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A proposal of skill evaluation method for production systems digital design with production simulation

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Abstract

Since we recognize needs for official training of personnel for the digital age, we expect a skill evaluation method of training skills for personnel in production systems design fields. To address this situation, we propose a skill evaluation method for production systems digital design with production simulation. The proposed method was developed by the subcommittee of JSME (the Japan Society of Mechanical Engineers). The subcommittee consists of experts from industry, the government and universities. The proposed method will promote the training of personnel for the digital age as a standard across different industries, taking advantage of production simulation.

Keywords: Skill evaluation method; Production system; Digital design; Production simulation

1. Introduction

Production systems are developing into new forms, integrating digital technologies using IoT and other technologies. Production system design, in this respect, has become much more important than conventional system design.

Companies or organizations provide training programs to train their human resources in production system design. In this case, however, since those programs are created using their own methods for their own objectives, training skills standards for human resources across different industries have not always been established.

More specifically, since the current concept of training for human resources has been provided based on Kaizen-type activities corresponding to specific on-site problems, systems that use production system simulation, which are considered to be important systems for the future digital age, have not yet been made available. Furthermore, since it is expected that official training programs will be needed for human resources to implement production system design utilizing digital technologies to enhance production competitiveness, the prompt standardization of training skills for human resources in the field of production system design is expected to be able to handle this situation.

To address this situation, we propose a skill evaluation method for production systems digital design with production simulation. The proposed method was developed by the subcommittee of JSME (the Japan Society of Mechanical Engineers) [1]. The subcommittee consists of experts from industry, the government and universities. The proposed method will promote the training of personnel for the digital age as a standard across different industries, taking advantage of production simulation.

2. Outline of skill evaluation for production system digital design skills

Our proposed skill evaluation for production system digital design skills consist of three definition items. These are a

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definition of particular field, a definition of skill level, and a definition of relationship between the particular fields. In the following chapters, we describe three definitions.

3. Definition of particular field

We clarify a production systems digital design procedure into three design processes as a concept design process, a basic design process, and a detailed design process.

The concept design process is the first stage for the design. In the concept design process, we design a production system considering five managements as a production systems configuration management, a factories synchronization management, a global production management, a CPS (Cyber Physical Systems) management, and an investment planning management.

The basic design process is the second stage for the design. In the basic design process, we design a production system considering five managements as a process design management, a facilities management, an in-factory logistics/ material handling management, a maintenance management, and a cost management.

The detailed design process is the third stage for the design. In the detailed design process, we design a production system considering three managements as a high-mix low-volume production management, a production fluctuation management, and an environmental management.

We define these thirteen managements in the following sections.

3.1. Production systems configuration management

With the knowledge of production systems configuration, such as area configuration of the entire factory, main lines, auxiliary lines and work stations, while drawing up production methods and layout configurations etc., it is to control the impact of those factors on production systems.

It is also comprehensively to examine the impacts of those factors together with the individual production system factors on production systems as a whole, and to design the optimum configuration with the optimum resources.

3.2. Factories synchronization management

With the knowledge of entire domestic and overseas supply chains (S/C) integrating factories, suppliers etc., while executing assessments of the impacts of those factors on each production system, it is to identify the impact of the supply chain structure. It is comprehensively examining the impacts associated with supply chains on individual production systems.

3.3. Global production management

With the knowledge of product properties in the life cycles of each product and system from the startup to the termination of mass production, while selecting the appropriate production site from globally developing factories, it is to determine the management system corresponding to the product life cycles of each product in a factory and designing production systems for the management system. It is to select the production site, preparing mass production and allocate production lines for new products in each factory, and decide production systems of multiple products and production systems for long-tail production at the final stage of the product life cycle etc.

3.4. CPS (Cyber Physical Systems) management

With the knowledge of production systems design regarding CPS (Cyber Physical Systems), establishing production methods to introduce CPS into the production system, layout and IoT configuration, etc. It is to analyse the effect CPS have on capabilities related to fluctuating market demand, productivity, production costs, the flexibility to cope with a wide variety of products and production volumes, etc. to decide which methods will improve by introducing CPS.

3.5. Investment planning management

With the knowledge of production systems design related to sales strategy, product strategy and production strategy as a business strategy for the establishment plan of a new factory, it is to draw up production systems for a wide variety of different business strategies. It is to analyse the investment effect of a business strategy, and to draw up the basic design from the perspective of plant locations, production systems design of each factory, in-factory logistics, procurement, etc.

