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RESEARCH ON APPLICATIONS OF CONTINUOUS IMPROVEMENT IN MANUFACTURING COMPANIES

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ABSTRACT

The ability to continuous improvement is part of an enterprise's core competitiveness. Only by continuous improvement can we better adapt to market changes and social progress and development. This study focuses on the problems of inventory backlog and low production efficiency faced by SZ Company, and deeply analyzes its root causes: inaccurate market demand forecasts, excess inventory caused by batch production mode, time differences between processes and imbalanced production capacity, etc. These problems not only increase capital occupation, but also cover up the deep-seated problems of the production system. In order to solve the above problems, this paper adopts a qualitative analysis method, applies the theory of Toyota Production System continuous improvement, and combines the successful experience of Mazak iSMART Factory project to propose a series of continuous improvement measures based on advanced technologies such as IoT , big data, and AI. By optimizing market demand forecasts and production plans, improving batch production modes, solving time differences and imbalanced production capacity between processes, improving employee skills and production efficiency, and realizing visualization and continuous improvement of the production process. This paper to provide SZ Company with a practical and feasible continuous improvement path combining the latest technology. Continuous improvement is solved the problems of high inventory and low production efficiency. It will help SZ Company significantly improve production efficiency, reduce operating costs, enhance market competitiveness, and ultimately achieve sustainable development and transformation and upgrading.

Keywords: *continuous improvement, inventory backlog, low production efficiency, Toyota Production System,*

1. Introduction

Continuous improvement mainly means that small reforms should be carried out continuously, gradually and in an all-round way, so as to achieve the purpose of continuously improving efficiency (Van, 2021). Continuous improvement is of great strategic significance to enterprises in an era of change. It organically combines enterprise development with performance improvement and can make a direct and lasting contribution to the improvement of the company. Continuous improvement is not only a practical method, but also a strategic competitive weapon. In fact, changes in the business environment also require companies to elevate continuous improvement to a strategic level, making it a must-have for companies in the era of change a function (Vinodh, et al., 2021).

Continuous improvement is achieved through improvement processes. In other words, continuous improvement needs to be based on conscious, planned and systematic improvement. Only when an organization carries out extensive improvement activities can it be possible to talk about continuous improvement. Continuous improvement has the following characteristics:

Continuous improvement is never-ending. No one-improvement effort can end the opportunity for improvement (Van, & Kokkinou, 2021). This means that even if an improvement effort is completely successful, there will still be room for continued improvement.

Continuous improvement is something organizations actively pursue (Chuang, 2021; Van, 2020). General continuous improvement is often carried out only when there is a quality problem, and corrective measures and preventive measures are taken. Continuous improvement is about organizing employees to actively and proactively seek improvement opportunities. If corrective and preventive actions are a kind of defence, then continuous improvement is a kind of offense.

The content of continuous improvement involves all aspects of the organization. General continuous improvement often only targets specific products or processes, while continuous improvement not only includes improvement measures for specific products or processes, but also includes improvement measures for management, up to long-term improvement projects (Bernal, et al., 2021).

The purpose of continuous improvement is to improve efficiency and effectiveness to ensure the achievement of expected goals. General continuous improvement is also to improve effectiveness and efficiency, but they all focus on reducing quality cost, while continuous improvement emphasizes improving quality and efficiency (Van, 2021).

Through years of continuous verification and exploration in the actual production process, the continuous improvement management method has gradually matured in the field of large-scale automobile and its supporting parts manufacturing, and the improvement effect after implementation are also very obvious. However, small and medium-sized enterprises of the same type, such as SZ Company, whose scale level is not enough and whose main product characteristics are "multiple varieties, small batches, and short delivery time", cannot directly adopt it. This article provides practical operation and theoretical guidance for the same type of manufacturing enterprises to carry out lean production management by studying the manufacturing enterprises with the characteristics of frequent product switching, a wide variety, and a short customer demand cycle.

By applying the concept of lean production methods, analyzing the current actual situation and existing problems of SZ Company, referring to the successful experience of MAZAK Company, a set of continuous improvement management methods that meet the needs of SZ Company is formulated, so as ensure that SZ Company gains competitive advantages in the severe market environment challenges. Through the continuous improvement of product production quality within the enterprise, enhancing the flexibility of the production management process, reducing production management inventory, and enhancing the turnover rate of materials and funds, a unique production management system is form.

