Research on MES-oriented Reducer Process Planning System

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Abstract—In the railway locomotive reducer manufacturing industry, due to the characteristics of multi variety and small batch, the efficiency of process planning is low, the cycle is long, and the production link is seriously disconnected. To solve this problem, an integrated process planning system based on Manufacturing Execution System (MES) was proposed, this system used decision-making models of process based on typical process library to make process planning more efficient. At last, ASP.NET platform and C# programming language were used to complete the development of the system.

1. INTRODUCTION
In the reducer manufacturing industry, process planning is an indispensable technical work, and informationization of process planning is the future development trend, besides, integration is the inevitable development [1]. Manufacturing Execution System (MES), as a "shop-oriented management information system between the upper-level plan management system and the lower-level industrial control" [2], can provide basic information including process, equipment, parts, and persons for process planning. This paper takes MES as the platform and integrates the process preparation system, focuses on the decision-making models of process, elaborates the basis of the process decision, including the reducer parts information and typical process library, and finally introduces part of the process preparation system.

2. PROCESS ANALYSIS OF REDUCER PARTS
We analyzed the production process of the reducer in the company. Taking gearbox production process as an example, starting from the receipt of castings, it goes through the workpiece numbering, rough turning, carbonization, normalizing, quenching, tempering, etc., and finally ends with storage. In the process of drafting the process route, the process designer first analyzes each surface of the part and divides the processing stages. In each processing stage, the relevant procedures are selected according to the material, size, surface shape, and surface roughness of the part. For example, in end milling, when the surface roughness——Ra of the end face of the gear shaft is between 5µm~20µm, rough
milling is selected, 0.63µm~5µm is fine milling, and 2.5µm~10µm is semi-fine milling. The process of manual selection of processes involves complex and onerous decision-making processes.

In the process of the company's formulation of the process, the process is the basic unit, and the process can be subdivided into clamping, stations, and steps. There is a one-to-one or one-to-many relationship between each other, as shown in Figure 1. The clamping involves the choices include equipment, fixtures, knives, gauges and more. The processing of parts at a certain position is a work station. Each work station can be further divided into several work steps. A work step refers to the use of a cutting tool on the same cutting surface to select a specific spindle speed. And the feed amount is used for processing. If the machining allowance is large in this step, it can be divided into multiple feeds to complete the content of this step in combination.

![Figure 1. The process content of gear shaft](image)

3. DECISION-MAKING MODELS

Process planning is decision-making based on multiple resources. The input of the decision includes part structure, process information and manufacturing resource information. The decision-making model is a non-universal model constructed based on the specific parts of the reducer. The model building process involved in the system include input of part process information, processing of manufacturing resource data.

3.1. Part process information entry

Choosing a suitable part information entry method suitable for the company, record and store the structural characteristics (shape, size, etc.) and process characteristics (roughness, accuracy, etc.) of the parts.

The rotating parts are coded using the JLBM-1 coding system. This coding system is a pointing technical document formulated and agreed to be implemented by the Ministry of Machinery Industry of China. It is a 15-digit decimal mixed structure classification coding system. Using relational database to store component information and let them as a database table field. It is displayed through the web, Information entry personnel only need to select from the drop-down box and fill in the value to complete the coding, and the related structural features and process feature codes of the parts are stored.

For complex non-revolving parts, such as gearboxes, due to its complex structure, irregular shape, and many profile parameters. Using multi-level and multi-directional feature description method combined with Web to entry information. The specific operation method is a gear box as an example. First, the feature is used to abstract the box into a polyhedron. Each side is defined as an azimuth plane. Each azimuth plane is composed of multiple processing feature units. From this, a part information tree can be established. The locations of machining feature units and the link order between them are recorded in each level of the part information tree.
3.2. Typical process library

Manufacturing resources include workshop element information and process knowledge. Workshop element information refers to various production factors in equipment, personnel, tools, etc.. Process knowledge is divided into selective rules and decisions. These data have complex data characteristics such as multi-source, heterogeneity, correlation, heterogeneity, etc..

It is proposed to use the steps in the process as the minimum granularity to formulate the entry of the process, based on the process and process data previously prepared by the company. These data are based on the past process habits, equipment conditions, selection rules, decisions of the company, rules and other factors. These typical process data are stored as a system process library to form typical process knowledge [4], which is effectively managed to provide process knowledge data for process decision-making.

