

Optimization of Panel Furniture Plates Rework Based on Intelligent Manufacturing

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Panel furniture uses an intelligent management system, combined with the production method of splitting orders by process, to achieve large quantities and large-scale manufacturing, but because of the insufficient and incomplete use of technology, capacity bottlenecks still exist. The problem of rework and replenishment is a long-term problem in furniture production. Under the constraints of existing production rules, the time difference of plates rework forces the original batch of plates to wait, which reduces the efficiency of warehousing. From the perspective of intelligent manufacturing for the optimization of the plates rework process, this study, through on-site observation records and data analysis of the production system, aimed to find short-term solutions and long-term solutions. In the short-term response, the time node for the completion of the replenishment is mainly according to the process regulations, and the plates are packaged into the warehouse after the replenishment is completed in batches. The long-term response strategy is mainly to achieve the interconnection of different production systems to achieve mutual information, and the paperless online operation of the plates rework process increases the subjective initiative of each process to improve the overall efficiency of the plates rework process.

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INTRODUCTION

China's household products manufacturing technology has taken a solid step from traditional handmade manufacturing technology and industrial manufacturing technology to informatization and digital manufacturing technology, and it has gradually advanced towards intelligent manufacturing technology (Xiong *et al.* 2018; Xiong and Wu 2018). Intelligent manufacturing is a manufacturing system composed of virtual network and physical objects, which is a production and manufacturing method that uses information networks to change the production organization mode of the manufacturing industry; it has the potential to reduce operating costs, improve production efficiency, and improve product quality (Lv and Han 2015). Among them, the rapid development of customized furniture has played a key role in the upgrading of home intelligent manufacturing technology (Wu 2017). Panel custom furniture has achieved a breakthrough in the energy level with its mass production method. The custom furniture manufacturing model has been proposed since around 2002, and it has been applied to research and development processes, such as product standardization technology, information control technology, information collection and processing technology, flexible manufacturing technology, and information

integration platform construction technology (Li 2015; Xiong *et al.* 2018; Xiong and Ren 2021). Until 2015, China first proposed the implementation of the “Made in China 2025” concept in the “Government Work Report”, requiring the deep integration of informatization and industrialization “two”, leading and driving the development of the entire manufacturing industry, focusing on the development of intelligent equipment and intelligent products, promoting intelligent production processes, cultivating new production methods, and comprehensively improving the intelligent level of enterprise research and development, production, management, and services (Xiong 2022; Zhou 2015; Zhang *et al.* 2020). The first 10-year action plan for intelligent manufacturing characterized by innovation-driven, intelligent transformation, strengthening the foundation, and green development has been formed, and the implementation of the strategic transformation from a manufacturing country to a manufacturing power has been accelerated, and it is also a commanding priority to be occupied by China’s manufacturing industry (Wang 2017; Zhang *et al.* 2020). The main development directions of intelligent manufacturing in the manufacturing industry are the intelligent production line, intelligent workshop, and intelligent factory, and its goal is to pursue the optimization of the production process and greatly improve the performance, function, quality, and efficiency of the production system (Zhou *et al.* 2018; Zhou 2022). Driven by intelligent manufacturing, the panel furniture industry has continuously upgraded its production methods, greatly improved productivity, and its production process has been continuously optimized.