2. Literature Review

This paper will discuss a continuous improvement method: the Toyota Production System. This effective continuous improvement method has been verified in business management practices.

The Toyota Production System

The Toyota Production System (TPS) was developed by Mr. Taiichi Ohno, who once served as the chairman of Toyota (Wada, 2020). It combines two systems, real-time management and kanban management, and adds high-level production automation rules. It aims to complete eliminate waste and will continue to improve it. As a foundation, it has gradually developed into an effective management system including corporate business philosophy, production unit organization, logistics and transportation, quality management, cost control, inventory management, etc. The Toyota Production System aims to eliminate waste, with just-in-time production and automation as its two pillars, and continuous improvement as its important foundation (Aoki, & Nomura, 2023). Improvement is the foundation that runs through the entire Toyota Production System, and all Toyota people require themselves to be "continuous improvement." The improvements mentioned in Toyota's way of working mainly include the following aspects:

a. All improvements must be based on demand. The fundamental idea of TPS is that everything starts from needs. As the basis of TPS, improvement must also take needs as the starting point, so that the purpose of improvement can be clearer and the results of improvement can be more effective (Chiarini, et al., 2018).

b. There is room for improvement from both local and overall aspects. From daily work to production management to quality assurance, the space will be constantly transformed. It is necessary to not only identify problems with genchi genbutsu, but also improve the problems with an overall approach (Wada, 2020).

c. Improvement is a continuous process. Improvement is not a one-time task, but a continuous task, and there are always problems that can be improved during the work process. We must be aware of problems and constantly discover problems at work. Improvement must not only be carried out in production, but also among all employees. Only when everyone participates in improvement and has an awareness of problems, can the entire work become smoother through unremitting efforts (Ribeiro, et al., 2019).

In the context of Industry 4.0, continuous improvement has become an effective tool to improve the competitiveness of enterprises. In the past, continuous improvement was main used to improve production processes, but with the development of Industry 4.0, its application scope and implementation methods have been expanded, thus achieving more efficient and flexible production methods.

Firstly, factory automation in the era of Industry 4.0 involves all aspects of intelligent manufacturing, and continuous improvement can provide effective tools and methods for these links to achieve more efficiently automated production (Shahin, et al., 2020). At the same time, through continuous improvement and PDCA cycle, the production process can be optimized to achieve more efficiently production.

Secondly, digital manufacturing is an important part of the era of Industry 4.0. The application of continuous improvement in digital manufacturing is main reflected in improving production line efficiency, reducing production costs, and improving product quality (Arredondo-Méndez, et al., 2021). For example, through the method of continuous improvement, the production process can be optimized and improved, thereby improving production efficiency and quality. At the same time, through the application of digital technology, the production process can be fully monitored and managed, thereby achieving more efficiently production (Borowski, 2021).

Thirdly, in the era of Industry 4.0, data has become increasingly important and can be used to monitor production processes, improve product quality, and optimize production plans. Continuous improvement can use data to optimize production processes and respond to changes in real time (Wang, et al., 2022). Through data collection and analysis, bottlenecks and problems in production can be identified and solved, thereby improving production efficiency and quality. At the same time, through intelligent technology and data analysis, production activities can be driven and adjusted, so as to timely discover and solve problems and ultimately achieve production effectiveness.

Fourthly, in the era of Industry 4.0, production models need to be more flexible to meet the ever-changing market needs. Continuous improvement can help companies achieve a more flexible production model to meet different market needs (Margherita, & Braccini, 2023). Through the method of continuous improvement, the production process can be streamlined and standardized, thereby improving production efficiency and quality.

Finally, artificial intelligence and machine learning are important components of the era of Industry 4.0. Continuous improvement can use artificial intelligence and machine learning technologies to realize the automation and intelligence of the production process (Rai, et al., 2021).. For example, through the method of machine learning, data analysis and optimization in the production process can be realized, thereby improving production efficiency and quality. At the same time, through artificial intelligence technology, intelligent monitoring and management of the production process can be realized, thereby improving the stability and reliability of production.

