

Research on Workflow-based Modeling Method of Product Manufacturing Process

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Abstract

In order to improve ability and competitiveness of enterprises to fit market faster, and to short time of productions' designing and manufacturing. With the developing of the technology of manufacturing cell turning into intelligence, the method of productions' manufacturing process model that is based on work flow was put forward in this passage. The model of product manufacturing process which was based on the process model defined by the workflow standard was expanded. It was not only to reflect the structure of manufacturing process, but also to describe the dynamic distribution of manufacturing resource in the manufacturing process. The methods and correlations of the modeling of production procedure process, the dynamic modeling of manufacturing resource and the modeling of product manufacturing process were expounded in details. Finally, the accuracy and validity of this model were verified by the system simulation of the manufacturing process of high-compression cylinder which was a key component in steam turbine.

Keywords: *manufacturing process modeling, manufacturing resource modeling, workflow, model mapping*

1. Introduction

With the development of economic globalization, information technology and communication technology contribute to pushing forward global manufacturing industry [1]. It is urgent for manufacturing enterprise to carry out all or part of the whole life cycle business activities, such as product design, manufacturing, sales, procurement and management, to realize enterprise resources sharing and integration for the market to provide the necessary products with high speed, high quality and low cost. Therefore, study of manufacturing process modeling methods is to quicken the generation of feasible products manufacturing process model to meet product production plan conditions, according to the enterprise manufacturing resources and capacity to shorten the production cycle time, cut the cost and improve the ability to quick respond to the market. The model should be open, flexible and reassemble to meet the needs of the environment and manufacturing resources [2].

Enterprise can be regarded as a complex system formed by plenty of process with specific organizational target. Process is the core of the enterprise, reflecting the enterprise efficiency and properties [3]. Research about the process reflects the situation of manufacturing technology [4].

The purpose of constructing model is to make people, equipment and resources be part of the manufacturing enterprise [5]. Process model is a kind of model defining composition activity and the logical relationship between the activities to describe the workflow. And the

process modeling is a kind of method and technology to set up a description of the process model by defining the activities and relationship between the activities to describe the business process or workflow. The main purpose of process modeling is to solve the issue about how to organize the system activities effectively to make sure the operation process is done accordingly to process goals and the constraint conditions of system. Manufacturing process modeling is the important basis of product manufacturing process analysis and manufacturing process optimization.

2. Product Modeling

2.1. Definition of Workflow Standard Process Model

WFMC(Workflow Management Coalition) defines a meta model describing process definition (Figure 1), to describe the top entity contained by process definition and the relationship between these entities and attributes (except for the execution of the properties, including some simulation and monitor attributes). The meta model helps to improve the universal applicability and computer supporting. Process modeling of integrated enterprise modeling method is based on the meta model. Process meta model mainly include: process definition, activities, Information transition, definition of workflow participants, definition of workflow application, the workflow-relevant data.

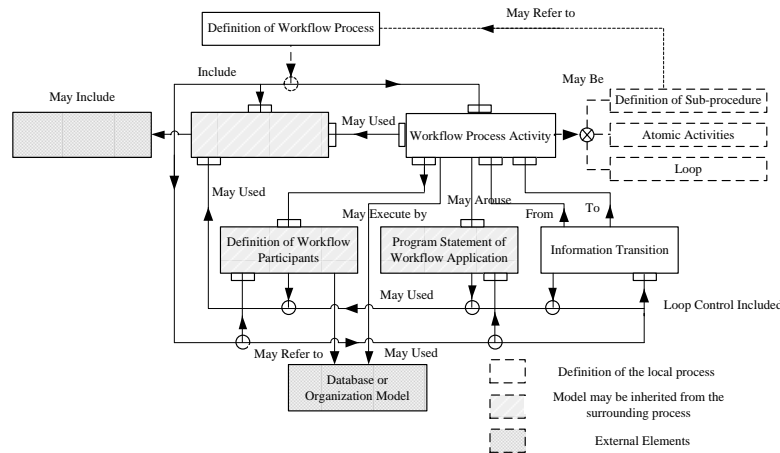


Figure 1. The Modeling of Process Definition Meta-Model

2.2. The Definition of Product Process Model

The nodes of process model conclude three types: task node, logic node and mark node. The task node which represents all types of activities and tasks needed by actual process includes atomic level "artificial type activities", "automatic application" and the Non-atomic level, decomposition "process". Logic node includes "and node", "or nodes" and "empty activities". Mark node includes "start node" and "end nodes" [6].