China’s industrial manufacturing has developed rapidly, but it still started late compared with Western countries. The advantage is that it can learn from the direct experience and theories of Western countries, but the foundation is generally weak (Deng and Qi 2000). In the future development, in the face of complex and changing political and economic environments, the product technical barriers between enterprises are constantly being broken, making the same industry more transparent in terms of production costs and profits. This situation makes lean technology and lean management increasingly important in enterprise management; mastering this technology can allow enterprises to achieve breakthroughs in cost and profit and seize the high position of market competition (Zhang and Wu 2023). Changing the design mode of products, reorganizing manufacturing modes, and integrating and sharing management processes through information means is the core of solving the industrial production of single products, and it is also the key to realizing intelligent manufacturing (Li and Yao 2021; Xiong and Yue 2022). Through the improvement measures made by the recording and analysis of the production line, the company can greatly save costs and improve processing efficiency in mass production. The micro-specific improvement measures also need to think backwards to the macro system and strive to fundamentally optimize the production process from the system. The panel custom wardrobe determines the non-standard nature of the board with its customized characteristics. When it comes to scheduling production, every piece is unique. Therefore, when quality problems lead to the need for plates to be reworked, they must be reproduced or repaired according to the plate information. Therefore, plate rework is a supplement to the normal production of the production line, and it is the last step of the completion of the product. This has a great impact on production efficiency, so this study studies the rework process of the plate on the production line. It is expected to increase the efficiency of the plate rework process, which will have an effect on the efficiency of the entire production process. This study documents and analyzes problems that arise during panel rework or rework in panel furniture production lines. The ESCR (Eliminate, Simplify, Combine,

Rearrange) concept in IE's process analysis method was used to improve production factors such as people, machines, materials, methods, and the environment (Li and Zhou 2007; Ling and Guo 2012). The idea is to eliminate waste and thereby shorten the production process cycle and improve the work process. Finally, short-term improvement and medium- and long-term systemic improvement of the problem are proposed.

COMPLETION PROCESS AND REPLENISHMENT STATUS OF PANEL FURNITURE

The panel furniture manufacturing factory investigated by the authors is located in Huanggang, China. The production characteristics of panel furniture are modular, decentralized, and mass-produced. After the structural plates are divided into the smallest unit, they are divided into workshops and production lines according to the processing characteristics. Therefore, how to plan its classification method, logistics route, and transportation mode determines the processing efficiency of the plate in the factory. At present, the factory has established a relatively mature and stable completion process. So to complete the replenishment process at the lowest cost, it is necessary to be as close as possible to the actual completion process of the factory. Therefore, the authors made research records on the existing order completion process and its replenishment process of the surveyed factory.

Panel Furniture Completion Process

The mass production of panel furniture is scheduled to the production hall by splitting orders by process, that is, a certain number of orders are classified according to the delivery dates of different process types in the same order can be packed and stored at the same time, so that they can be shipped on time (Niu *et al.* 2021; Chai and Wu 2022). This is shown in the schematic diagram of the circulation process of the plates in the order of Fig. 1.

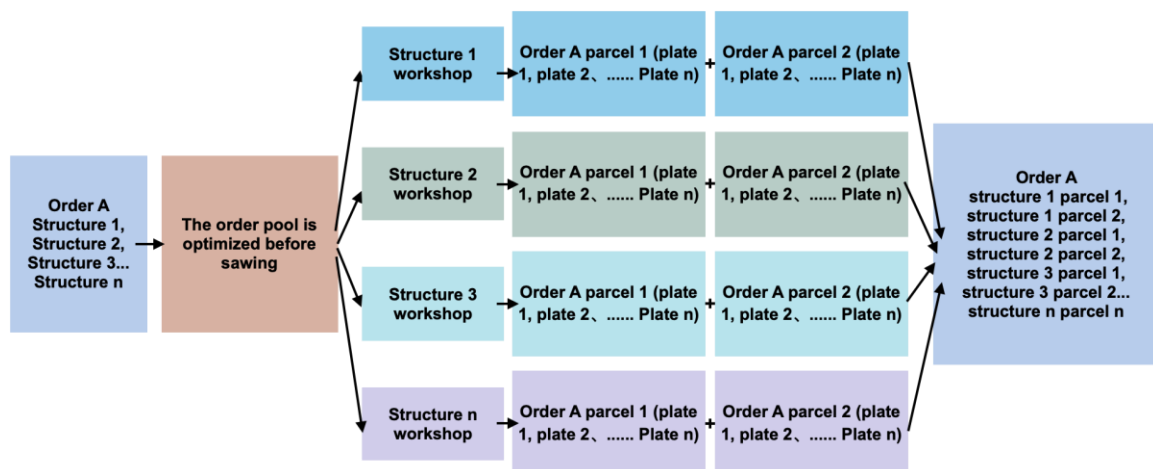


Fig. 1. Schematic diagram of the flow process of panels in a panel furniture order

