Research and Analysis of Low-Carbon Manufacturing Operation Model in Life-Cycle Oriented Mechanical Manufacturing Enterprises

Chuntang Cai

Sichuan Vocational and Technical College 629000

Abstract: Mechanical manufacturing industry is an important part of China's national economy, it is the main source of material used in people's life, which provide large-scale production materials for the society. Based on the previous work experience, this paper introduces the framework model of low-carbon operation process in machinery manufacturing enterprises oriented to life-cycle, and discusses the construction process of multi-dimensional process model of low-carbon operation in mechanical manufacturing enterprises from four aspects, including target system framework, low-carbon operation strategy, life cycle process and support system.

1. Introduction

With the gradual improvement of social energy saving and low-carbon awareness, the low-carbon manufacturing operation technology has been introduced into the development process of mechanical industry, which has led to great changes in the development mode of mechanical industry in China. At present, low-carbon manufacturing has become the focus of the research in relevant departments, the research theory mainly focuses on the concept and theoretical model of low-carbon manufacturing, comprehensive assessment of carbon emissions and so on. However, in the process of low-carbon development of one product life-cycle, there are few researches on low-carbon operation and implementation mode in the view of system engineering. So the study of the model is helpful to the overall development of mechanical manufacturing enterprises.

2. The framework model of low - carbon operation process in life-cycle oriented Mechanical Manufacturing Enterprises

Low-carbon manufacturing can comprehensively consider the consumption of product resources and pollution emissions, and establish a sustainable manufacturing model for carbon emissions, in the form of new technologies, such as production mode, management mode, staff quality and so on, in order to achieve effective resource utilization, reduce carbon emissions throughout the product life-cycle, we can add raw materials acquisition and product design to the whole life-cycle to provide the quantitative control of carbon. At present, there are still many problems that have not been solved in the low-carbon manufacturing operation mode design process of mechanical manufacturing enterprises. For this reason, relevant researchers need to summarize the research results of domestic and foreign machinery manufacturing enterprises, according to the development characteristics and life-cycle process of Chinese machinery manufacturing enterprises, to improve the utilization of resources and energy and construct a general framework of low-carbon operation for mechanical manufacturing enterprises with a four-layer structure, which is often referred to as the overall process

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model. [1]

The first layer of the model is called the target system layer, it mainly constructs the enterprise low-carbon target system and describes the goal that the low-carbon operation wants to achieve, so as to achieve effective coordination between economic benefits and social environment, improve energy efficiency. The second layer of the model mainly involves the design of low-carbon operation strategy, the low carbonization control of machinery manufacturing enterprises, which needs to be implemented from the aspects of source control, process control and so on. In this process, source control is the use of carbon footprint small raw materials to replace traditional materials, so as to achieve the overall use of clean energy. Process control mainly from three aspects to achieve, including energy saving, emission reduction, material saving, and reduce the discharge of pollutants. The third layer of the model is the process layer, which is mainly controlled by the whole process of the product life-cycle. The whole process of the product life-cycle mainly refers to the process from raw material design to product manufacture, and then to scrap recovery. The development of low-carbon manufacturing needs to start from all aspects of the whole life-cycle process to realize the development of low carbonization in the whole process. The forth layer of the model is the supporting system layer, this layer mainly constructs the low-carbon operation technology platform and system reasonably, which includes product data generation and management, machine manufacturing management, data platform optimization technology and so on.

3. The construction process of the multi-dimensional process model of low-carbon operation in machinery manufacturing enterprises

3.1 Target system framework

In the current climate change environment, it is very important for machinery manufacturing enterprises to carry out low-carbon manufacturing. Different from the traditional way of pursuing economic benefits, the aim of low-carbon manufacturing operation mode is to solve the contradiction between the increase of carbon emissions and the future development of enterprises, establish a low-carbon development road that coordinates economic and social benefits. The low-carbon operating targets of machinery manufacturing enterprises can be expressed by the following :

MinZ=（E,R,G,C）

In this formula, the overall goal of low-carbon operation is mainly composed of ERGC and other sub-objectives, each sub-goal can also be regarded as a vector form, such as vector E=（E1，E2……Ee）. This relational expressions can sum up the energy consumption of a workshop in a mechanical manufacturing enterprise, e is the type of energy consumption, Ee is the consumption of the No.e energy. Vector G=（G1，G2……Gg） may represent actual greenhouse gas emissions， g represents the number of major sources of carbon emissions， Gg is the emission quantity of the No.g carbon emission source.