"Process" which contains all the elements of workflow model inside is a node of decomposition, essentially it is a sub workflows. The introduction of the "decomposition process" enhances model expression ability, so as to take process activities of some part together, described in the map with a node. It can reflect the overall logic structure of product process model clearly. As shown in Figure 2, process node with shadow in high pressure cylinder of turbine process model is a "process", which expresses a collection of craft

activities of a part; in the point of the product, parts process model of HP cylinder is also a decomposition "process" node.

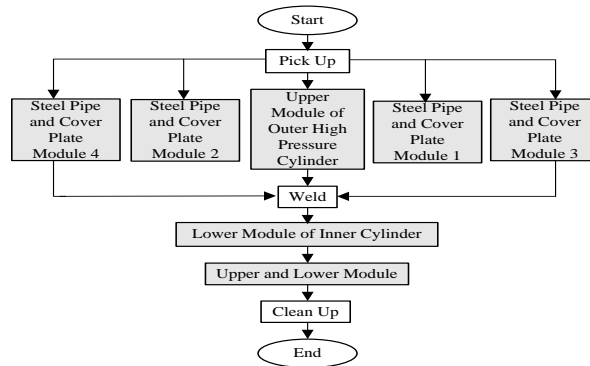


Figure 2. Process modeling of High-Pressure Cylinders in Turbines

As the model has the concept of hierarchical structure, product process model can be divided into parts process model and components process model by process analysis. Finally, we can get product process model with multi-layer sub-processes by top-down modeling process, which describes processing process model and assembling process model of all the product parts.

2.3. Conversion between CAPP Process Planning and Product Process Model

Parts model and the component model are hierarchical structure. Therefore the same model of structure, control and management strategy can be used. Different models are stored in model libraries as templates, called in product process model initialization by the modeling tool, generating process model. The construction process of model is a former sequence to traverse the corresponding product structure tree process. The search process, starting from the root node, followed by the first, second sub-tree, is conducted by the readers. When approach to a node, first read the node ID information, then determine the node type, while the process reading the appropriate type of template, and then enter the process information into templates, generate the corresponding process model. While traverse to the end of product structure tree, a new complete product process model is established.

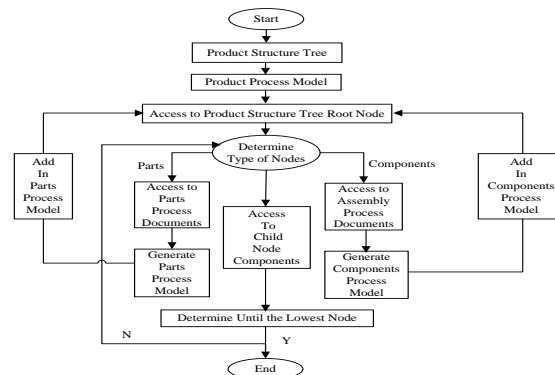


Figure 3. The Sketch Map of Conversion from Process Procedure to Product Process Mode

3. Dynamic Modeling Supporting Automatic Mapping of Manufacturing Resources Classification

Resource model, resource entities, resource pools, and resource combinations are used in traditional resource modeling to describe the classification of resources and structural elements. The similarities of modeling method of manufacturing resources in this article and traditional resource modeling is that they are resources sort modeling, formed by resource type, resource entities, other concepts and so on. Thus, we can use traditional resource-based classification model to describe the resource model and the entity's public property.

3.1. The Dynamic Characteristics of Manufacturing Resource Model

If the same group of resources is classified by the processing availability of high-pressure cylinder of a steam turbine, as the resources of the state changes at different times, classification model is different, as shown in Figure 4, the change can be described only by adding environmental resource category, or not.

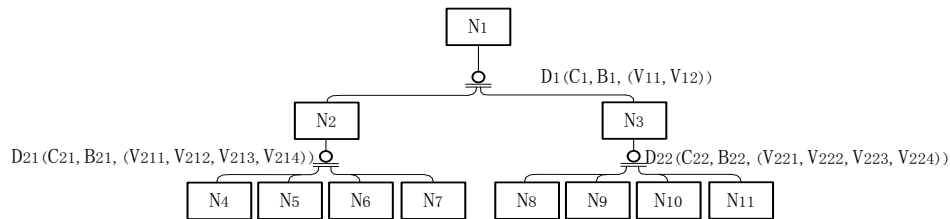


Figure 4. The Classification of Usability in Producing High-Pressure Cylinder at the Time of t1

In Figure 4, N_1 is selected as the start classified node, is the cylinder-type parts processing resources, C_1 at a time t_1 , B_1 as the processing availability of a cylinder opposed to another, V_{11}, V_{12} as availability and unavailability, N_2 as the resources can be used for cylinder-type parts processing at time t_1 , N_3 as resources can't be used for the cylinder-type parts processing at time t_1 ; B_{21}, B_{22} are classified by category, N_4, N_5, N_6 are the milling machine, boring machine, drilling machine; N_7 grinder, N_8 the planer, N_9 the lathe.