Overall, continuous improvement can provide companies with a more efficient and flexible production method in the context of Industry 4.0. Whether in factory automation, digital manufacturing, smart logistics, data-driven production, flexible production models, artificial intelligence and machine learning, continuous improvement can bring significant improvements and enhancements to enterprises. Therefore, enterprises can improve production efficiency and quality through the application of continuous improvement, thereby occupying a more advantageous position in market competition.

By collecting and sorting out relevant domestic and foreign literature, a scientific view on the use of continuous improvement methods by enterprises is form after sorting and summarizing, providing theoretical basis and guidance for the research of this topic.

By analyzing a certain actual case and combining it with literature, the general law of things is obtained. This paper analyzes and summarizes the experience of SZ and MAZAK companies in implementing continuous improvement methods and processes, verifies and improves the effectiveness of each specific countermeasure of the company, and obtains constructive optimization and improvement measures through screening, classification and analysis of problems.

By understanding and analyzing the actual status of MAZAK company, the actual application effect of lean continuous improvement method in MAZAK company is obtained.

3. Research Method

3.1 Contextual Framework

This chapter describes about the methods used in the study, the population, sample, sampling techniques, sources and methods of data collection, the operationalization of variables and data analysis methods. For articles that are not in the form of the research results can contain explanations about the subject to be the focus of discussion (eg green purchase behavior phenomenon in Indonesia plastic pay policy) as well as the measures proposed to resolve the problems faced.

This study starts with the background of continuous improvement characteristics, studies the methods of continuous improvement through literature review, and provides theoretical support for analyzing the actual situation of enterprises. Then, the root causes of SZ company's inventory backlog and low production efficiency are deeply analyzed, pointing out key problems such as inaccurate market demand forecasting, drawbacks of batch production mode and imbalance between processes. By drawing on the successful experience of Mazak's iSMART Factory project, this study proposes a solution to optimize market demand forecasting, production planning, batch production mode and process balance by using advanced technologies such as IoT, big data, and AI and adopting continuous improvement methods. This study provides SZ company with a comprehensive and systematic continuous improvement strategy, aiming to improve enterprise production efficiency, reduce inventory costs, enhance market competitiveness, and promote sustainable development and transformation and upgrading of enterprises through continuous improvement measures such as accurate forecasting, flexible production, resource optimization and intelligent management. The contextual framework is shown in Figure 1.