In order A, the plates in the order are divided into structure 1, structure 2, structure 3 and structure n according to the processing technology. The sawing path is optimized together with plates of the same structure in the order pool, and a certain number of plates

are divided into a parcel under the limitation of weight or volume, forming a list of plates in the parcel. This step is called scheduling. After the processing information is defined, the production line starts production, and after the plate processing is completed, the plates are packed according to the parcel document list, and the plates in the parcel are marked in the manufacturing production system to be completed, and when the parcels belonging to the same order are complete, they can be put into storage, and the storage location is marked in the storage system to wait for delivery (Xiong and Zhou 2022).

The plate processing process is shown in Fig. 2, which is usually cutting-edge banding-drill-checkout-pack-warehousing.

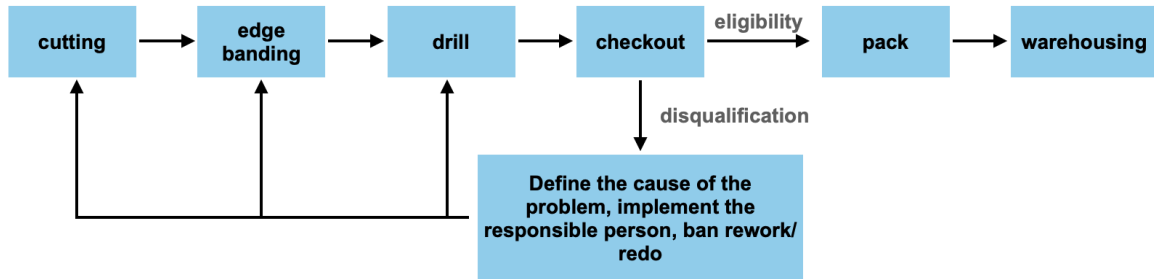


Fig. 2. Schematic diagram of the plate machining process

After the cutting process prints out the plate processing label, each process is carried out according to the information given by the label. The inspection process checks the appearance size of the plates according to the quality requirements, and after there is no problem, according to the number of board list points in the package, the number of plates is complete and sent to the designated area. The quality problems of furniture panels often occur such as size inconsistencies, edge banding, degumming, and corner breakage. Some problems make it necessary to return an item to the problem process to rework, and some problems such as plate scratching, deformation, and hole opening errors need to be redone (Yao *et al.* 2022). When the quality problem of the plate needs to return to the previous process for reprocessing, or the central production of the plate is required due to the problem cannot be repaired, it becomes a redo or rework process of the plate. Because of the abnormal quality in the production process, the problem plate is intercepted at this time, the cost of replenishment is minimal.