In actual manufacturing process, it is needed to re-classify the support resources while adjusting the manufacturing process in order to support the restructuring of manufacturing process in different levels.

3.2. Mapping between Activities and Resources in Manufacturing Resource Model

Supporting activities can support resource generation framework shown in Figure 6. It consists of the generation of a capability template based on activity, the generation of resource capacity and the combination of activities and resource capacity.

The mapping process of activities and supportable resources in manufacturing process: first, determine and supportable resources, as the manufacturing process involves a lot of resources, while a certain aggregation of supportable resources to each process activity, so in order to reduce the search space, it is necessary to define the existence range of supportable resources of each activity while selecting supportable resources, it is achieved by the resource classification model; then, on a range of resources, judge feasibility according to the rules, generate all possible supportable resources of the process activity.

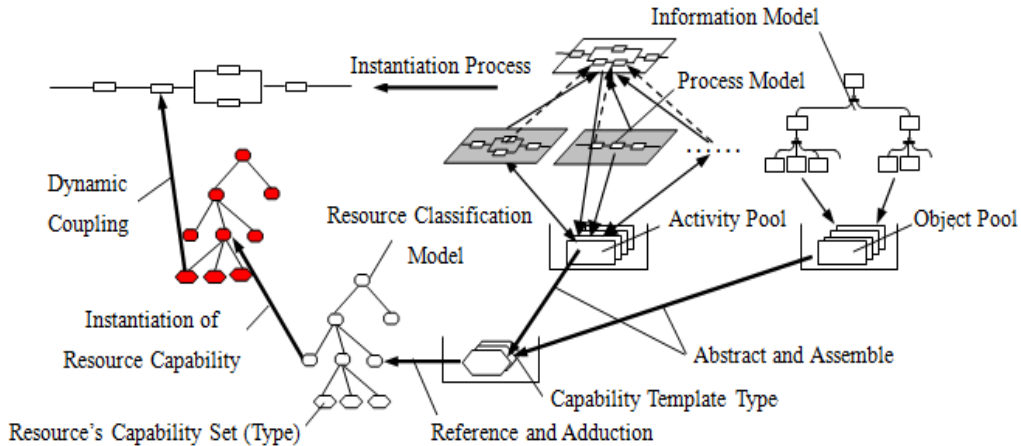


Figure 5. The Frame of Capability Generation of Manufacturing Process

An activity may have one or more supportable resources, or none. In the situation that more than one supportable resource exists, there are issues about resource optimization and manufacturing process optimization under the condition of limited resource. If the supportable resources do not exist, the activity is not feasible under the conditions of existing resources.

4. Modeling of Product Manufacturing Process

Although the product process model is established, this model does not fully consider the manufacturing resource constraints, a complete manufacturing process the model can be got only after the completion of the mapping between manufacturing resources and process, namely, the definition of supportable resources for each activity. Manufacturing process model essentially contains not only the manufacturing resources, but also the product's Master production schedule, the workshop production planning of parts, *etc.*, [7].

4.1. The Relationship between Product Manufacturing Process Model and Process Model

Product process model mainly based on the product design drawings, including all the product process from raw materials to finished products, mainly includes the design of process, process step and process route, the selection of tools, fixtures, measuring tools and machine tools, *etc.* Manufacturing process model is defined as the actual production process under the constraints of limited resources, according to master production schedule and workshop production planning of the product.

Because of these differences as mentioned above, in the actual production process, it is common that the process or workshop production planning can't be implemented, unless being modified according to the actual situation of plant; resources bottleneck often appears in plant production process, but other resources are not at full, so it is necessary to adjust workshop production planning or modify process; can't make rapid and effective response to some unexpected equipment failures, resulting in long-term interruption of workshop production and so on. These issues significantly affect the production schedule, resulting in the production management of chaos, disorder [8]. The problems can be resolved through modeling and simulation of manufacturing processes before the actual production.

4.2. The Establishment of Product Manufacturing Process Model

The process of the establishment of product manufacturing process model is the dynamic matching process of the process models and enterprise manufacturing resource model. As shown in Figure 6, first, get the product assembly model by expanding the product process model; then, expand the lower node, if the node type is part, the relative or similar process model can be found by searching enterprise standard process model library, add to the superior model by editing process; similarly, if the node type is component, get component assembly process model by matching the resources of assembly process, and then expand the module, continue work to lower node. After traversing the entire root node, the manufacturing process model can be established.