3.2 Low-carbon operation strategy

3.2.1 Source control

In order to realize the low-carbon development of manufacturing enterprises, relevant researchers need to start with various sources of energy, reasonable adjustment of the overall energy consumption structure, and input of cleaner energy, such as natural gas and other energy sources, improve the proportion of clean energy in energy consumption, and finally achieve the overall popularization of low-carbon energy, improve the degree of improvement of energy technology, and promote the reasonable optimization of low-carbon energy structure. In the development process of machinery manufacturing enterprises, it is mainly the process of transforming manufacturing resources into physical parts, many people call it logistics flow process. In general, the mechanical manufacturing system can continuously input manufacturing resources, and through a series of manufacturing processes, the final output of the actual product, while the carbon dioxide generated in the process is

brought into the output input system. The output and input of manufacturing resources have a profound impact on the later mechanical manufacturing, forming a resource flow. Therefore, in order to realize the reasonable development of low-carbon manufacturing industry, it is necessary to select the raw materials with small carbon emissions, and thus to realize the low carbonization material input.

3.2.2 Process control

The implementation of process control is mainly for the effective improvement of energy efficiency of the system. Carbon emissions in the process of mechanical manufacturing mainly include carbon dioxide in primary energy consumption and indirect carbon emissions in secondary energy consumption of electric power. Overall, the implementation of low-carbon manufacturing process needs to improve the original process flow to avoid the impact of energy consumption efficiency in mechanical production. Then is the effective improvement of resource utilization. The amount of carbon emissions in the preparation of material resources is high, people need to reduce the use of material resources and increase the use frequency of lightweight products. Thus, the development of low carbonization in manufacturing process can be indirectly realized. Finally, reduce the emission of pollution effectively. The concept of low-carbon is mainly focused on the reduction of carbon emissions and reasonable desalination of other pollutant types. Among the atmospheric pollutants produced by enterprises, other greenhouse gases are also abundant. Therefore, in order to realize low-carbon manufacturing completely, it is necessary to control the emission of pollutants comprehensively.

3.2.3 Terminal control

In the terminal control, the designer studies many new manufacturing modes, such as the development and re-manufacturing. Among them, re-manufacturing can make full use of old resources, and achieve energy saving effect of 50%, and the rate of materials saving will be over 60%. By contrast, re-manufacturing has a significant low-carbon characteristic model, because of the extreme shortage of resources around the world, people pay more and more attention to re-manufacturing, and it has developed rapidly in the process of people's key research, now it has formed a certain scale of development [3].

3.2.4 Product low carbonization

Low carbonization products have the advantages of high efficiency and low energy consumption. From the point of view of the whole life-cycle, the energy consumption of many mechanical products is mainly embodied in the stage of production and use. For example, it has been clearly pointed out in the relevant literature that the energy consumption of machine tool equipment in the service phase accounts for more than 90% of the total life-cycle energy consumption. So far, low-carbon products are becoming more and more popular in the market, and some new products such as fuel-efficient cars have appeared one after another. The progress and development of machinery industry can provide products for other industries, and it is also the main source of energy consumption. Therefore, the development of low-carbon products is the most important for enterprises to achieve low-carbon development.

3.3 Life-cycle process

The life-cycle of a product mainly refers to the process of collecting raw materials, producing them in packaging and using them, and finally disusing them, in other words, the whole life process from birth to death. The mechanical product life-cycle process is shown in figure 1.