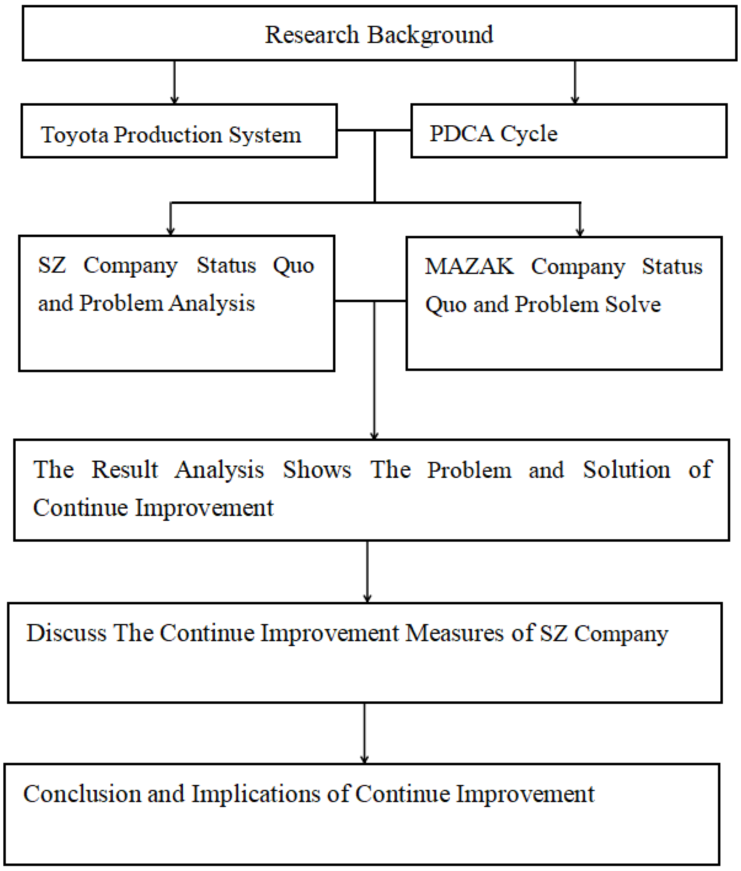

Figure 1. Contextual Framework

3.2 Case Analysis

3.2.1 Company Profile of SZ

SZ was founded in 1998. It is a joint-stock company specializing in research, development, manufacturing, service and sales of vehicle air-conditioning systems. It was successful listed on the Shenzhen Stock Exchange in 2010. This makes SZ the first listed company in the Chinese transport vehicle air conditioning industry. SZ devotes itself to automobile air conditioning systems as a premium brand and will become a world class supplier with state-of-the-art technique and in-house processing in the near future.

The company specializes in the research and development, production and sales of mobile thermal management related products and is one of the leading companies in domestic automotive thermal management related products. The company's product coverage is relatively comprehensive and has been widely used in various types of vehicles such as large and medium-sized buses, passenger cars, special vehicles, trucks, light buses, rail cars and refrigerated trucks. In addition, the company has further expanded its business in the field of energy storage temperature control in recent years and is engaged in the research and development, production and sales of thermal management products for energy storage power stations.

In the large and medium-sized bus thermal management business segment, the company's products mainly include large and medium-sized bus air conditioners and new energy bus battery thermal management system products. In the car thermal management business segment, the company's products mainly include thermal management systems for traditional/new energy vehicles, air conditioning boxes, front-end cooling modules, valve islands and other thermal management assemblies and module products, as well as condensers, radiators, battery coolers and other key thermal management components. In the rail transit air conditioning business segment, the company's main products are various types of rail vehicle air conditioning products, which currently cover models including 160km EMUs, subway vehicles, trams and conventional rail vehicles. In the refrigeration unit business segment, the company has created a "dual brand + four major product platforms" brand and product architecture, and its products cover non-independent fuel vehicle refrigeration units, new energy electric units, special refrigeration units, independent refrigeration units, etc. In the automotive air conditioning compressor business segment, the company's products include electric compressors suitable for large and medium-sized buses, new energy passenger cars/MPVs/heavy trucks/light trucks/pickup trucks, battery thermal management and other fields, as well as high-voltage platform electric compressors. In the battery thermal management business segment, the company has upgraded and iterated the development of commercial vehicle (heavy trucks, construction machinery, etc.) thermal management systems and liquid-cooled energy storage power station battery thermal management systems. We have newly developed and mass-produced several new thermal management products for energy storage power stations, including horizontal 3-6kw, vertical 50-70kw, etc.

3.2.1.1 Problem Analysis

During the operation of SZ Company, due to market changes, there are problems of inventory backlog and low production efficiency.

3.2.1.1.1 Inventory backlog

The factory's inventory is divided into raw material inventory and finished product inventory. Raw materials include various flat tube fins used to produce condensers and evaporators, as well as various shells, fans, wiring harnesses and other parts used to produce HVAC. Finished product inventory refers to materials that have not been sold to customers after production is completed, or materials that cannot be invoiced and settled after delivery to customers. Controlling factory inventory is to reduce inventory costs. Excessive inventory will increase costs, including warehouse storage, maintenance, personnel, etc. Excessive inventory may also lead to stagnant inventory due to the failure to use accessories in time, and raw materials are not used and cannot be put into production due to expiration. Excessive inventory will also increase transportation costs and reduce inventory capital turnover. If the factory implements the implementation of reducing inventory as much as possible without considering the delivery period, once the equipment is shut down or the supplier cannot deliver on time, the delivery period will not be able to meet the customer's car manufacturing needs. This will affect the customer's production rhythm and be fined, which will make the cost higher. Considering the impact of equipment and logistics, a moderate increase in inventory quantity was adopted. Since the appropriate number of materials cannot be determined, various engineering departments would rather prepare more materials than delay delivery in order to ensure the delivery of materials. Therefore, they try every means to order materials in advance, resulting in a continuous increase in the inventory of accessories. At the same time, the inventory quantity in 2023 has increased significantly compared to 2022. The specific quantities are shown in the table 1.

