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Management Optimization of Equipment Maintenance and Spare Parts for Automobile Intelligent Manufacturing Enterprises

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Abstract: *With the changes in the world economic environment, the vigorous development of network information and sensor technology, the combination of traditional manufacturing and advanced technology has produced tremendous changes. After decades of development, intelligent manufacturing has gradually become popular among people, and has achieved amazing results in a large number of enterprise practices. The main purpose of this paper is to study the optimization of equipment maintenance and spare parts management in automobile intelligent manufacturing. This article is mainly based on the WBS work decomposition method, combined with the product life cycle theory, ABC classification method, demand forecasting method, inventory management method, etc., described and introduced in detail and properly. Experiments show that C-type parts (1/3 of the parts are wire harness connectors) only account for 5% of the entire sales. Therefore, in the case of limited resources, C-type spare parts can be managed in a differentiated manner according to needs, such as a small amount of stock, or by referring to past experience to order C-type spare parts with less than 5 quantities.*

Keywords: *Automobile Enterprises, Intelligent Manufacturing, Equipment Maintenance, Spare Parts Management*

1. Introduction

With the continuous development of science and technology, equipment is the core part of enterprise production, and its management level directly determines the economic benefits of the enterprise. Efficient enterprise management methods can not only increase the kinetic energy of the enterprise, but also help the sustainable and healthy development of the enterprise, effectively prolong the business cycle of the enterprise, and naturally increase the competitiveness of the enterprise. In recent years, the rapid development of new energy vehicles such as hybrid power and pure electric power has not only subverted the original pattern of traditional automobiles, but also put forward higher requirements for after-sales spare parts and services of automobile products. Even the well-known joint venture brand auto companies at home and abroad still have many problems in the management of after-sales spare parts, mainly due to the large number of non-critical after-sales spare parts, sluggishness, inaccurate demand forecast for after-sales spare parts, shortage or insufficient supply of key after-sales spare parts, etc.. Therefore, it is necessary to carry out research on the inventory management system and optimization method of automobile after-sales spare parts [1, 2].

As the industry demands increased efficiency and reduced costs, the integration between the Intelligent Maintenance System (IMS) and the Spare Parts Supply Chain (SPSC) increases the availability of parts and services, avoiding breakdowns and unplanned production disruptions. Therefore, Regal T is exploring these challenges and proposing a conceptual model of this integration, using existing ontologies from domains such as supply chain, maintenance and manufacturing to build on top of it a concept designed to allow and serve as a foundation for the integration of concepts between IMS and SPSC ontologies to build future information systems to integrate these two domains [3]. Andrew focuses on the application of fuzzy logic to maintenance planning decisions, using key inputs such as mean time between failures, mean time to repair, spare parts availability and equipment age. A fuzzy rule base is generated for real cases and applied to the maintenance planning process to verify the results [4].

ISSN 2706-655X Vol.4, Issue 5: 33-41, DOI: 10.25236/IJFET.2022.040507

Based on the WBS work decomposition method, combined with the actual problems in J Company's after-sales spare parts management, from the perspective of after-sales spare parts project management, this paper takes "two highs and two lows" (ie high turnover, high income, low cost, low inventory) as the final The goal is to study the after-sales spare parts classification method, demand forecasting method, inventory management strategy, etc. with the life cycle of the in-production and discontinued models as the research object. First, the development of the theory and practice of intelligent manufacturing is researched and analyzed, combined with the actual situation of the enterprise, the company's intelligent manufacturing system is optimized and upgraded based on the MES system, which improves the efficiency and convenience of the system. Secondly, the optimization and upgrading of the manufacturing execution system fills the information gap between the intelligent manufacturing resource planning layer and the execution layer, improves the ability to collect and use workshop-level data, and effectively supports the improvement of quality, cost and delivery. Finally, the MES functions are enriched and added to meet the needs of the company's production and operation management development, and at the same time provide a good foundation for the company's continuous upgrade of intelligent manufacturing.