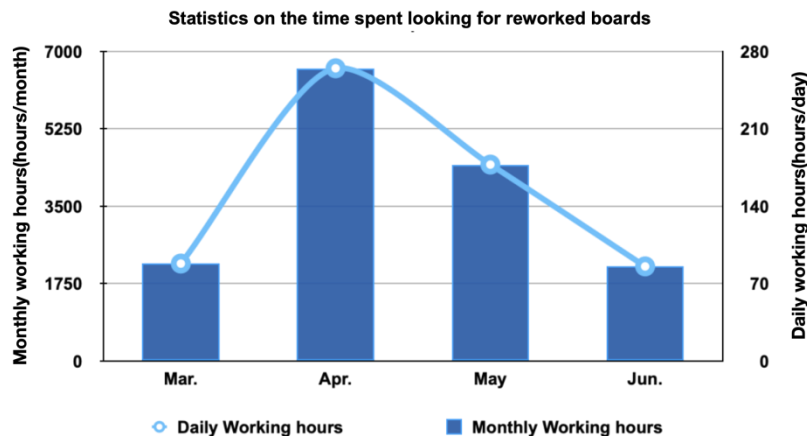


Fig. 3. Statistics on the time spent looking for reworked boards

By contrast, if the quality problem is found in the dealer's quality inspection or to the customer's installation after delivery, the time and economic cost generated are greatly increased. When the quality problem is found, the plate will leave the original batch and enter the plates rework process flow, which will affect the original parcel storage progress due to the different processing progress from the original batch. According to the author's investigation in the survey, as shown in Fig. 3, from March to June 2021, the monthly cumulative time of finding boards and the average daily time of finding boards in a workshop were huge, and the cumulative average daily time of finding boards exceeded dozens of hours, expending huge manpower.

The time to cancel the owed status of the board in the manufacturing system is shown in Fig. 4, with an average of 523 min. To solve the problem of the board rework, enterprises have spent a huge amount of manpower and material resources.

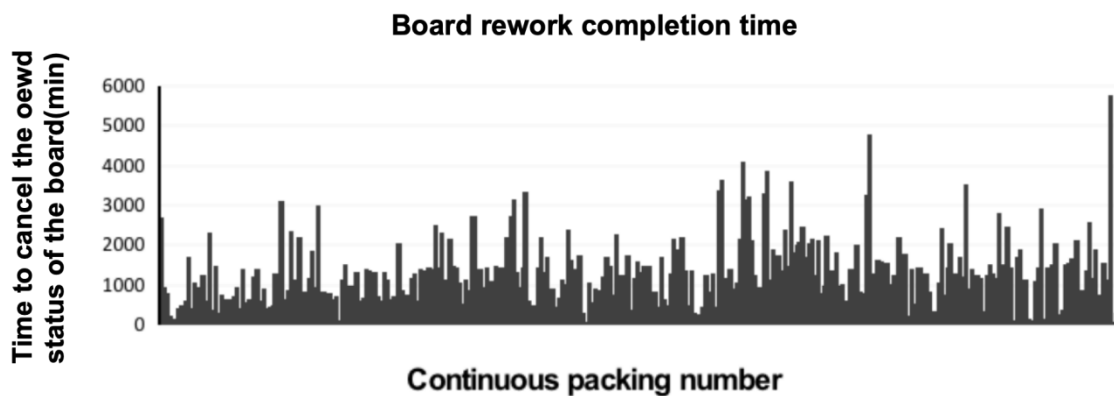


Fig. 4. Time to cancel owed board within the system

Firstly, the panel furniture manufacturing industry usually adopts the piecework wage system that does not produce actual value but is needed to pay additional wages, which is the loss of the enterprise.

Secondly, after a day of high-intensity labor, workers need to find the plates in the owed board package on the production line, which is time-consuming and laborious and occupies the remaining time.

Finally, the process of replenishing the missing parts is not perfect, which costs additional manpower and material resources, and directly affects the further improvement of production capacity. Therefore, it is necessary to improve the efficiency of the underfeed process.

Panel Furniture Replenishment Process

As shown in Fig. 5, the layout plan of a production workshop, from left to right, is divided into the cutting machine table area, the edge banding machine area, the drilling machine area, the inspection and packaging table area, and the finished package placement area. The replenishment process of panel furniture starts from a different point from the production process and is usually an inspection process. The inspection process starts the feeding process after discovering quality problems.



Fig. 5. A floor plan of a workshop

Step 1. Inspector: find the problem board, mark the missing parts in the production system, reprint the problem board label, paste the owed package label to the kanban, place the owed package in the open space near the workbench, fill in the replenishment rework list, and hand the reworked board label and the replenishment list to the board finder.

Step 2. Board finder: collect and sort out the replenishment rework order every 1 to 2 h, hand the replenishment rework order to the person in charge of the corresponding process to sign and confirm, clarify the person responsible for the cause of the problem plate; find the plate needed for the owed plate in the remaining plate area, and hand the label and plate to the operator of the feeding line cutting machine. The cutting operator waits for the replenishment plates to accumulate a certain number before centralizing the cutting.