Table 1. Stock of 2023 & 2022

No.	Product Categories	2023 Stock Quantity (KPCS)	2022 Stock Quantity (KPCS)	Annual growth rate
1	Thermal Management Products For Large And Medium-Sized Buses	6.3	7.0	-10%
2	Independent Battery Thermal Management System	4.6	1.3	253%
3	Car Air Conditioning Condenser	784.0	948.5	-17%
4	Car Air Conditioning HVAC Assembly	438.8	304.2	44%
5	Rail Train Air Conditioning	0.23	0.08	196%

6	Refrigeration Unit	0.85	0.26	228%

Source: Annual Report for 2023 of SZ Company

The inventory of independent battery thermal management system products, car air conditioning HVAC assemblies, rail car air conditioning and refrigeration units are increase more than 44% over the previous year.

Through interviews with the warehousing and logistics department personnel of SZ Company, it was learned that the reasons for the inventory of SZ Company are as follows:

Inventory due to inaccurate forecasts

It takes about 1 month to place an order to prepare raw materials before product production. This order is based on the production forecast for the next month. Then when it comes to actual production, the expected output is often not achieved, which increases the inventory of materials. Some materials will be directly discontinued because there is no demand from customers. These materials are not universal, which will cause these materials to be stagnant, resulting in an increase in inventory.

Inventory is generated due to scheduling too early than demand

When preparing for production, the company will prepare for accidents, such as batch defective products, equipment failure, etc., which will lead to lower-than-expected production and ultimately lead to the inability to meet customer demand for car manufacturing and cause the customer to stop production. Therefore, in order to prevent the above problems from happening, a safety stock of about 3 days will be prepared in advance. All these finished products are formed into inventory. With the increase in product models, the total amount of inventory continues to increase.

Inventory is generated due to batch production

When producing condensers and evaporators, large-scale production has cost advantages over small-batch production, and management and scheduling are relatively simple. Therefore, when each batch is produced, as many materials of the same specifications as possible will be produced, and these extra materials will be placed in the finished product warehouse for inventory. As the number of customer orders in each batch decreases, the total amount of inventory continues to increase.

Inventory is generated due to different working hours

This is caused by uneven process capacity. For example, the evaporator welding is three shifts (considering that the line cannot be stopped), while the assembly operation is only one shift. In this way, a large number of semi-finished products will inevitably be squeezed before assembly, resulting in an increase in the inventory of semi-finished materials.

As the requirements of the real market for automotive air-conditioning products have gradually changed from the original: few varieties, large batches, and long delivery time to the current: many varieties, small batches, and short delivery time. This has led to an increasingly prominent inventory problem. The inventory amount continues to increase. If the factory's inventory management level is insufficient, it will cause a large amount of inventory backlog and sluggish waste. A production and manufacturing system full of inventory will cover up all the problems generated in the production and manufacturing system. For example, the waste of man-hours caused by equipment failure maintenance in the production process; the rework and scrapping of products caused by the low first-time qualified rate of products in the production process; and the generation of a large amount of semi-finished product inventory during the production process due to imperfect plans. These can be digested by using various inventories, so that the problems in the production system are covered up, and finally a false impression is created that the production system is still running smoothly without any problems, but in fact the entire production system has. What's more terrible is that in the long run, everyone will recognize and get used to the current state, and the various problems in the production system will no longer be a problem. Therefore, inventory is the culprit for unreasonable production system design, unbalanced production process, and production of defective products, and inventory problems need to be improved first.

3.2.1.1.2. Low production efficiency

The production process is too complicated, which affects production efficiency. At present, SZ's customer categories are clearly differentiated, such as large and medium-sized bus air conditioners and new energy bus battery thermal management system products, traditional/new energy vehicle thermal management systems, air conditioning boxes, front-end cooling module products for passenger cars, etc. The products of these customers extend to many categories and models, and customization is relatively common, which leads to a large number of line changes, stable quality, and fast production requirements for the production line. This is a typical "multi-variety, small batch, short delivery" manufacturing production model. Based on the layout restrictions of the existing production line, the rapid switching between products is severely restricted, and the rate of restoring the process balance of the production line after switching is slow, which is easy to cause accumulation waste and quality risks at different workstations.