2. Design Research on Equipment Maintenance And Spare Parts Management Optimization

2.1. Equipment Management System

As the main production factor of equipment, its management has always been paid attention to by manufacturing enterprises. In recent years, in order to cater to the development of enterprise intelligent manufacturing, a variety of equipment management systems that are independent or integrated in the MES system have appeared on the market. This paper will study some well-known domestic and foreign related software systems, analyze their functions and characteristics, and compare the systems currently being used by S Corporation, and then analyze its shortcomings [5, 6].

2.1.1. eMaint System

Mainly used in European and American markets or European and American enterprises in other regions, its main functions are:

(1) Submit and confirm repair and maintenance requirements on the mobile terminal through the APP. Managers can also allocate maintenance tasks and resources through the APP.

(2) Provide spare parts management function. Inquiry and receipt of spare parts, management of spare parts inventory, and submission and approval of spare parts replenishment orders.

(3) Report function. Provide reliable and timely equipment maintenance status reports, supplier compliance documents and other reports, which can provide effective support for audits.

2.1.2. GM Mate System

Mainly used in European and American markets or European and American enterprises in other regions, its main functions are:

(1) Work order. Work orders are used to plan activities in GP MaTe, as well as to identify all actions taken during the execution of tasks. Users can define various types of work orders and manage workflows around these types of work. A work order consists of one or more tasks and can include work orders, estimated resources (manpower, inventory, and procurement materials), and progress information [7, 8].

(2) Inspection and calibration. Full support for any inspection and calibration needs as part of preventive and corrective work tasks. This is useful when you want to acquire data as you perform tasks for future trend analysis, and to identify values outside of the allowable range to trigger subsequent actions.

(3) Inventory management. GP MaTe's inventory module is designed to manage all aspects of maintenance, repair spare parts. Through tight integration with all other modules in the system, users can access inventory status, availability and documentation throughout the system at any time. GP MaTe's inventory module can be used for open or closed inventory, as well as enterprise-wide access to multiple users' stores and sharing information.

(4) Procurement. In GP MaTe, all spare parts, non-stock materials, services and other purchasing activities can be carried out through purchasing requests within the system. Purchase requests for

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in-stock spare parts are automatically generated by the system based on replenishment parameters (reorder point and reorder quantity), and non-stock purchase requests are created manually by users and can be linked to work order tasks for better control over the flow of information. This module also supports receipt of materials and matching of invoices.

(5) Report generation. GP MaTe has over 150 standard, pre-formatted reports. The system supports standard columnar reports as well as tables and pie charts. Project reports are also available as an option on some versions of GP MaTe.

2.1.3. RAMCO's Equipment Management System

The system is also mainly used in European and American enterprises, and its main functions are as follows:

(1) Enhance effective maintenance management with predictive maintenance and built-in analytics.

(2) Reduce equipment risks by improving safety standards.

(3) Improve regulatory compliance through compliance and asset lifecycle tracking to effectively support audit efforts.

(4) Process control over the acquisition, planning, budgeting and approval of equipment assets.

(5) Manage maintenance and repair work, provide downtime analysis, failure analysis and equipment maintenance history.

(6) Equipment withdrawal mechanism, which can provide suggestions for new equipment investment or scrapping.

2.1.4. Domestic Equipment Management Software

The equipment management system of Qianyuankunhe, a domestic equipment management software developer, has more comprehensive functions, including:

(1) Equipment maintenance management. Generate maintenance work orders, assign tasks, record maintenance information, and confirm maintenance results.

(2) Maintenance personnel management. Maintenance personnel files, maintenance personnel qualifications, maintenance schedule.

(3) Spare parts management. Contains inventory details, inbound and outbound management, usage statistics and inventory reminders.

(4) Equipment operation management. Maintenance announcements, operation records, and fault repair reports.

(5) Maintenance plan management. Lubrication plan, maintenance plan and technical transformation plan.

(6) Equipment file management. Basic files, maintenance requirements and file inquiries.

(7) Asset management. Contains asset classification, asset consolidation, asset daily, location management, asset query and statistical analysis.

(8) Purchasing management. Supplier management, item acceptance, purchase approval, purchase requisition.