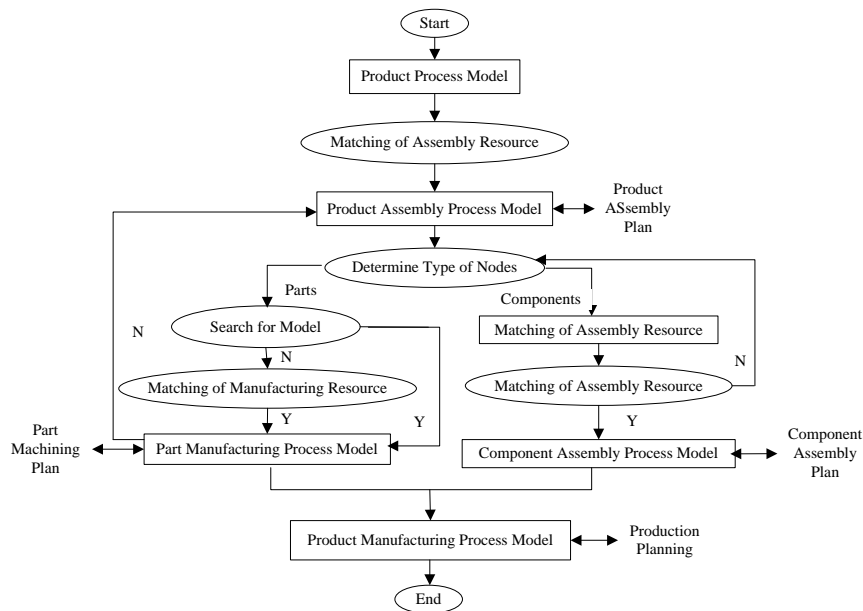


Figure 6. Modeling of Product Manufacturing Process

5. Establishment and Application of the Model

The overall design of steam turbine discussed by us involves in multi-level, multi-criteria problems, the overall design decisions of turbine high-pressure cylinder as an examples for verifying. First, establish the manufacturing process model of turbine high-pressure cylinder by a method of product's manufacturing process modeling; then, achieve the optimization of manufacturing process model by analysis of simulation results about manufacturing process for turbine high-pressure cylinder.

5.1. The establishment of process model about high-pressure outer cylinder's lower module

Production process is an important part of business process, production process modeling is the basis of enterprise modeling, production process modeling applies enterprise integrated modeling approach, including: the process view modeling, organization view modeling, resource view modeling, product view modeling, functional view modeling, information view modeling and integration between different view models [9]. The paper introduces some kinds of modeling related to the process view modeling of high-pressure outer cylinder's

lower module process, including process view modeling, organization view modeling, resource view modeling and the establishment of process planning.

5.1.1. Process View Modeling: Process view describes the activities in the production process and the connections between these activities, the participants of the activities, the applications of workflow activated while implementation of activities and the relationship with other view. High-pressure outer cylinder's lower module techniques process model complete describes the process of the part machining process, the connections between the processes, the participants of the activities, the resources and organization used in process.

5.1.2. Organization view modeling: Organization view describes the organization entities in the production process, the connection between organization entities, the connection between organization entities and entities in other view. Organization modeling of high-pressure outer cylinder's low-half, first, establish the root node of the organization tree "a steam turbine plant," and then add child nodes, including technical management office, design research center, material technology research center, quality inspection center, archives center, large piece branch factory, middle and small piece branch factory, *etc.* Add sub-node to child nodes. At the same time add each node with department person.

5.1.3. Resource view modeling: Resource view describes resource entities in the production process, the connection between resource entities, the connection between resource entities and entities in other view [10]. Resource modeling of high-pressure outer cylinder's low-half, first, add child nodes "process equipment" and "equipment" to the root, and then add related resources about high-pressure outer cylinder's lower module techniques process.

5.1.4. The establishment of process planning: Generated techniques procedure of for high-pressure outer cylinder's lower module. First, establish the process model of the part, organization model, resource model, *etc.*, and then generate techniques procedure of the high-pressure outer cylinder's lower module according to manufacturing processes, process step, the part process route, based on existing equipment, tooling and other resources.

5.2. Manufacturing Process Modeling of Turbines' High-pressure Cylinders

The modeling method of enterprise integration mainly includes various view modeling, the integration of views and evolution of models in different stages in the life cycle and so on. The establishment of manufacturing process model for turbines' high-pressure cylinders establishes the relevant process model of various parts of the composition, organization model, resource model, *etc.*, generates manufacturing process model of turbines' high-pressure cylinders under the constrains of workshop production planning, cost, cycle and other conditions.