Step 3. Edge banding operator: wait for the feeding plate to be finished and perform the edge banding operation. After the edge banding is complete, set aside the reworked plates.

Step 4. Drilling operator: Before the rest time, the finished feeding plate will be transported to the drilling rig table for drilling operation.

Step 5. Inspection of packaging operators: If the packing area for unfinished packages is full, look for the processed missing plates in the front process and check the appearance dimensions of the finished plates. If the quality of the plates is satisfactory, the missing parts are cancelled in the system. The plates are wrapped in packages and placed in the finished parcel area.

Step 6. When all packages ordered in the same area are completed, they can be sent to the warehouse.

ANALYSIS OF FEEDING PROCESS PROBLEM

Analysis of Production Site Factor Problems

Through analyzing the five elements of the production site, namely people, machines, materials, methods, and environment, the replenishment and rework process is analyzed in detail. 1. Manual pull production: the feeding process belongs to the auxiliary line in the workshop, which is a single line planned to assist the production of feeding plates in addition to production. Because of the irregular and non-concentrated production of rework plates, processing personnel often summarize the centralized production of

supplementary plates in half a day, during which they can only be tracked by the inspection bench of the package that is not owed, resulting in too long waiting time for the unfinished packages to enter the warehouse. 2. Machine position dispersion: Because there is no special feeding line, the position between the various processes of feeding is relatively scattered, resulting in inconvenient and untimely communication between processes and the transfer of plates, which reduces the efficiency in the production process. 3. The use of residual material board feeding: It is conducive to the improvement of the utilization rate of the plate, but it increases the production link of finding the remaining material, coupled with the contingency of the feeding plate, the plate finder finds the board once in 2 h, which further reduces the efficiency. 4. High degree of paper-based dependence: the handwritten rework list and its operation process are too long, fill in the unfinished plates list - re-mark the unfinished plates label - sign the responsible person - summarize the label to the cutting machine for reproduction, and the waiting time for each step is not customized specifications, which cannot force the subsequent process to enhance the urgency awareness of the production of the unfinished plates. 5. Low degree of informatization: there is no visual process data, so that it is not possible to locate and track the board. When the feeding plates stay in the process before the inspection, the information between the processes is not connected, and each process can only wait passively, and it is impossible to actively track the number of owed plates and the processing progress.

Intelligent Manufacturing Production System Problem Analysis

At present, there are many types of management systems used in the manufacture and production of panel furniture. For example, enterprise resource planning (ERP), manufacturing execution system (MES), Warehouse management system (WMS), Manufacturing Operations Management (MOM), *etc.* However, each system is developed based on a broad category of functions and is not connected to each other. If digital networking is the initial stage of intelligent manufacturing in China, then the breakthrough and widespread application of the next round of intelligent manufacturing requires upgrading the existing intelligent manufacturing system. With the transformation and upgrading of manufacturing, intelligent manufacturing must propose higher requirements for the information exchange of the management system. For example, the manufacturing information is stored in the MOM system, but the manual information after the production batch is stored in the MES system, which causes inconvenience to the definition of the person responsible for the problem of replenishment and rework.

Improvement Measures

To solve the problems in the feeding process, it is divided into short-term improvement measures and medium and long-term solutions. Short-term improvement measures are to improve the production factors on site to achieve immediate results. The medium- and long-term solution is to improve the outcomes from a systematic perspective, and the improvement effect can maximize the efficiency of the entire system.

Short-term responses

(1) Clarify the time limit. On the one hand, the operator sends the replenished and reworked plates to the next process within a limited time. On the other hand, the board finder regularly tracks the production progress according to the batch of the unfinished plates and supervises the production of the operators of each process.

(2) Establish a system for making up the unfinished package according to batches. Improve the tracking attention of the owed package, the inspection process will be the owed package in batches, the inspector and the board finder pay attention to the owed package, urge each process to replenish the production and processing of reworked plates, the same batch of plate processing is completed, before the next batch of plate processing is completed, the previous batch of owed parts should be all completed, so that the owed packages can be stored in batches.

