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Analysis and optimization of the efficient press shop operation

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Abstract. In the last decade, stamping and forming manufacturing methods have been widely used in the manufacturing industry, and the stamping and forming industry has gradually shifted from the competition of scale and quantity to the competition of high quality, cost-effectiveness, and multi-category. Therefore, it is of far-reaching significance to study the efficient operation method of the press shop. In this paper, the efficient operation modeling method, digital simulation platform, and production line improvement of the press shop are reviewed. According to analysis, it can be concluded that the dynamic data-driven modeling method is perfect, but the theoretical basis involved in the practical application process is too complicated, therefore, press shop managers may be required to have a certain degree of theoretical basis so that the method can be effectively realized. Besides, the virtual-real combination of digital simulation platforms is easy to operate in the press shop, but the model assumptions analyzed in this paper are too idealized, and potential unresolved problems may arise in the practical application of the press shop with a larger scope and wider coverage. Finally, the production-based transformation of the shop floor production line is a more suitable management method for older factories that are ready for upgrading.

Keywords: Press shop operation, Stamping and forming, Automotive cladding, Numerical simulation, Manufacturing automation.

1. Introduction

With the development of the manufacturing industry, the automated stamping production line has the advantages of high efficiency, low cost, and low energy consumption. However, product quality defects have also become a problem in the quality management of automated stamping production. Therefore, improving the work quality and product accuracy of press molding can not only improve the production efficiency of enterprises but is also of great significance to the development of China's manufacturing industry. Many researchers at home and abroad have conducted research on the press shop. The main research directions include simulation of press shop operation, optimization and adjustment of efficient press shop operation, dynamic processing of data collected from the model, and management methods for the press shop. Among them, in terms of the production line and the press forming process, Li et al. [1] proposed a planning method focusing on energy saving and energy efficiency improvement, which is able to balance the production energy consumption and the maximum completion time of the press in a multi-system situation. Tian Zhipeng [2] realized the optimization and practical application of mixed-flow production planning and scheduling for automotive presses by studying automotive mixed-flow production planning and assembly line sequencing methods. Yu Fei [3] studied the efficiency improvement method of automotive press factories based on the efficiency improvement

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theory of lean production and industrial engineering. In terms of theoretical models, Chen et al. [4] constructed the energy efficiency monitoring and management system of the machining workshop, which analyzed and defined the energy consumption characteristics and energy efficiency indexes of machine tools, machining tasks, and machining workshop for the first time, and it was of significant help in identifying the reduction of energy consumption in the workshop as well as the improvement of energy efficiency.

Based on the above domestic and international research status, this paper analyzes and summarizes three types of methods that can improve the efficient press shop operation. The research of Xiong et al. [5] and Teng et al. [6] are taken as the main analytical references. Xiong et al. [5] used dynamic data-driven modeling and analysis to study the modeling and optimization methods for efficient press shop operation. Teng et al. [6] studied the digital simulation platform of the press shop based on Plant Simulation. Ning et al. [7] improved the press shop production line research based on the lean production theory. Although there is a slight distinction between the theories and methods applied, all of the literature mentioned above has improved the operational efficiency of the press shop. This paper summarizes the different theoretical bases applied in different methods and their research results so that readers can easily refer to them according to the rules and regulations and production characteristics of different workshops, in order to help improve the efficiency of press shops.

2. Dynamic data-driven modeling method for efficient press shop operation

To explore the optimization method of efficient workshop operation, the first step is to implement a complete model construction method. This includes clarifying the key indexes involved in workshop operation, the type of workshop operation model, and the dynamic data-driving mechanism of the model. Press shops are typical Discrete Manufacturing Workshops (DMWs), and discrete manufacturing products are often assembled from multiple parts through a series of discontinuous machining processes. Because discrete manufacturing workshops are characterized by stochasticity, dynamics, and nonlinearity of results, the modeling of the operation process must be accurate and precise to reflect the operation status of the real workshop as much as possible. In order to further improve the accuracy of the discrete event model, the effect of the fluctuation of input data on the model must be considered, and the fluctuation data must be processed in time to ensure that it can be integrated with the discrete event model. At the same time, the production scheduling method of the workshop is established and scheduling rules are set up, so as to realize the efficient operation and low energy consumption of the workshop.