5.3. The Simulation of Manufacturing Process for Turbines' High-Pressure Cylinders

Considering the needs of the integration and development of various analytical tools and software which regard integrated enterprise modeling system as the core, neutral of models represent data sharing and exchange between modeling tools and simulation tools IGrafx in this paper.

5.3.1. The Integration of Modeling Module and Simulation Module: Neutral model based on the demand which the user asks content of model for simulation tools IGrafx define the model field and structure; modeling tool provide exports data about the neutral data of the

model, according to IGrafx simulation tools need to extract the required information of model field as input of its analysis model, to analyze the simulation results.

The nodes in process model can be divided into four sections: task node, logical node, mark node and condition node. There are connections between process model nodes, which show the time sequence of nodes.

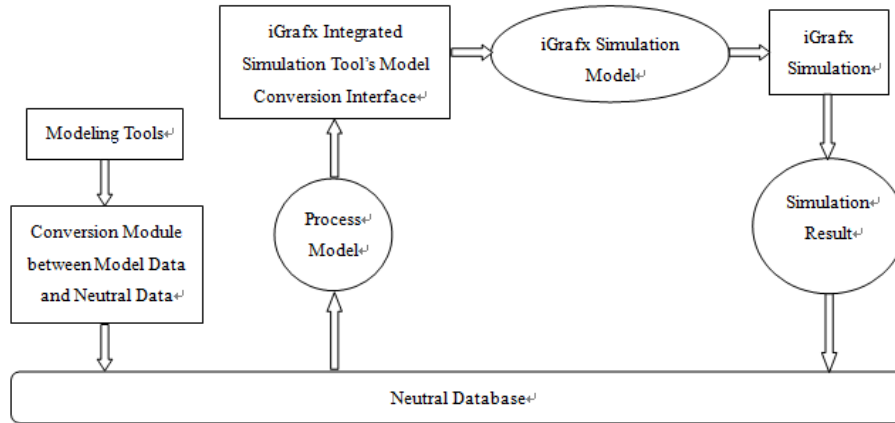


Figure 7. The Integration of Modeling Module and Simulation Module

5.3.2. Simulation of manufacturing process based on IGrafx: The simulation of manufacturing process for turbines' high-pressure cylinders model by application of IGrafx, effectively verify the accuracy of result about conversion of product process and manufacturing process model.

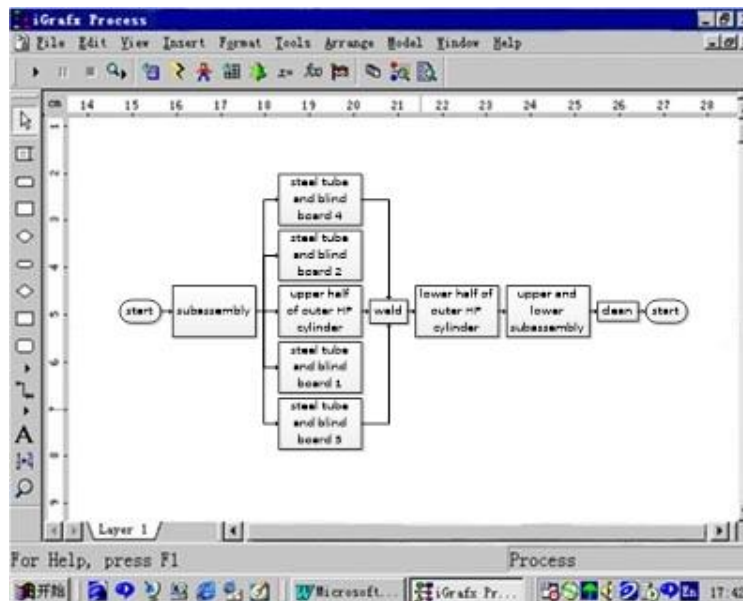


Figure 8. Simulation Result of Manufacturing Process for Turbines' High-pressure Cylinders

6. Conclusions

In this paper, taking turbines' high-pressure cylinders of a steam turbine work as an example, verified the manufacturing process modeling method. Turbines' high-pressure cylinders are key components of the product. Its process is characterized with features of complication and diversity. Its manufacturing technology plays key role on improving turbine performance, shortening development cycles and reducing manufacturing costs. The comparative analysis of the simulation result of manufacturing process for turbines' high-pressure cylinders and the actual process indicates that process model of the product manufacturing based on workflow standard accurately reflects the actual manufacturing process of the component.

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