The Manufacturing Equipment Support Model Based on the Manufacturing Equipment Role

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Abstract: This work aims to investigate the manufacturing equipment support model for the purpose of improving the efficiency and quality of manufacturing. First, the concept of manufacturing capacity is defined, and the relationship between practical and expected manufacturing capacity is described. Then the concept of role is introduced and the manufacturing equipment role is defined in detail. Based on the analysis of manufacturing capacity and manufacturing equipment role, the three-stage manufacturing equipment support model is proposed. With this model, the manufacturing task can be decomposed into several manufacturing equipment roles, and the expended manufacturing capacity involved in the manufacturing equipment role can be matched with the practical manufacturing capacity of the enterprise. The measures are discussed depending on different matching degrees.

Key words: manufacturing equipment; manufacturing capacity; manufacturing equipment role; support model

1 Introduction

The manufacturing equipment mainly refers to the capital goods which are all kinds of technical equipment manufactured to meet the sectors of the national economy development and national support needs, including machinery and electronics and investment manufactured goods in the weapon industry, etc. The manufacturing equipment is the necessary way to finish a manufacturing task. From the perspective of the enterprise, the manufacturing task should be assigned to suitable manufacturing equipment to be done. Thereby, the support degree of manufacturing equipment towards the manufacturing task is an important element to the product quality, the cost and the time to market. However, any single enterprise hardly has all the manufacturing equipment needed whenever and wherever possible. So, how to carry out the manufacturing equipment support is an urgent problem to be solved.

At present the research on manufacturing equipment support mainly focuses on manufacturing resource configuration and selection. In the aspect of manufacturing resource configuration, Wang [1] researched on the technology of manufacturing resource configuration under variable mass production modes. Wang [2] analyzes the optimizing configuration problem of cloud manufacturing resource and establishes the optimized model of resource aiming at cost and time minimization as well as quality optimization. Wang [3] concerns resource configuration decision making of product

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combination under the limited resources and constructs a multidimensional game model using the quantitative decision element as dimension. In the aspect of manufacturing resource selection, Liu [4] presents a double-link genetic algorithm to solve the sourcing configuration problem under the condition of global manufacturing. Fang [5] constructs a comprehensive evaluation system for manufacturing resource selection and uses both the Analytic Hierarchy Process(AHP) and grey relation theory to realize the rapid selection of manufacturing resources. Zhao [6] puts forward an orthogonal differential hybrid evolution algorithm for manufacture resource selection. An [7] presents the selection method of extended manufacturing units oriented key parts.

The existing research mainly focus on the technology of manufacturing resource configuration and the selection and evaluation methods of manufacturing resources. From the angle of matching manufacturing equipment and task, this paper focuses on the support problem of manufacturing equipment. Based on the analysis of the concepts of manufacturing capacity and manufacturing equipment role and their structures, the matching of the expected manufacturing capacity and practical manufacturing capacity is researched. According to the matching degree, the support model of manufacturing equipment based on the manufacturing equipment role is presented.

2 Manufacturing capacity and manufacturing equipment role

2.1 Definition of manufacturing capacity

Manufacturing capacity refers to the product quantity which could be manufactured or raw material which could be handled by all the fixed assets involved in the manufacturing of the enterprise under certain conditions of organization and technology in the planning period. The description definition of manufacturing capacity is as follows.

Definition 2.1 manufacturing capacity: suppose a piece of manufacturing equipment has a group of operable activities and they are described as set $A=\{a_1, a_2, \cdots, a_n\}$, and the manufacturing equipment has a property set which is described as set $P=\{p_1, p_2, \cdots, p_n\}$ ($p_{1a} \leqslant p_1 \leqslant p_{1n}$, $p_{2a} \leqslant p_2 \leqslant p_{2n}$, $\cdots$, $p_{na} \leqslant p_n \leqslant p_{nn}$), and also suppose the part to be machined has a group of features which is described as a set $F=\{f_1, f_2, \cdots, f_n\}$. If we make A act on F, the manufacturing equipment will finish machining the features of the part to be machined in the feature set by playing a function or the set of functions under the performance bound and reach a certain quality of process and result, then we say that the manufacturing equipment has manufacturing capacity.

In the formalized description of the manufacturing capacity, the set A includes all of the machining activities such as turning, milling, boring, grinding and drilling, etc. The set P includes all the properties of the manufacturing equipment such as the maximum speed, the maximum processing size, rated power and precision grade, etc. The set F includes all the features of the part to be machined such as the plane, curved surface, groove and hole, etc. The action that A plays on F can be either a single activity like turning or milling, or mixed by several activities like boring and grinding acting at the same time.