First, Xiong et al. [5] proposed a prediction method based on data-driven discrete event simulation (DES) and established a dynamic prediction mechanism. A decision rule based on the "offline plus online" model is further developed to identify the "effective changes" of the fluctuating data, reduce the number of runs in the simulation process, and lower the computational cost. Through the historical data and multi-factor sensitivity analysis, the correlation relationship between energy consumption and operation efficiency and input variables is obtained, the relationship network is constructed, and the decision threshold is determined. For the fluctuation data with gamma distribution, the Bayesian inference-Markov chain Monte Carlo method is used for dynamic processing to obtain the latest probability distributions to obtain the latest prediction results of energy consumption and operation efficiency. Finally, the change mechanism of the workshop energy consumption and operation efficiency prediction model considering fluctuations is established, and the feasibility of the proposed method and the established mechanism is verified by taking the simplified workshop as an example.

Combined with the actual engineering, the efficient operation production scheduling model of the press shop is established to meet the following requirements. Firstly, the production is reasonably planned. Under the premise of guaranteeing the process route of each stamping part, the processing sequence of each stamping part on each press is reasonably arranged to reduce the waiting time; secondly, a brand-new production program is formulated when dynamic events such as failure and new order insertion occur; thirdly, after obtaining a new number of groups of feasible production programs, the optimal program can be quickly selected and executed.

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By analyzing the concept and connotation of workshop data service flow, the basic idea of constructing workshop data service flow is determined, and the model structure of input-processing-output is established, forming the architecture of data service flow. The corresponding software system is developed, including hardware deployment and software development, and the corresponding functional modules are built to provide support for production monitoring, energy consumption and operation efficiency prediction and analysis, and production scheduling for efficient operation of the workshop.

The literature comprehensively considers all stages of press molding production and establishes a theoretical model for the efficient press shop operation according to the actual situation in a targeted manner. The definition of the model and the algorithm are elaborated in detail and clearly in each part, fully combining the theoretical foundation. The article comprehensively considers the discrete and random nature of workshop operation and establishes a prediction and analysis model of key indexes for efficient operation based on the discrete event simulation method. A dynamic data-driven mechanism is identified, which improves the accuracy and practicality of the workshop operation process model. On the practical side, several problems may exist. First, the literature cannot predict the feasibility of a more permanent development, as new challenges and changes may arise in practice. Second, the practical application may involve staffing and cost issues in terms of actual shop floor operations and mobilization. In addition, there may be differences in the results achieved with different regulations for each workshop, therefore, the optimization needs to be adapted on a case-by-case basis.

3. Press shop digital simulation platforms based on plant simulation

Teng et al. [6] studied the digital simulation platform of the press shop based on Plant Simulation combined with the background of the press shop production and carried out the simulation study of the press shop production line. Similarly, Fang et al. [7] selected Plant Simulation version 13.0 simulation software developed by Siemens. Plant Simulation simulation software is used to construct a generalized discrete system simulation platform for press shops, in order to analyze and demonstrate the planning and scheduling, resource planning, logistics analysis, and layout analysis of the press shop for workshop planning and workshop transformation. At the same time, combined with virtual reality technology, it constructs an interconnected virtual-reality simulation environment and digital model of the production system. The results show that the optimized scheme can substantially improve the capacity of the press shop and provide theoretical and technical support for press shop planning and stamping line transformation.

By analyzing the process logistics of the press shop, the press shop is characterized by long film change time, mass production, and demand-pull. The simulation platform takes the workshop as the research object, which can be simulated and optimized for a variety of objectives. In order to make the simulation platform to be able to face the majority of users, first of all, it is necessary to research and analyze the demand for the simulation project of the press shop. After establishing the model type library and defining the specific content of the objects in the class library according to the process type, the objects are extracted from the class library to build the model, and the individual objects are customized.

The Plant Simulation model can establish a virtualized digital simulation platform synchronized with the physical factory. The virtual physical factory can dynamically display the operation process of the press shop with the help of the 3D model and feedback on the simulation results to the press shop. Through the combination of virtual and real, the virtual factory can realize the real-time display and monitoring of the physical factory.

By generating images from the statistical data and analysis of the research results, this digital simulation platform is able to meet the adjustment of the functional area of the press shop by analyzing the size of the workshop cache area, transferring batches, and adjusting the production plan, thus effectively improving the efficiency of workshop planning. The virtual-real interconnected workshop can dynamically display the operation process of the press workshop, and the operation status and relevant parameters of the actual workshop can be viewed in real time on the simulation platform, so as

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to realize the monitoring and management of the production workshop. However, it should be noted that the model applied in this literature is simulated under certain assumptions, and potential unresolved problems may arise in the practical application of the press shop with a larger scope and wider coverage. Xia et al. [8], in the study of modular management of the press shop equipment in automobile factories, carried out a detailed cost impact analysis of the average single-vehicle manufacturing cost of the basic production module of the press shop. In the actual production process, managers can learn from the situation.