Through the research on the more popular equipment management software in the current domestic and foreign markets, it can be analyzed that although the functions and focuses of the software in the market are different, they basically include: the use of mobile portable terminals; repair and maintenance management, Spare parts management and data analysis and reporting capabilities and support for audits; equipment performance evaluation. Some software embodies the concepts of financial management, equipment life cycle management and system self-learning, which are also worth learning and reference [9, 10].

2.2. After-sale Spare Parts Management

The new model project is usually a small project as the main project. From the project point of view, there is a professional project team to follow up the status in real time. Therefore, the after-sales spare parts management of the new project is relatively high and level. It won't appear completely unattended.

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However, since the best resources, manpower and material resources are all on the production of new cars [11, 12], the management of after-sales spare parts for new models still has the following problems:

(1) Insufficient monitoring of fixed-point purchases leads to substandard stock-in rate of key after-sales spare parts (can not reach 100% before official sales by dealers);

(2) There are many engineering changes before JOB1, resulting in a short procurement period, and the warehousing rate is not up to standard. For example, for imported parts purchased from abroad, because the shipping is 3-6 months ahead of schedule, the change problem causes about 20% of imported after-sales spare parts to be later than plan storage;

(3) The packaging scheme, the minimum order quantity, etc. lead to the high after-sale price, and the financial audit cannot be passed, and the warehouse cannot be delivered on time;

(4) The parts that fail to be localized are transferred to the import, and the time delay causes them to fail to arrive in the warehouse;

(5) Sluggish inventory caused by inaccurate forecast;

(6) After-sales claims caused by parts quality problems (color difference, size, etc.).

2.3. Algorithm Research

2.3.1. Exponential Smoothing Prediction Method

Picks the weighted sum of all past observations of the product. The weight values of different time periods are different, the value of the value with a closer time is given a relatively large value of the weight, and vice versa, to ensure that the predicted value is more accurate. The exponential smoothing method is calculated as follows:

$$S_t = \alpha Y_{t-1} + (1-\alpha) S_{t-1} \tag{1}$$

Where: St represents the predicted value at time t; Yt represents the actual value at time t-1; St-1 represents the smoothed value at time t-1; α represents the smoothing constant, whose value range is [0,1].

2.3.2. Demand Forecast Based on Univariate Linear Regression

Use an independent variable to explain the change in its dependent variable. Although there are various forms of factors restricting the demand for after-sales spare parts, for some specific spare parts, it is mainly affected by one of the factors. The specific formula is as follows:

$$y_t = \beta_0 + \beta_1 x_t + u_t \tag{2}$$

Where yt is the dependent variable, xt is the independent variable, 0 is the constant term, 1 is the regression coefficient, and ut is the random error.

2.3.3. Demand Forecast Based on Diversified Linear Regression Method

A prediction method for establishing regression equations by finding the relationship between the dependent variable and multiple independent variables. details as follows:

$$Y = b_0 + b_1 x_1 + \cdots b_k x_k + \varepsilon \tag{3}$$

In the formula: b0 is the constant term, b1, b2...bk are the regression coefficients, and ε is the error term. Let Y be the dependent variable, the independent variables are x1, x2,..., xk (x1 is the monthly sales volume, x2 is the market holding quantity, x3 is the consumable degree, x4 is the consumables,..., xk is the price factor), the error term ε (regional, overall economic factors).

3. Experimental Research on Equipment Maintenance and Spare Parts Management Optimization

3.1. MES Equipment Management Function Diagram

3.1.1. Equipment Maintenance and Management

Obtain maintenance items and cycles through Windchill. When equipment maintenance files are updated in the Windchill system, the MES system automatically updates the relevant information. The system generates maintenance schedules based on the maintenance cycles of different equipment and the system calendar, and triggers maintenance task orders three days in advance. The task list will be prioritized according to the completion date and published to the maintenance personnel task list. All equipment is assigned a unique barcode, and the tablet is used as a mobile terminal to scan the barcode of the equipment and call the maintenance items of the corresponding equipment. Equipment maintenance personnel must operate according to the maintenance date and maintenance items required by the system. After completing the maintenance operation, use the mobile terminal to upload the evidence and the information of the replaced spare parts. After the system receives the confirmation of the completion of the maintenance operation, it will record the man-hours generated by the maintenance operation and the information of the spare parts used. In addition to the maintenance operations performed according to the fixed preset maintenance cycle, the MES system performs preventive maintenance on some high-risk equipment through production process evaluation.