2.2 Practical manufacturing capacity and expected manufacturing capacity

In the light of the requirement of our research, the manufacturing capacity can be divided into three types and they are the practical manufacturing capacity, the expected manufacturing capacity and the satisfactory manufacturing capacity. Among them, the first two

are the focus of our concern.

The practical manufacturing capacity is the capacity that the existing manufacturing equipment in the enterprise has. They mean the "actual" manufacturing capacity. But it's different from the expected manufacturing capacity. The expected manufacturing capacity refers to the capacity that people expect the equipment has to finish the manufacturing task. The starting point of expected manufacturing capacity is manufacturing task, but not the manufacturing equipment itself. It reflects the requirement of the manufacturing task. The expected manufacturing capacity may be realized by the existing manufacturing equipment in the enterprise in a certain condition, or not, e. g., the expected machining precision of equipment is IT05, but the practical precision only can reach IT10.

Figure 1 shows the relationship of practical manufacturing capacity and expected manufacturing capacity. In Figure 1, the horizontal axis shows all the basic activity properties of manufacturing equipment and the vertical axis shows all the satisfactory activity properties of manufacturing equipment. The oblique line in quadrant I and quadrant II is the expected manufacturing capacity. The curve at the lower right is the practical manufacturing capacity and the curve at the upper left is the satisfactory manufacturing capacity. Figure 1 shows that from the quality of the activity property involved in the manufacturing capacity, the expected manufacturing capacity is stronger than the practical capacity.

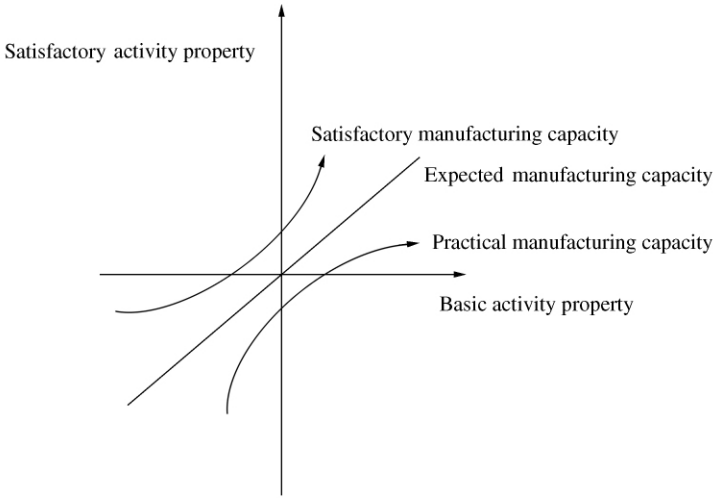

Figure 1 The relationship of practical manufacturing capacity and expected manufacturing capacity

3 Manufacturing equipment role

3.1 Role

Derived from the theater, "Role" was widely used in the research of sociology and psychology. The sociological definition of role is: "the behavior patterns are manifested by individuals in a certain social status, according to the social norms and expectations of society, with their own subjective ability to meet the social environment."

Referring to enterprise management, different employ-

ees have different expectations and requirements of organizations in the role of employees in enterprises. This role is not fixed, and continues to change with the development of enterprises and requirement of enterprises management. For instance, some project members may be the leader of the original functional department in project management, while their role in a project team may become service providers. The role is an abstract concept, rather than a specific individual. It essentially reflects a social relationship where a specific individual is a certain role player.

The scientific definition of the role has been given in the application of computer technology and network. The definition of the role referring to the "role-based access control" theory is that the role is a work or position in an organization or a task which represents a qualification, rights and responsibilities. On the one hand, it indicates the division of responsibility of the users and on the other hand, it shows a feature set of the system that a certain type of users can access.

In the synthesis of the above contents, the formal definition of the role is given as follows:

Definition 3.1 role: a set of all the features of entities is denoted as $A = \{a_1, a_2, \cdots, a_n\}$, and several or all characteristics of the entity is called role. If R_A represented the role, then $R_A \subseteq A$, where a_i represents the characteristics of the entity. For example: a_1 represents the processing capacity of the entity; a_2 represents the shape of the entity; a_3 stands for entity economy; a_4 means environmental friendliness of the entity; a_5 signifies the rationality of the entity design and a_6 is property stability of the entity etc.