As shown as table 1, The process parameter information involved in the process step is selected into a suitable data format and stored in the process table. A foreign key in the form of a GUID (Globally Unique Identifier) data is associated with the operation table. For different process steps, the process is different.

| Step name                  | Spindle speed (r/min) | Cutting speed (m/min) | Feed rate (mm/r) | Cutting depth (mm) | Feed times |
|----------------------------|-----------------------|-----------------------|------------------|--------------------|------------|
| Half finished turning φ52  | 578                   | 100                   | 0.15             | 1.8                | 1          |
| circle                     |                       |                       |                  |                    |            |
| Half finished turning φ52  | 578                   | 100                   | 0.1              | 1.8                | 1          |
| circle                     |                       |                       |                  |                    |            |
| Half finished turning φ120 | 578                   | 100                   | 0.15             | 1.5                | 1          |
| circle                     |                       |                       |                  |                    |            |
| Heavy boring φ36 bore      | 1129                  | 110                   | 0.3              | 2.1                | 1          |
| Semi fine boring φ36 bore  | 1108                  | 115                   | 0.15             | 1.5                | 2          |

3.3. Process decision-making models

Based on typical process library, proposing a process decision-making models, as shown in Figure2, the core part of this model is a decision tree. Starting from the input of part information, the part enters the determination process after reading the structural features and craft features of the part. The determination conditions come from the company’s typical process knowledge. If the judgment condition is true, it will match the typical process library with the minimum granularity of the step. Otherwise, the next judgment will be made. This decision process is formulated according to the type of each part, the same type of parts has the same decision tree, different types of parts correspond to different decision processes. The order of the decision conditions of the decision-making process is based on the typical processing order of each feature of the part, so as to determine the order of the procedures, and finally achieve an orderly process route.
4. SYSTEM ARCHITECTURE AND MAIN FUNCTION

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4.1. The architecture of the MES-oriented reducer process planning system

The architecture of the MES-oriented reducer process planning system is shown in Figure 3. The system uses a role-based access control method, and the rights management function can assign rights based on user roles. The equipment management function provides relevant data such as processing machine tools, process equipment, etc. The data is associated with the process table in the form of an intermediate table. The electronic ticket management is used to review the process, and the form management function is used to generate electronic documents such as process cards and process cards. Process control is responsible for controlling the entire process of the project from beginning to end.

4.2. Process planning function

As shown in Figure 4, the left side is the process library, and the right side is the process route. In manual mode, after selecting a process, click the right arrow to drag the process into the right process route. At this time, the process details box will pop up. Select the person in charge of the process and the sequence of the process. After filling in the process description, the process will enter the process...
route on the right. Repeat this step to compile the process route. After the compilation is completed, you can adjust the process sequence by the up and down arrows. Using automatic mode, click "automatic process preparation" at the top right to automatically generate the process route. The principle of automatic process preparation is to write the process decision model with C# code in the form of an algorithm. The system automatically processes the process information of parts and components and process content to automatically decision-making process route.

5. IMPLEMENTATION OF PROCESS PLANNING SYSTEM
The system adopts B/S (Browser/Server) architecture [5]. This architecture unifies the client and concentrates most of the system function implementation on the server. The main transaction logic such as the decision-making models of process algorithm is implemented on the server side, and a few transactions are implemented on the client side, which simplifies the development, maintenance and use of the system. Use ASP.NET as a development platform [6], which is launched by Microsoft Corporation and can provide developers with various services required for company-level Web projects. Considering the code reusability, system scalability, and reducing page dependencies during the development process, the ASP.NET MVC5 architecture is used, the object-oriented programming language C# is used, and the database uses the relational database SQL Server 2012.

Figure 4. The interface of process planning function

6. CONCLUSION
This paper expounds the advantages and feasibility of using MES as a platform to integrate the process planning system, and introduces the two main function of part process information entry and process planning, focusing on the analysis of process decision models based on typical process library. This system has been successfully deployed and applied in the reducer production line of a domestic research institute company. After a period of operation, it proves that the system can indeed improve the efficiency and quality of process preparation in the face of multiple varieties and small batches of reducer products.

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