3.1.2. Maintenance Task Management

When equipment failure occurs, employees of the production line or other related units can submit a maintenance application on the equipment management interface of the MES system, and select the equipment failure code according to the actual situation. The system generates a maintenance work order based on the requested equipment information, and notifies authorized equipment maintenance personnel to perform maintenance operations through emails and a mobile terminal maintenance task list. After the repair is completed, replace the spare parts information, and confirm or correct the fault band code filled in by the submitting unit. After completing the above actions, the equipment maintenance personnel can close the maintenance work order. Whether the maintenance operation is finally completed will be confirmed by the authorized personnel of the unit applying for the maintenance operation. After the maintenance work order is closed, the MES system will automatically calculate maintenance man-hours and maintenance costs for query and use. According to S company's exception handling process, the alarm information trigger time is set for different equipment. For tasks that have not started maintenance or have not been repaired due to timeout, the system will issue warning messages according to the preset route to obtain more management resources to support problem solving.

3.1.3. Management of Equipment Spare Parts and Maintenance Tools

Import the material number, purchase price and purchase cycle of all spare parts into the system, and combine the use frequency of equipment spare parts recorded by the system to manage the spare parts in the system into three categories: A, B, and C. The MES system provides spare parts in and out management to replace the current manual ledger management. Spare parts and storage locations are bound by barcodes. When equipment management personnel carry out spare parts entry and exit management operations, they can quickly identify the inventory quantity and storage location of spare parts by querying the material number or scanning the barcode, so as to quickly access spare parts. After the spare parts out-of-warehouse action occurs, the system determines whether a spare parts purchase reminder needs to be issued by comparing the actual inventory of each spare part with the specified minimum inventory. If the purchase conditions are met, the MES system generates a spare parts purchase task and sends it to the task list of the relevant personnel. To support rapid repair response, tool management is also essential. The equipment management module developed based on the MES system provides system support for tools that need to be shared, such as special tools and medium and large-scale tools. It uses the tools that have been put into use in the workshop to visualize the display, and bind the tool barcode and tool storage location barcode. When equipment maintenance personnel use the tool, they can scan the barcode of the tool through the portable terminal to carry out the warehouse operation, and take the tool away from the storage position for use. When other equipment maintenance personnel need to use the tool and find that the tool is not in the storage location, they can scan the location code to identify the current tool user information, and then

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communicate quickly. The system will suggest the order in which the tools should be used according to the priority of the current equipment maintenance task and the current maintenance status.

3.1.4. Equipment Performance Management

The reliability of the equipment is analyzed by analyzing the equipment failure time, the number of failures per unit cycle, the equipment failure time interval (MTBF), and the equipment mean time to repair (MTTR). The maintenance cost is calculated through the maintenance time record of the maintenance work order and the replacement record of the maintenance parts. For machines with poor reliability and high maintenance costs, the system will issue an improvement task list to the relevant personnel task list to promote improvement actions. Through the statistics of equipment maintenance and repair work time, the workload of equipment maintenance and repair personnel is calculated to provide a data basis for personnel allocation. Calculate equipment availability (OEE) for key equipment and examine the comprehensive performance of key equipment.

3.1.5. Maintenance Personnel Management

The equipment management module of the MES system provides maintenance personnel skills and qualification management. According to the position, skills and qualifications, push information such as maintenance, maintenance and spare parts inventory warnings, and specify the operation authority of each equipment personnel in the system in detail.

3.1.6. Equipment Acceptance and Exit Management

The equipment management module of the MES system provides a standardized equipment acceptance process, and provides key acceptance indicators for new equipment based on the comprehensive performance of the current equipment. The equipment reliability analysis data and equipment comprehensive performance data of the comprehensive equipment performance management, the recommended service life or life of the equipment, and the current maintenance cost are used to propose exit suggestions for equipment with poor comprehensive performance and high maintenance costs. Equipment managers can also initiate new equipment investment applications or take overhaul, repair and other measures to extend the life of the equipment according to the system recommendations and the actual situation.