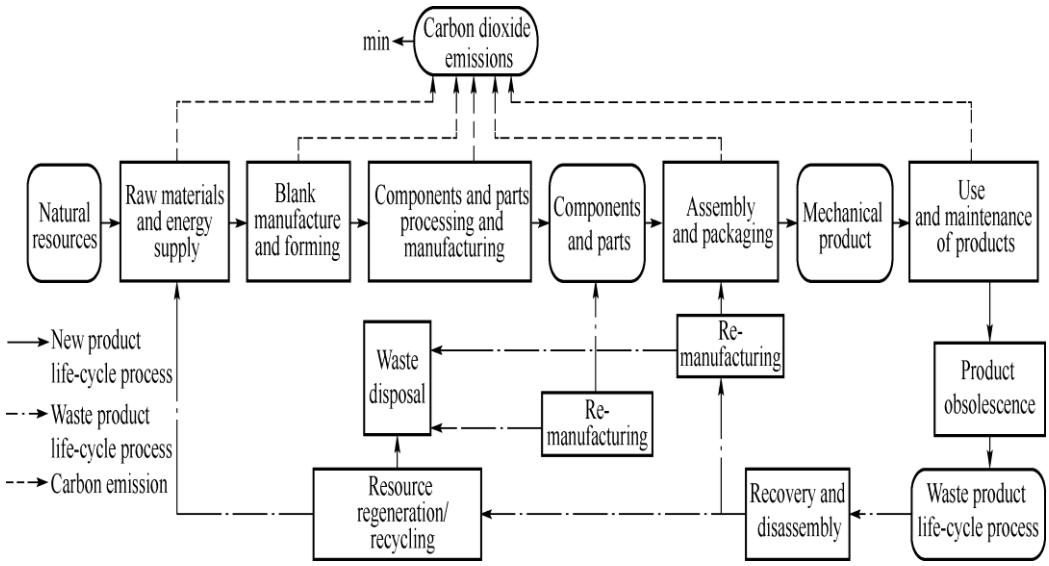

Figure 1 Mechanical product life-cycle process diagram

The life-cycle process of the product mainly reduces the influence on the environment during the process of raw material supply, storage and use. In order to truly realize the low-carbon development of mechanical manufacturing enterprises, low-carbon manufacturing cannot be confined to the three stages of product design, manufacturing and waste disposal, we need to incorporate the processes of raw material production and product use into the management work, in order to achieve low-carbon emissions in the process of production and use of products. It is worth noting that the realization of low-carbon manufacturing operation mode needs to change the habit of starting from the end and avoid the use of simple production process to control the overall energy saving and environmental protection of the enterprise. We should gradually realize the all-around, whole-process low-carbon control of the life chain at each stage of the product cycle, this is also the basic requirement of low-carbon operation and development of machinery manufacturing enterprises in life-cycle.

3.4 Support system

Machinery manufacturing enterprises are the specific process of low-carbon operation and low-carbon technology implementation. In this process, every link will almost involve the support of the information platform. The design of low-carbon operation support platform mainly includes support system, manufacturing system, real-time monitoring and control system, etc. The schematic diagram of low-carbon operating support system for machinery manufacturing enterprises is shown in figure 2.

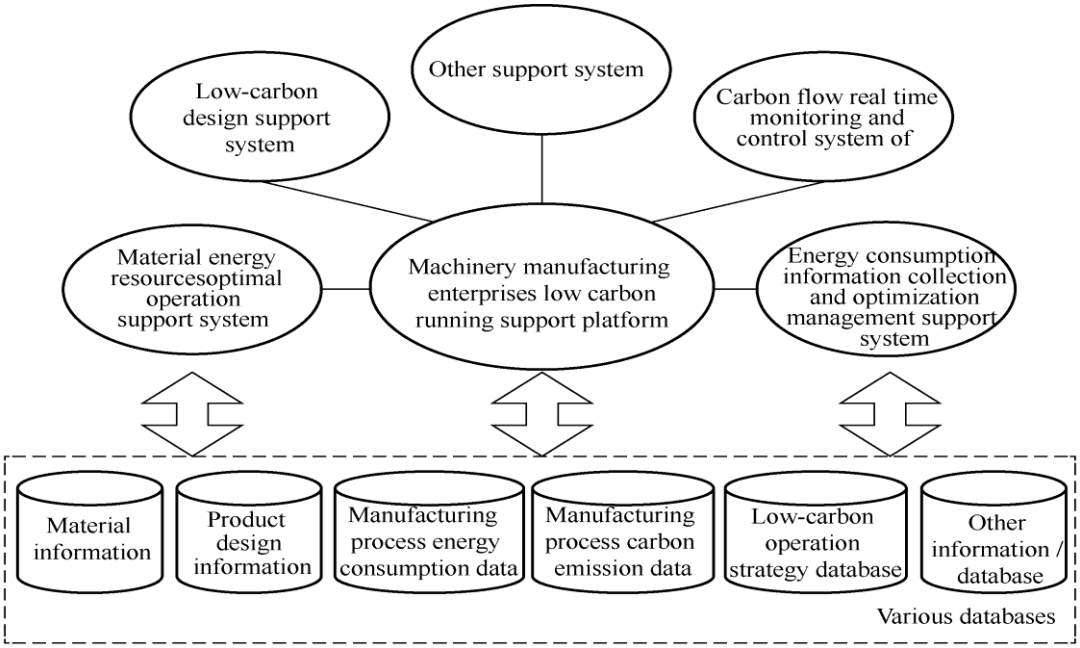

Figure 2 Schematic diagram of low-carbon operation support system for mechanical manufacturing enterprises