4. Improvement of the press shop production line based on lean production

Lean production is currently recognized as the best production organization system in the industrial world, and industrial engineering (IE) is not only the engineering basis for the completion of lean production methods but also an important part of lean production. Lean production is from the Massachusetts Institute of Technology of the United States, a number of international automotive planning organization experts on the Japanese Toyota's "JIT (Just in time) production method" of praise. It is characterized by eliminating all unnecessary waste, removing all non-value-added work in the production chain, and maximizing profits by producing products of a quality that meets customer requirements in the shortest possible time at the lowest possible cost.

The application of lean production in actual factories can refer to the quality management improvement study of the automated stamping line at Changchun FAW Mold Manufacturing Co., conducted by Qi et al. [9]. Besides, in the improvement study of the press shop production line based on the lean production theory, Ning et al. [10] take the whole production process of the press shop as the research object and apply lean production as the theoretical basis to analyze and adjust the production process in order to achieve the optimal efficiency of the production workshop.

The key problems to be solved include: reducing the waste of intermediate links and defective products through the optimization of the process flow; reducing the time of replacing the tooling through the planning of the new production line; improving the arrangement of the production line and the layout of the workshop of the existing factories by combining the lean ideas to improve the efficiency of the production; and carrying out the continuous improvement for the new problems arising from the use of new equipment.

By reconstructing the production line in the press shop through program analysis techniques and the 5W1H method, improving the sheet cleaning process combined with the ECRS principle, eliminating the offline cleaning unit, and integrating sheet cleaning into the press line, the intermediate links of inventory waste are reduced of 0.44 days, avoiding manufacturing too much premature waste; moreover, the waste of repeated handling in the process of sheet cleaning and the waste of defective products caused by cleaning too early are also reduced. The new robot (robotic arm) is a new type of robot that can be used in the cleaning process. The use of a new type of robot (robotic arm) reduces the waste of movement during part handling, and the improvement of press layout shortens the distance of part handling between processes. This literature applies lean production and basic IE methods and tools to the workshop transformation, and it finally realizes the remarkable results of 81.38% productivity improvement, 1.64% reduction of the product defect rate, and 37 reduction of the number of necessary direct production personnel. It has important reference significance for similar transformation of other manufacturers in the same industry. In the case of structural overcapacity in China's automotive industry and the state's control of disorderly expansion of production capacity, the replacement of the old production line is the simplest way. The theory of robot motion analysis used in the literature can help manufacturers to make simple and intuitive screening when selecting robots. In summary, the literature is the most helpful reference for manufacturers who are going to carry out large-scale replacements on the factory floor, and the new production line also contains many concepts of visualization and prevention in lean production.

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5. Conclusion

This paper summarizes the different theoretical foundations used in different methods and their research results by analyzing different methods for improving productivity in press shops. To conclude, the use of dynamic data-driven modeling approaches is an effective means, but there may be some challenges in the practical application of this approach. Firstly, the theoretical foundations involved in this approach are complex and require a certain level of specialized knowledge and skills from shop floor managers to be effective. This may mean that additional training and learning costs are required to ensure that the team can fully understand and apply the method. In addition, while digital simulation platforms do achieve some success, the modeling assumptions applied in the literature may be too idealistic. In practice, press shops may face a variety of complexities and challenges that may not be fully covered by these models. Therefore, in the practical application of a larger and more involved press shop, some potential unresolved issues may arise, which need to be targeted for adjustment and optimization. In addition, retrofitting the shop floor production line based on Lean Manufacturing is another effective management method, but relatively speaking, it is only targeted to be applied to older factories for reference when they are about to upgrade.

In summary, although dynamic data-driven modeling approaches, digital simulation platforms, and lean manufacturing transformation bring new possibilities for the management and operation of press shops, there are some challenges that need to be overcome in their practical application, and various factors need to be considered comprehensively and adjusted and optimized according to the actual situation in order to ensure their effectiveness and feasibility. Due to the many types of press shops and the countless methods included to improve the efficiency of the factories, the study is not comprehensive due to the limited personal knowledge and references. At the same time, it is believed that the progress of science and technology will bring new research methods on the management style, cost control, and operational efficiency of press shops.

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