3.2 Manufacturing equipment role

The manufacturing equipment role refers to some behavior pattern of the manufacturing equipment to meet certain manufacturing requirements and embodies the expectation and requirement of manufacturing task. The manufacturing equipment role and expected manufacturing capacity has a close connection. The manufacturing equipment role is the macroscopic expression form of the set consisting of manufacturing capacities. The expected manufacturing capacity is the microscopic support element of the manufacturing equipment role. The manufacturing equipment role has a higher level than the manufacturing capacity and the manufacturing equipment role contains the manufacturing capacities which have different structures and different contents.

The formalized definition of the manufacturing equipment role is as follows.

Definition 3.2 manufacturing equipment role: suppose A' expresses the set of all of the expected manufacturing capacities of manufacturing equipment and $A' = \{a'_1, a'_2, \cdots, a'_n\}$, R means manufacturing equipment role, then $R \subseteq A'$.

In definition 3.2, a'_i means manufacturing capacity, $i = 1, 2, \cdots, n$, such as a_1 means pipe diameter, a_2 means thickness, a_3 means production rate, a_4 means cutting precision, a_5 means feed speed, etc. It's important to note that, R_A includes the pseudo-role, namely, the combination of any processing capacity of the manufacture equipment does not always constitute a certain role, and the combinations of some processing capacity which make no sense cannot constitute a role.

4 The support model of manufacturing equipment based on the manufacturing equipment role

The support model of manufacturing equipment based on the manufacturing equipment role can be divided into three stages as shown in Figure 2.

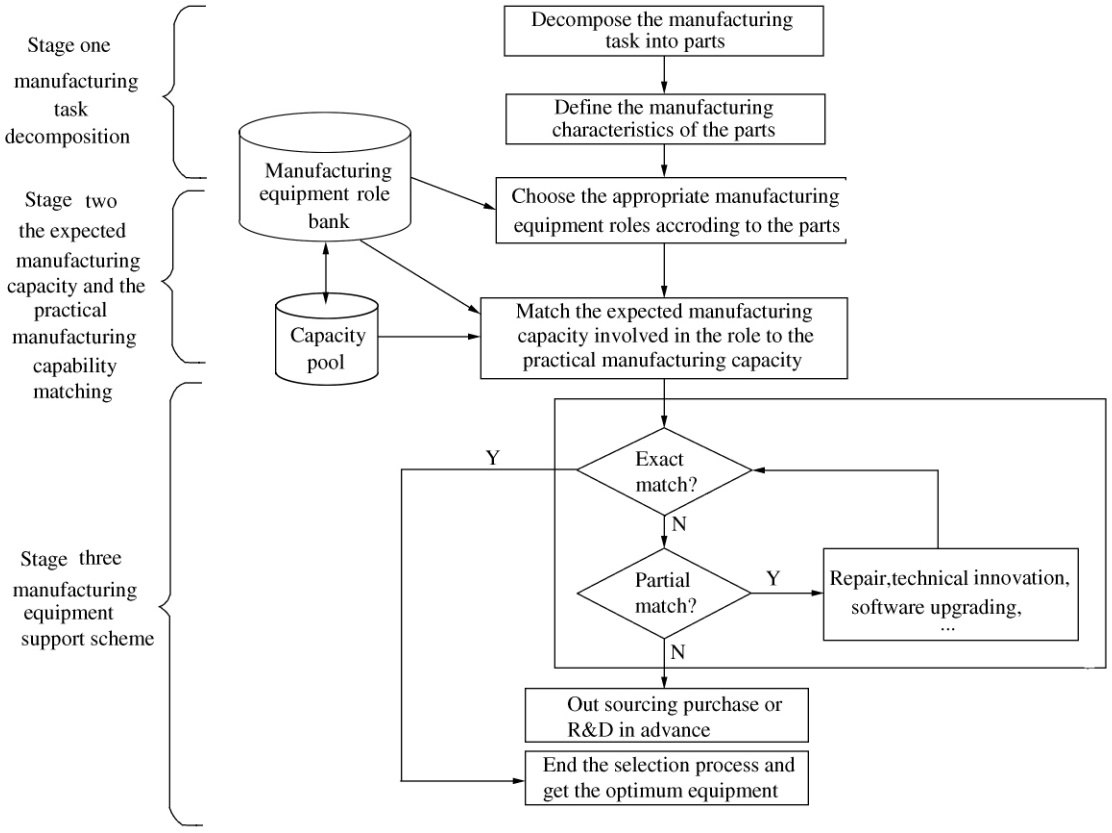

Figure 2 The manufacturing equipment support model based on the manufacturing equipment role

Stage one is the stage of manufacturing task decomposition. First, the manufacturing task is decomposed into part levels. Then the manufacturing features of all the parts are defined. At last, the manufacturing roles required are selected from the manufacturing role bank according to the manufacturing features of the parts. The manufacturing equipment role could conduct the operation on certain manufacturing features and it is the set of several expected manufacturing capacities. The manufacturing role bank is the set of all manufacturing equipment roles, and it also takes the function of storing and managing the manufacturing equipment role.