3.6. Process design management

With the knowledge of production systems design associated with productivity, it is draw up production methods, layout configurations, formations of workers teams, etc. to improve productivity of production systems. It is to analyze the impact of factors such as production processes, allocation of production lines, layouts and formations of teams of workers on productivity, and to draw up methods for improving productivity etc.

3.7. Facilities management

With the knowledge of production systems design related to automatic devices, it is to draw up production methods, layout configurations etc. to introduce automatic devices into production systems. It is to analyze the impact of automatic devices on productivity, production costs, the number of workers etc., and drawing up methods to improve the effect of introducing automatic devices

3.8. In-factory logistics/ material handling management

With the knowledge of in-factory logistics in factories, it is to draw up in-factory logistics systems as part of production systems design. It is to analyse the effects in-factory logistics methods have on production methods such as production planning and on-demand production, the in-factory logistics of assets, factory layouts, the in-factory logistics pass design on productivity, lead times, required amount of inventory to decide which in-factory logistics methods will improve the flow of materials through the entire production system.

3.9. Maintenance management

With the knowledge of maintenance in factories, it is to create maintenance plans, and to take into account the impact on production systems. It is to analyse the impact of suspending the use of equipment during preventive maintenance and inspections, replacement of tools, changing a course of action, cleaning etc. for each of the facilities in the entire production system to create a maintenance plan.

3.10. Cost management

With the knowledge of production costs, particularly cost planning, it is to draw up methods to promote the design of production systems from the perspective of production costs. It is to analyse production costs corresponding to production planning for each production line and their production methods for the purpose of cost planning, and to draw up production systems designs when measures to reduce production costs have been taken.

3.11. High-mix low-volume production management

With the knowledge of configurations and systems for producing multiple products (items) in production factories, it is to draw up the allocation of production lines, production methods for multiple production, and in-factory logistics corresponding to multiple production in factories, etc. to control the impact of those factors on the entire production system. It is comprehensively to examine the impacts of the different processes for each product on other areas of production and the whole production system, and to design the optimum configuration with the optimum resources.

3.12. Production fluctuation management

With knowledge of the perpetually changing varieties of products and production volumes driven by demand, it is design production systems for a factory which will enable production according to market demand. It is to draw up methods etc. for production costs, occupancy rates of factories, and minimizing inventory to cope with production fluctuations based on demand forecasts (sales plans) after the startup of mass production.

3.13. Environmental management

With the knowledge of production systems design associated with energy or environmental emissions, it is to draw up production methods for production systems configured from the perspective of environmental management. It is to analyse the impact of production systems design on energy consumption, environmental emissions etc., then to draw up production systems which will be able to appropriately cope with the environmental issues.

4. Definition of skill level

We define that necessary skills for the production systems digital designs level consists of seven skill levels. We define seven skill levels in the following sections.

4.1. Level 1

Engineers who can carry out the required tasks under the guidance of their seniors. Those who have the basic knowledge and skills necessary for a professional with a specialty in production systems design.

4.2. Level 2

Engineers who can carry out part of the required tasks by themselves under the guidance of their seniors. Those who have the basic knowledge and skills necessary for a professional with a specialty in production systems design.

4.3. Level 3

Engineers who can carry out the required tasks by themselves. Those who aim to become a professional with a specialty in production systems design and have the necessary applicable knowledge and skills.

4.4. Level 4

Professionals who have cross-sectional specialties and are ahead of identifying and resolving business problems, freely using their specialized skills in production systems design. Those who can systemize the experience required for a professional and then contribute to the business performance of other team members.