4. Case analysis of low-carbon manufacturing in automobile industry

4.1 A low-carbon operating process model for an automobile manufacturing enterprise

An enterprise mainly produces all kinds of cars and produces the corresponding parts. The energy consumption is much higher than the advanced level of foreign countries, and the pressure of carbon emission is also very great. In view of the situation of high energy consumption and high carbon emission, the enterprise needs to implement the low-carbon manufacturing process quickly, so as to improve the overall manufacturing level of the workshop, reduce the overall energy consumption of the enterprise, and develop low-carbon automobile products.

The whole life-cycle of the automobile products includes the input of automobile products raw materials, the production of appearance, the heating treatment of parts, the operation and maintenance. Through the analysis of energy consumption in automobile production process, the energy consumption of enterprises is mainly concentrated in body painting, heat treatment and other production links. Many cars consume a lot of fuel in the process of driving and naturally increase the carbon emissions. In view of the above problems, enterprises need to make the low-carbon operation strategy reasonably from the perspective of the whole life-cycle of automobile products. The main work is as follows: Green product design, green processing technology, green coating process, etc. The main technologies for low-carbon operation of enterprises are shown in table 1, When the carbon emissions are too much, enterprises should actively promote the new green low-carbon technology, upgrade the energy-saving equipment and reuse the waste heat. In the process of low-carbon operation strategy construction, the establishment of the whole life-cycle is the main condition, which involves many processes, such as automobile manufacturing, recycling, etc. In addition, low-carbon operation provides software and hardware technical support for low-carbon manufacturing, including green design systems, energy monitoring technologies, etc., the ultimate goal of the related manufacturing enterprises is to reduce the energy consumption in the process of development and to achieve low-carbon operation. [4].

Table 1 An automobile manufacturing enterprise low-carbon operation processing technology

Green design	Green processing technology	Green coating process
Selection of green low-carbon materials	Promotion of new green technology	Pre - cleaning reverse working water replenishing method
Light weight design of automobile	Upgrade and manufacture of technology and equipment	Phosphorus - free pretreatment process
Environment-oriented automobile design	Reuse of waste heat	Coating cycle technology

4.2 Effect analysis

In the process of automobile manufacture low carbonization design, it is necessary to reasonably control and optimize the material and energy consumption used in automobile manufacture, and to introduce new technology and new technology reasonably. In general, in the traditional production process, the power required for the production of the bicycle is about 454 kilowatt-hours, and in the low-carbon manufacturing operation mode, only 424 kilowatt-hours can be achieved. In the automobile manufacturing process, the average carbon emissions will also be reduced by 8% to 12%, and the emissions of exhaust gas and waste liquid can also meet international requirements and standards, and more than 90% of the wastes have been recycled. In the process of low carbonization design of automobile products, many products have reached the IV standard, and some even meet the V standard, especially in the maintenance of the performance level condition, the related automobile products have achieved lightweight development, reduced carbon emissions, and the new car has a fuel consumption of 6.2 litres / 100 km, compared with the traditional car reduced by about 15%, low-carbon effect is very obvious. In the initial development of auto parts, the re-manufacturing of each component has a high efficiency in reducing carbon. Nowadays, many manufacturing enterprises have more mature parts re-manufacturing technology and remanufacture of large equipment, such as engines. Due to market factors and other factors, many parts of the re-manufacturing project is still in the development stage. [5].

5. Summary

To sum up, the continuous development of the mechanical manufacturing industry has provided a large number of production reference materials for the development of our national economy, at the same time, the carbon emissions have also been obviously increased. In view of the fact that the mechanical equipment manufacturing industry in China is mostly in the stage of development and transformation, it is particularly important to establish a low-carbon manufacturing operation model with the aid of the whole life-cycle. The related enterprises need to introduce the most reasonable low-carbon technology according to their own development conditions, so as to promote the enterprises to achieve sustainable development.

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