Case description: Taking the part No.ALZWM46376 HVAC product as an example, the product has a total of 11 processes in the finished product assembly section, with a total process time of 616 seconds, and a total of 11 operating employees. The process bottleneck time of this product is 56 seconds. According to the Operator Balance Chart (OBC), the balance rate of this product is only 63%, and the actual production capacity is 38 units per hour. According to the basic requirements of the industry, the current process balance is still at a relatively low level. The differences between processes have created an imbalance in the processes, which has resulted in a large amount of time wasted waiting for operations. The example of OBC in the table 2.

Table 2. Operator Balance Chart

No.	Item	Value	Unit
1	Number of operators	11	Person
2	Maximum time of the single station	56	Second
3	The total time of the standard	616	Second
4	Total actual manpower time	386	Second
5	Pitch time	42	Second
6	Output per hour	38	Second
7	Standard labor time	0.171	Hour
8	Operators' balance rate	63%	%

Source: Monthly Meeting Presentation of SZ Company

Through interviews with the production department staff of SZ Company, we learned that there are some reasons for the low production efficiency of SZ Company.

Bottleneck process

Most products have obvious production bottlenecks, and the bottleneck process time accounts for a large proportion. The bottleneck process will limit the output speed of the entire production line, causing other processes to wait, resulting in time waste.

Low process balance rate

The operation time between each process is unevenly distributed. Some processes have too long operation time, while some processes are relatively idle, resulting in low overall production efficiency. For example, the operator balance table in the above example shows that the balance rate is only 63%, which is far below the ideal level.

Differences in skill levels:

There are differences in the skill levels of operating employees, which leads to uneven production efficiency. Employees with higher skill levels may be able to complete tasks faster, while employees with lower skill levels may need more time, which will also aggravate the imbalance between processes.

Improper production planning and scheduling

Irrational production planning or improper production scheduling leads to confusion and increased waiting time in the production process. Especially in small batch production, if the production plan does not fully consider the time difference and balance problems between processes, it may cause congestion in some processes while other processes are idle.

3.2.2 Company Profile of Mazak

Mazak Machine Tool is a world-renowned machine tool manufacturer in Yamazaki, Japan, founded in 1919. It mainly produces CNC lathes, composite turning and milling machining centers, vertical machining centers, horizontal machining centers, CNC laser systems, FMS flexible production systems, CAD/CAM systems, CNC devices and production support software. The products are well known in the industry for their high speed and high precision, and their products are used in various industries in the machinery industry. It has 11 production bases around the world, with more than 8,400 employees, and more than 80 support bases in 26 countries and regions, providing equipment, technology and service support for the development of manufacturing industries around the world.

3.2.2.1 ISMART Factory of Mazak

The smart factory built by Mazak is called iSMART Factory. Its goal is to create a highly digitalize manufacturing practice and a constantly evolving factory to create new value and provide products and services to customers. The planning of iSMART Factory is divided into five steps:

Build the underlying IoT security network and make it visible;

ISMART Factory uses IoT technology to digitize all production activities in the factory and realize communication and data collection between devices. Intelligent machining centers, loading and unloading robots, automated warehouses and other intelligent equipment realize communication between devices based on the MT Connect protocol, collect big data on equipment operation through IoT , and transmit manufacturing data to the upper-level MES system. These data make it possible to visualize the production process, and management can understand the operating status of the equipment and production progress in real time.

Use the analysis of big data in manufacturing to improve production;

Through the data collected by IoT, iSMART Factory is able to conduct big data analysis to identify bottlenecks and waste in the production process. These data provide scientific basis for production improvement. Based on data analysis results, adjust production plans, optimize production processes, and improve production efficiency and product quality.

System coordination and collaborative analysis and optimization;

Utilize ERP, MES and other systems to interconnect underlying equipment with upper-level operation and management systems to form a networked factory to realize real-time transmission and sharing of data, thereby supporting more efficient decision-making and collaboration. Through cooperation between systems, the production process is optimized and production lead time and inventory are reduced.