Stage two is the stage of the expected manufacturing capacity and the practical manufacturing capability matching. In this stage, all the expected manufacturing capacities in the manufacturing roles selected are matched with all the practical manufacturing capacities for searching for the same or the similar practical manufacturing capacities that existed or were available. The practical manufacturing capacities are stored in the manufacturing capacity pool which is the set of practical manufacturing capacities with a certain structure. The manufacturing capacity pool can conduct the function of practical manufacturing capacity storage and management.

Stage three is the stage of manufacturing equipment support scheme. In this stage, the appropriate equipment is selected from all the existing manufacturing equipment or other measures are considered under the condition of no suitable equipment is available. First, judge whether the expected manufacturing equipment role selected is "exactly match" with the practical manufacturing capacity involved in the manufacturing capacity pool. If the answer is yes, end the judgment and get the suitable equipment. If there are several pieces do equipment that meet the requirement at the same time, choose the most efficient one. If the answer is no, continue to judge whether they "partly match" if the answer is yes, check out the equipment and based on the actual situation take the appropriate measures such as equipment repair, technical reformation and software upgrade and so on, then continue

to judge whether "partly match" and start another cycle. If not "partly match" in the first cycle, analyze whether the manufacture characteristics that can't be realized by the practical manufacturing capacity belong to the core parts of the product. If they are the core parts, then suggest that make a purchasing plan in advance to purchase the parts. However, if a technological blockade exists, we should research and develop the equipment in advance and try to grasp the core manufacture technique. If the manufacturing features that can't be finished by the practical manufacturing capacity don't belong to the core parts, then suggest outsourcing. The number of the cycles in the dashed box in Figure 2 depends on the enterprise's actual situation. For example, if there is short time left, the number of cycles should be reduced appropriately, and if time is enough, the number of circulation should be increased.

5 Conclusions

This paper presents and analyzes the three-stage manufacturing equipment support model based on the manufacturing equipment capacity and role. In this model, manufacturing task is decomposed into different manufacturing roles and expected manufacturing capacity involved in manufacturing equipment role is matched with the practical manufacturing capacity involved in the manufacturing capacity pool. The matching result is used to make the requirement support scheme. This model considers most of the conditions that may happen in the process of manufacturing requirement selection and presents both comprehensive and detailed solutions accordingly. However, there are some concrete problems that should be studied further, such as the similar degree calculation method between expected capacity and practical capacity.

References

[1] Wang Q A, Hu X Q. Research on matching of manufacturing resources for scalable batch production [J]. Machine Building & Automation, 2006,35(6): 77 ~ 79 (In Chinese)

[2] Wang S L, Song W Y, Kang L, *et al*. Manufacturing resource allocation based on cloud manufacturing [J]. Computer Integrated Manufacturing Systems, 2012,18(7): 1396 ~ 1405 (In Chinese)

[3] Wang Y Z, Hu Y G, Zhang R J. A game theoretic approach to product-mix resource allocation [J]. Manufacturing Automation, 2011,33(4): 72 ~ 75 (In Chinese)

[4] Liu J S, Liao W H, Guo Y. Sourcing configuration in global manufacturing based on double-link genetic algorithm [J]. Journal of Mechanical Engineering, 2008,44(2): 189 ~ 195 (In Chinese)

[5] Fang Y D, Du L H, He W P, *et al*. Manufacturing resource selection technology based on rapid extended manufacturing environment [J]. Computer Integrated Manufacturing Systems, 2009,15(3): 515 ~ 521 (In Chinese)

[6] Zhao Z F, Ma L X, Xu J W. Manufacture resources selection based on orthogonal differential hybrid evolution algorithm [J]. Computer Engineering,2012,38(2): 181 ~ 183 (In Chinese)

[7] An B, Liao W H, Guo Y, *et al*. Research on selection method of extended manufacturing units oriented key parts [J]. China Mechanical Engineering,2010, 22(1): 44 ~ 48 (In Chinese)

Brief Biographies

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