Results of short-term responses

According to the data statistics in the production system, the average production time of reworked panels was shortened from 4.9 hours before optimization to 3.5 hours, which is a 28.5% shortening of time.

Medium and long-term solutions

From a systematic analysis, the problem of non-circulation of information in the manufacturing process of panel furniture is ultimately solved through the interconnection of various systems. As shown in Fig. 6, the series connection between MES, MOM, and WMS management systems allows the systems to read key information from each other.

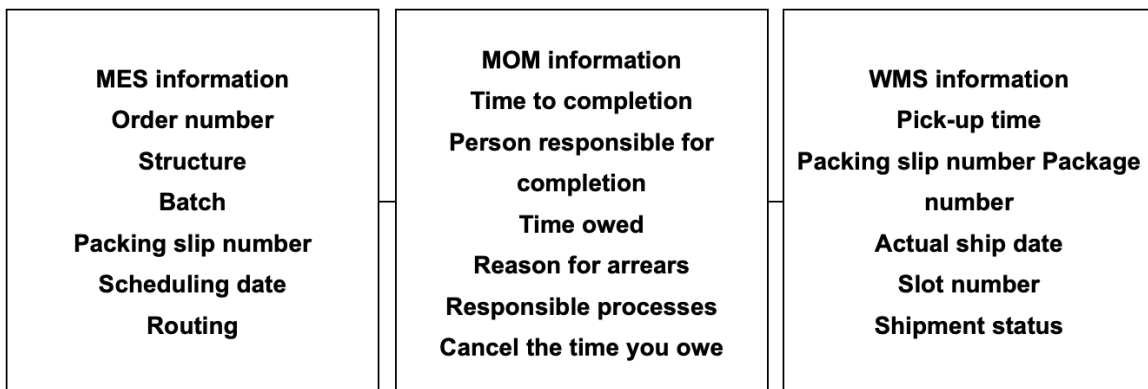


Fig. 6. Schematic diagram of the management system information interconnection

The specific improvement measures are as follows:

- (1) The feeding process is paperless. It enables MES and manufacturing systems to jointly share production data. Inspectors mark outstanding parts and quality problems in the production system, and the system associates relevant processes with responsible persons to reduce the handwritten rework list process.
- (2) The board finder refreshes the information of the missing parts in real time through the MES system, replenishes and reworks the production of small batches of plates multiple times, and the packages of the missing parts can be completed in time to improve the speed of warehousing.
- (3) Each process can query the specific information of the replenishment rework plates circulating on the feeding line in real time through the MES system, such as processing location, completion progress, *etc.*

CONCLUSIONS

1. In the research process of panel furniture feeding optimization based on intelligent manufacturing, the specific feeding process and management system information connection are analyzed from two aspects. The production materials in the manufacturing process of panel furniture can be tracked through information labels, which brings great convenience to the intelligent management of the manufacturing process, but there is still room for further improvement at the practical operation level. Improving the degree of informatization in the production and manufacturing process further enhances the great advantages brought by intelligent manufacturing to the production of panel furniture.
2. At present, manual operation of production methods still occupies the mainstream of panel furniture production methods. Under the general trend of intelligent manufacturing, a large number of furniture companies are introducing intelligent manufacturing systems to assist production and greatly improve production efficiency. The informatization of the production process has brought a new perspective to research and manufacturing, and it has also brought a new perspective to enterprises to optimize the production process and improve production efficiency.
3. The application of intelligent manufacturing systems in furniture companies has been carried out over the course of time, but it seems that it has encountered certain bottlenecks. If the process recorded by the intelligent manufacturing system in the process of production execution fails to contact the lowest level of production, the information between the intelligent manufacturing systems is independent and the information is not connected, which brings new obstacles to the further development of production capacity. Furniture companies still need to face this problem head-on, and when full coverage and information connectivity are achieved, new useful observations may be generated.

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