4. Experimental Analysis of Equipment Maintenance and Spare Parts Management Optimization

4.1. ABC Taxonomy Spare Parts

Generally speaking, there are about 4,500 aftermarket spare parts for a car. The relationship between the number of spare parts and the actual demand for spare parts from the aspects of vulnerability, spare parts consumption, consumption frequency, etc., can help us identify the key parts list from 4,500 spare parts.

Taking J company as an example, according to the ABC classification method, it is divided into three different levels: A, B, and C according to the importance of after-sales spare parts. First, Class A parts are the spare parts that account for the top 75% of the total demand, and the quantity is about 400; followed by the Class B spare parts, the absolute value of after-sales demand accounts for 15% of the total after-sales sales, and the quantity is about 1,000; the sum of the final demand is only 5% Listed as a Class C item. The details are shown in Table 1:

Table 1: Quantity and proportion of spare parts according to ABC classification

ABC Category	Sales Percentage	Number of Parts	Percentage of Parts
A	80%	333	6.93%
B	15%	925	19.27%
C	5%	3542	73.79%
Total	100%	4800	100%

As can be seen from Figure 1, taking the L538 model as an example, there are a total of 4,800 after-sales spare parts and 333 A-type spare parts, accounting for only 6.93% of the total number of parts, but accounting for 80% of the entire sales. Obviously, in order to make A-type spare parts out of stock, we should focus on monitoring the fixed location of these 333 A-type spare parts, supplier quotations, and supplier capacity, so as to ensure that the first order can be ordered and delivered, and the later can be replenished in real time. For the C-type parts only accounted for 5% of the entire sales.

ISSN 2706-655X Vol.4, Issue 5: 33-41, DOI: 10.25236/IJFET.2022.040507

Therefore, in the case of limited resources, C-type spare parts can be managed in a differentiated manner according to needs, such as a small amount of stock, or by referring to past experience to order C-type spare parts with less than 5 quantities.

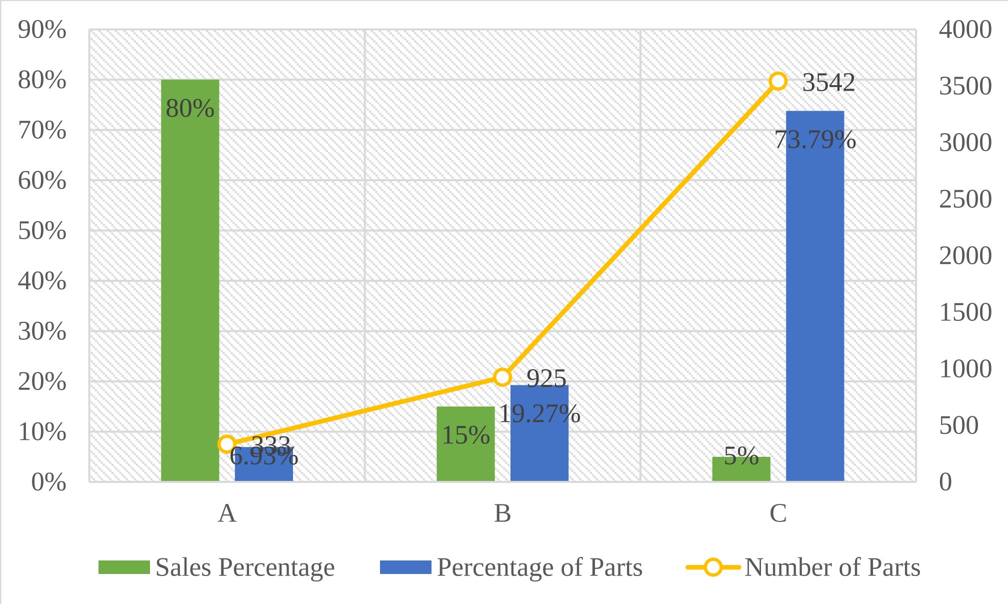

Figure 1: Quantity and proportion of spare parts according to ABC classification

4.2. Classification of Aftermarket Spare Parts Based on the ABC Rule

Take J Company's L550 listed model as an example. As shown in table 2:

Table 2: L550 after-sales spare parts ABC quantity and proportion

ABC Category	Sales Percentage	Number of Parts	Percentage of Parts
A	80%	343	6.72%
B	15%	967	18.96%
C	5%	3790	74.31%
Total	100%	5100	100%

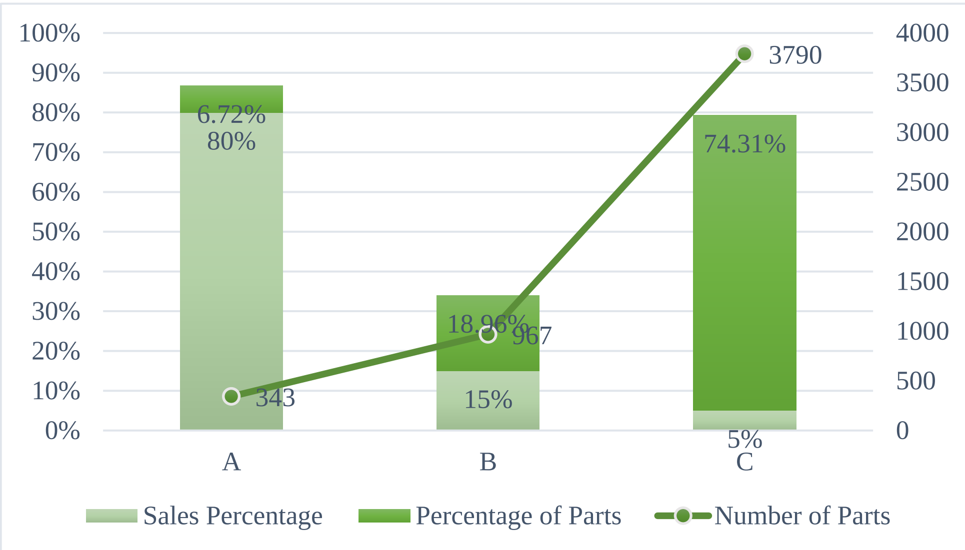

Figure 2: L550 after-sales spare parts ABC quantity and proportion

As can be seen from Figure 2, there are 5,100 after-sales spare parts, and 343 A-class after-sales spare parts, accounting for only 6.72% of the total, but accounting for 80% of the entire sales and sales. There is no doubt that the management of Class A after-sales spare parts is the focus of the entire after-sales spare parts management. The 967 category B after-sales spare parts, although not as high as the total sales of category A after-sales spare parts, are also the second key management objects, and it takes energy to ensure the timely supply of after-sales spare parts. The 3790 C-type parts (1/3 to 1/5 of the pieces are wire harness connectors) only account for 5% of the total sales. Therefore, in the case of limited resources, C-type spare parts can be managed in a differentiated manner according to demand, such as stocking a small amount according to the predicted quantity, or purchasing on-demand according to the characteristics of the parts.

5. Conclusions

The management of equipment has gradually become an important link in the production and operation of enterprises and the realization of profit growth. The higher the dependence on the equipment, the higher the requirements for the equipment and its management personnel. Strengthening the management of equipment and establishing a sound and powerful management mechanism are of immeasurable significance to ensure the normal production order of the enterprise, enhance the comprehensive competitiveness of the enterprise, and promote the development of the enterprise. The mode of equipment management cannot be static. Only by maintaining continuous innovation and combining theory with enterprise practice can the due performance of equipment be further exerted. The optimization and upgrading of MES system management has fully considered the actual situation of the enterprise, and has formulated an optimization and upgrading strategy, which has strong applicability. But on the other hand, it will also be limited by management and available resources, especially the lack of intelligent manufacturing technical talents of the enterprise itself. The optimized and upgraded system still has shortcomings in many aspects, and needs continuous research and optimization: (1) The optimized MES system is still weak in material management. (2) In terms of data collection, manual data collection still accounts for more than 50% of the data, and continuous optimization is required. (3) The human resource management system remains independent and has not been approved for integration with MES. (4) Complex modeling and sensor technology applications, which are not covered in this paper.

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