Skills item code	Skills category	Skills classified	Skills item	Concept Design					Basic Design					Advanced Design		
				Production systems configuration management	Factories synchronization management	Global manufacturing management	CPS (Cyber Physical Systems) management	Investment planning management	Process design management	Facilities management	In-factory logistics management	Maintenance management	Cost management	High-mix low-volume production management	Production fluctuation management	Environment management
S1001	Required knowledge	Production systems engineering	Production systems structure	◎	○	○	○	◎		○						
S1002			Production systems method	◎	○	○	○	◎			○					
S1003			In-factory logistics/material handling system	◎	◎	○	○	◎								–
S1004			Design of the flow of materials and information	◎	◎	○	◎	◎						○	○	
S1005			Production control	○	◎	◎	◎	◎	○			○				
S1006			IT system to support manufacturing	○	◎	◎	◎	◎						○	○	–
S1007			Reliability engineering		○	○								–	–	–
S1008			Cyber Physical Systems	◎	○	○	◎	◎								
S1009			Optimal control system	○	○	○	○	○		–		–	–			–
S1010		Cost management	Cost planning			◎	○	◎	–	○			○	○	○	–
S1011			Activity-based costing			○	○	○	–	○			○	○		–
S1012		Environmental engineering	Evaluation of energy	○		○		○	–	–	–	–	○	–	–	○
S2001	Systems design methodologies	Industrial engineering (IE)	Process analysis	○	○	○	○	○	◎	◎	◎	◎	◎	◎	◎	–
S2002			Operation analysis	○	○	○	○	○	◎	◎	◎	◎	◎	◎	◎	◎
S2003			Motion analysis	–	–	–	–		○	○			○			–
S2004			Time analysis	–	–	–	–		○	○	○	○	○	○	○	○
S2005		Operations research	Linear programming											○	○	–
S2006			Optimization algorithm						○	○	◎	○		◎	○	–
S2007			Production scheduling						◎	◎	◎			◎	◎	–
S2008			Queuing theory						○	○	○	○		○	○	–
S2009		Statistics	Summary statistics analysis						○	○	○			○	○	○
S2010			Inferential statistics analysis						○	○	○			○	○	
S2011			Experimental design method						○	○	○			○	○	○
S2012			Multivariate analysis						○	○	○			○	○	
S3001	Digital technologies	Production simulation	Production simulation						◎	◎	◎	◎	◎	◎	◎	◎
S3002			Algorithm design						○	○	○	○	○	○	○	○
S3003			Logical model definition						◎	◎	◎	◎	◎	◎	◎	◎
S3004			Simulation model definition						◎	◎	◎	◎	◎	◎	◎	◎
S3005		Software	Programming						○	○	○	○	○	○	○	○
S3006			Database						○	○	○	○	○	○	○	○

The symbols ◎ and ○ described in “Concept Design”, “Basic Design” and “Advanced Design” are linked to the same symbols on Page 2. The symbol “-” indicates “Not applicable”.

Fig. 1 Relationships between skills and knowledge to acquire and the proposed definition of the particular fields

Major item code of task	Large group of classified tasks	Code for mid-sized group of classified tasks	Mid-size group of classified tasks	Code for small group of classified tasks	Small group of classified tasks	Concept Design					Basic Design					Advanced Design		
						Production systems configuration management	Factories synchronization management	Global manufacturing management	CPS (Cyber Physical Systems) management	Investment planning management	Process design management	Facilities management	In-factory logistics management	Maintenance management	Cost management	High-mix low-volume production management	Production fluctuation management	Environment management
T11	Project definition	T1101	Project requirement definition	T1101001	Target definition	◎	◎	◎	◎	◎								
				T1101002	Target requirement definition	◎	◎	◎	◎	◎								
				T1101003	Constraint requirement definition	◎	◎	◎	◎	◎								
		T1102	Project conditions settings	T1102001	Boundary conditions settings						◎	◎	◎	◎	◎	◎	◎	◎
				T1102002	Target conditions settings						◎	◎	◎	◎	◎	◎	◎	◎
				T1102003	Constraint conditions settings						◎	◎	◎	◎	◎	◎	◎	◎
				T1102004	Objective equipment settings						◎	◎	◎	◎	◎	○	○	○
				T1102005	Uncertain event settings	○	○	◎	○	◎								
T12	Model definition for production simulation	T1201	Logical model definition	T1201001	Model granularity definition	◎	◎	◎	◎	◎					–			–
				T1201002	Shopfloor plan definition						○	○	○	○	○	○	○	–
				T1201003	Production process definition						◎	◎	◎	○	○	◎	◎	○
				T1201004	In-factory logistics/material handling definition						○	○	◎	–	○	○	○	–
				T1201005	Manufacturing assets definition						◎	◎	◎	◎	◎	○	○	○
		T1202	Data definition and settings	T1202001	Input and output conditions of data definition						○	○	○	○	○	○	○	–
				T1202002	Data acquisition method definition	○	○	○	○	○	○	○	○	○	○	○	○	
				T1202003	Uncertain data definition	○	○	◎	○	◎								
				T1202004	Data properties definition	○	○	◎	○	◎								
				T1202005	Data cleaning						○	○	○	○	○	○	○	–
				T1202006	Data conversion (normalization)						○	○	○	○	○	○	○	–
T13	Execution of production simulation	T1301	Established a simulation model	T1301001	Development from logical model to computation model	○	○	○	○	○	◎	◎	◎	◎	◎	◎	◎	–
				T1301002	Simulation model definition (Input)	○	○	○	○	○	○	○	○	○	○	○	○	–
				T1301002	Establishment of expanded computation model	○	○	○	○	○	○	○	○	○	○	○	○	–
		T1302	Validated a simulation model	T1302001	Debugging of computation model						○	○	○	○	○	○	○	–
		T1303	Confirmed validity	T1303001	Validity confirmed of logical model						◎	◎	◎	◎	◎	◎	◎	○
				T1303002	Validity confirmed of computation model						◎	◎	◎	◎	◎	◎	◎	–
		T1304	Production simulation execution	T1304001	Settings for duration of computation execution						◎	◎	◎	◎	◎	◎	◎	○
				T1304002	Settings for initial state and stable state						○	○	○	○	○	○	○	–
				T1304003	Draft of simulation execution planning						○	○	○	○	○	○	○	–
				T1304004	Implementation of simulation execution planning						○	○	○	○	○	○	○	–
T14	Analysis and decision making	T1401	Results analysis	T1401001	Understanding and analyzing the results	○	○	○	○	○	◎	◎	◎	◎	◎	◎	◎	○
		T1402	Proposal of a design draft	T1402001	Creation of a decision making draft	◎	◎	◎	◎	◎	○	○	○	○	○	○	○	○
				T1402002	Preparation of reports on project activities	○	○	○	○	○	○	○	○	○	○	○	○	○
		T1403	Report and determination	T1403001	Reporting	○	○	○	○	○	○	○	○	○	○	○	○	○
				T1403002	Determination and decision making	◎	◎	◎	◎	◎	○	○	○	○	○	○	○	○
				T1403003	Indication of reactive measures	◎	◎	◎	◎	◎	○	○	○	○	○	○	○	○