Adapt the experience and skills of skilled workers to AI and achieve high-level system cooperation.

Integrate the experience of senior technical workers into the manufacturing system through artificial intelligence technology to improve production efficiency and flexibility. Use AI technology to learn and simulate the operating experience and skills of skilled workers to optimize production processes and process parameters. At the same time, through the high degree of system cooperation, the work-in-progress time and semi-finished product inventory are reduced. Through the above measures, MAZAK has shortened the work-in-progress time by 30%, reduced the inventory of semi-finished products by 30%, and improved production efficiency and response speed.

Create a smart factory with self-learning, through the adaptability of AI, self-improvement and self-analysis.

Smart factories have self-learning capabilities and can continuously absorb new knowledge and experience to optimize production processes and decision-making models. Based on the results of self-learning, smart factories can automatically improve and optimize the production process to improve production efficiency and product quality. Through the adaptability of AI, smart factories can analyze production data in real time, predict potential problems and propose solutions.

The Diagram of iSMART Factory is shown in Figure 2.

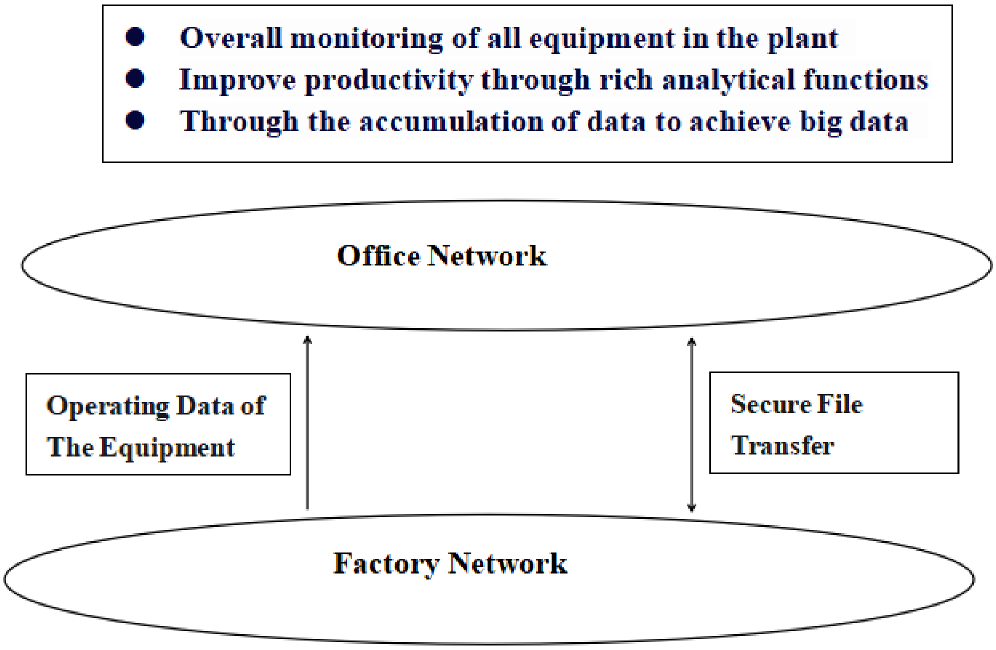

Figure 2. iSMART Factory Diagram
（Source: MAZAK iSMART Factory Profile）

3.2.2.2 Mazak Toyota Production System

Mazak has achieved the continuous improvement concept that is consistent with the Toyota Production System through a series of innovative measures and technical means in building the iSMART Factory. Mazak can carry out continuous improvement of the Toyota Production System from the following aspects:

Build an IoT security network to achieve visualization

Digitize all production activities in the factory through IoT technology, realize communication and data collection between equipment, and visualize the production process. Management can understand the operating status and production progress of the equipment in real time, which is consistent with the visual management emphasized in the Toyota Production System and helps to quickly identify problems and improvement points.

Big data analysis of data collected by IoT

Mazak uses big data analysis of data collected by IoT to identify bottlenecks and waste in the production process. This data based decision-making method makes production improvement more scientific and well founded. Continuous improvement in the Toyota Production System also emphasizes finding problems and continuous improvement through data analysis. Continuously improve work processes and adapt to changes to reduce costs and improve product quality. Encourage employees to make improvement suggestions and achieve continuous improvement through the PDCA cycle.

