAD for Environment) as DfE (Design for Environment) tools available for assisting in the design of a product's life cycle. According to these trends, IT investments by manufacturing industries are increasing and becoming a big burden.

At present, each factory of each enterprise devises means to reduce environmental impacts and develops its own methodology. From the viewpoint of production of mechanical products, such as a car, a personal computer, a mobile phone, a home electric appliances, and equipment for daily use, it is required to show the methodology for reducing carbon dioxide emissions by basically reviewing the structure and operation of the production system. For supporting such sustainable production, an IT tool which is constructed from the production view is necessary. (e.g. [4].) Furthermore, there are requirements to construct an integrated IT platform providing productivity data and environmental data from a product view and a production view at the same time. As a solution for the requirements, a digital eco-factory [5,6] has been proposed. And, as a solution for methodology the ISO 20140 series [7] is under development.

A digital eco-factory is a virtual factory and integrated IT platform on which a production scenario is examined from various viewpoints. In this paper, sustainable manufacturing using a digital eco-factory is proposed. When the proposed digital eco-factory is used, green performance of the planned production scenario is examined in addition to productivity and manufacturability at the same time with various granularities such as machine level, product level and factory level. By showing how to use a digital eco-factory at the production preparation stage and the production execution stage, its technical usefulness and practical requirements becomes clear [8]. When this digital eco-factory becomes available for practical use, IT supported tools for sustainable manufacturing will be ready for an eco-friendly society.

This paper is structured as follows. In this chapter, background and objectives are mentioned. In chapter 2, estimated advantages through the use of digital eco-factory are discussed. In chapter 3, the basic structure and elements of a digital eco-factory is explained [8]. In chapter 4, the way of how to use a digital eco-factory at the

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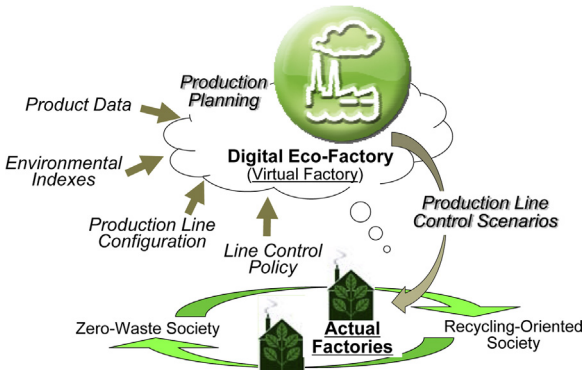

Fig. 1. Sustainable manufacturing using a digital eco-factory.

production preparation stage is introduced [8]. In chapter 5, the method of how to configure the virtual production line in a digital eco-factory is described [8]. In chapter 6, the example of an implemented digital eco-factory is shown. In chapter 7, an extension for a use case of a digital eco-factory and an e-catalogue library of machines/devices are newly proposed for spreading the concept of the digital eco-factory more widely. In the last chapter 8, this paper is concluded.

Estimated advantages about use of a digital eco-factory

The estimated advantages gained through the use of the digital eco-factory are discussed in this chapter. The application area is extended from green production [8] to sustainable manufacturing.

Production planning for sustainable manufacturing

Virtual manufacturing technologies such as a digital factory are used for productivity and manufacturability analysis [9,10]. When the proposed digital eco-factory is used, examination of green performance is added to the results of the analysis. Fig. 1 shows the concept of sustainable production using a digital eco-factory which is provided as a Web service such as cloud service.

At the planning stage of the sustainable production, a user such as the production system designer/developer sets the configuration of the production line, target production scenario including product data and production method, simulation parameters such as environmental index and line control policy, etc. Virtual manufacturing or production simulation is performed in a digital eco-factory according to the set data. Also the operating scenario for the actual production line control, green performance and production costs are obtained. By repeating these procedures, improvements of production processes and operation parameters are established at the same time from an environmental and economical view. Finally, the production scenario with the fewest environmental impacts is chosen for actual use. The obtained results will be used as reference values for the actual line operation.

The concrete image of a digital eco-factory is that, if a machine tool, a robot, a conveyance machine, a worker, etc. who are the components of a factory are modeled in a computer, they constitute a virtual factory which is a digital factory. By carrying this out easily, a composition is performed, a change of virtual equipment can be made, and detailed modelling also including the operation of each component can be attained. On the other hand, when the product model of the product is also designed with consideration of the environment using the eco-design tool, a process design is performed and all proposals of the production scenario that also took recycling/reuse into consideration are listed. Virtual manufacturing is carried out on a digital eco-factory according to these production scenarios. LCA is performed on the whole scenario, each process, equipment, etc [5].

Service contents provided by use of a digital eco-factory

Table 1 shows services which are provided by using a digital eco-factory for sustainable production preparation and planning. Service recipients are the production system designer including production engineer and plant manager, factory equipment vendor, and the manufacturing industry. A major service to the production system designers and developers are the pre-assessment of the configuration of the production line and production scenario in terms of both production cost and environmental view. A major service to the factory equipment vendor is showing the performance of his equipment. This service gives vendors the chance for making an appeal for their machine's excellence. A major service to the manufacturing industry is the enhancement of sustainable production with low ICT investment.

Structure of a digital eco-factory

The basic structure and elements of a digital eco-factory is more extensively explained in this chapter. Most of the contents have been discussed in reference [8].

Agent based structure of the digital eco-factory

The whole structure of the digital eco-factory is shown in Fig. 2. The digital factory [11] is the basis of the digital eco-factory. The digital factory is constructed on a virtual production line. To construct a virtual production line requires modelling an actual shop floor and its components, including their activities. Multi agent technologies can be applied to modelling them [12–14]. The virtual production line mirrors the structure of the shop floor in the actual factory. In these lines, all components such as machine tools, assembly machines, robots and workers are configured as software agents. These agents are called "machine agents" in this paper. In

Table 1
Services provided by a digital eco-factory.

Recipients	Service contents
Production system designer/developer	Pre-assessment of production line in terms of both cost and environmental view Pre-assessment of production scenario in terms of both cost and environmental view Pre-examination of the manufacturing equipment in the production line ICT aided manufacturing environment which is provided by low-cost cloud service Simulation environment which is easily able to set / change conditions
Machine tool and manufacturing device maker/vendor	Pre-examination of the machine tools and manufacturing devices on the production line using an e-catalogue Sales promotion of devices by trial on virtual production line (simulation using an e-catalogue)
Manufacturing industry	Promotion of sustainable production Decrease of ICT investment

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