The symbols ◎ and ○ described in “Concept Design”, “Basic Design” and “Advanced Design” are linked to the same symbols on Page 2. The symbol “-” indicates “Not applicable”.

Fig. 2. Relationships between the tasks to be executed by personnel and the proposed definition of the particular fields

4.5. Level 5

Professionals who can stay ahead of the technologies, methodologies and production innovations associated with production systems design inside the company. High-end players who are acknowledged inside the company.

4.6. Level 6

Professionals who can stay ahead of the technologies, methodologies and production innovations associated with production systems design both inside and outside the company. Domestic high-end players who have both the experience and proven performance, and are acknowledged as a professional from the perspective of not only inside-the-company but also from the markets.

4.7. Level 7

Professionals who can stay ahead of the technologies, methodologies and production innovations associated with production systems design both inside and outside the company. World-class players who have both the experience and proven performance, are market influencers, and have led the creation of advanced manufacturing methods or manufacturing structures.

5. Definition of particular field and skill level

We propose a relationship between the particular field and the skill level. Fig. 3 shows the relationship. Level 6 and 7 indicate national-class and world-class personnel respectively, whose capabilities and skills may be beyond the upper limit of evaluation.

6. Case study 1: Tasks to be executed by personnel

We applied the proposed definitions to tasks to be executed by personnel. Fig. 2 shows the example for the relationships between the tasks to be executed by personnel and the proposed definition of the particular fields.

7. Case study 2: Skills and knowledge to acquire

We applied the proposed definitions to skills and knowledge to acquire. Fig. 1 shows the example for the relationships between skills and knowledge to acquire and the proposed definition of the particular fields.

8. Summary

We proposed a skill evaluation method for production systems digital design with production simulation. Our proposed skill evaluation for production system digital design skills consist of three definition items. These are a definition of particular field, a definition of skill level, and a definition of relationship between the particular fields. We carried out two case studies to apply the asks to be executed by personnel, and the skills and knowledge to acquire. We are pleasure that the proposed method promotes the training of personnel for the digital age as a standard across different industries, taking advantage of production simulation.

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Particular field (View)	Concept Design					Basic Design					Advanced Design		
	Production systems configuration management	Factories synchronization management	Global manufacturing management	CPS management	Investment planning management	Process design management	Facilities management	In-factory logistics/material handling management	Maintenance management	Cost management	High-mix low-volume production management	Production fluctuation management	Environmental management
Level 7 (*)													
Level 6 (*)													
Level 5	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
Level 4	○	○	○	○	○	◎	◎	◎	◎	◎	◎	◎	◎
Level 3	–	–	–	–	–	○	○	○	○	○	○	○	○
Level 2	–	–	–	–	–								
Level 1	–	–	–	–	–								

(*) Level 6 and 7 indicate national-class and world-class personnel respectively, whose capabilities and skills are beyond the upper limit of evaluation.

Fig. 3. Relationship between the particular field and the skill level.

References

[1] Evaluation of Manufacturing System Design Skills subcommittee, <https://www.jsme.or.jp/msd/html/95/productionSimulationStandard_V1.0.pdf>, (Reference day:30th April 2019)