Interconnect underlying equipment with upper-level operation management systems

Mazak uses ERP, MES and other systems to interconnect underlying equipment with upper-level operation management systems to form a networked factory to support more efficient decision-making and collaboration. This kind of coordination and collaboration between systems helps to optimize the production process, reduce production lead time and inventory, which is consistent with the process optimization and waste reduction emphasized in the Toyota Production System.

Integrates the experience of senior technical workers into the manufacturing system

Mazak integrates the experience of senior technical workers into the manufacturing system through artificial intelligence technology to improve production efficiency and flexibility. This is similar to the employee participation and standardized work emphasized in the Toyota Production System, which optimizes the production process and process parameters through the experience and skills of employees, and standardizes these optimization results for promotion throughout the factory.

Optimize production processes and decision-making models

Mazak's smart factory has the ability to self-learn, can continuously absorb new knowledge and experience, and optimize production processes and decision-making models. This ability to self-learn and self-improve echoes the continuous improvement culture emphasized in the Toyota Production System, that is, to regard the improvement of products and processes as a never-ending process of continuous small progress.

4. Results and Discussion

The root cause of SZ's inventory problem lies in multiple aspects: first, inaccurate market demand forecasts and premature production scheduling lead to inventory backlogs; second, the pursuit of cost-effective batch production mode increases finished product inventory; third, the difference in working time between processes and uneven production capacity are also important factors in the increase of inventory. The conflict between the rapid changes in market demand and the old production model has made the inventory problem increasingly serious, which not only occupies funds, but also conceals many problems in the production system.

The main reasons for SZ's low production efficiency are as following. The existence of bottleneck processes limits the number of overall product outputs. The uneven distribution of working time between processes leads to a low production balance rate. There are differences in employee skill levels, which affects the balance of production efficiency. Finally, unreasonable production planning and scheduling, which fails to effectively manage the complexity of small-batch production and the time differences between processes, resulting in increased confusion and waiting time in the production process.

Through the iSMART Factory project, Mazak integrates advanced technologies such as IoT, big data, and AI to build a digital and intelligent production system. iSMART Factory realizes visualization of the production process, data-driven decision optimization, seamless collaboration between systems, and intelligent inheritance of skilled workers' experience. Ultimately, a smart factory that can learn and improve itself is created. These fully implement the concept of continuous improvement in Toyota's production method, continuously promote the reduction of product inventory, and improve production efficiency, product quality, and customer satisfaction.

In response to the inventory problems and low production efficiency challenges faced by SZ Company, the advanced technologies and concepts in Mazak iSMART Factory are used for continuous improvement, which can be measured from the following aspects:

Optimize market demand forecasting and production planning

By collecting multi-source information such as historical sales data, market trends, and customer feedback, use big data analysis and AI algorithms to improve the accuracy of market demand forecasting. Combined with the forecast results, dynamically adjust the production plan to avoid inventory backlogs caused by premature or excessive production. Establish a flexible production scheduling system that can quickly respond to changes in market demand, adjust production priorities and batch sizes, and reduce unnecessary inventory.

Improve batch production mode

Introduce lean production principles such as "just-in-time production" (JIT) and "single-piece flow" to reduce batch sizes and shorten production cycles, thereby reducing finished product inventory. Using iSMART Factory's intelligent scheduling system; automatically optimize production sequences and

batches based on real-time production capacity, material supply, and order requirements to improve production efficiency and flexibility.
Solve time differences and uneven production capacity between processes
Use IoT technology to monitor the working status and efficiency of each process in real time, use data analysis tools to identify bottleneck processes and overcapacity links, and optimize and balance processes. According to real-time data, dynamically adjust human resources and equipment configuration to ensure balanced working time between processes, reduce waiting time and production waste.
Improve employee skills and production efficiency
Combined with the experience data of skilled workers accumulated in iSMART Factory, develop an intelligent training system to help employees quickly improve their skills, achieve skill inheritance and standardized operation. Establish a data based performance management system to encourage employees to continuously improve and innovate, and set up a reasonable incentive mechanism to improve employee enthusiasm and production efficiency.
Realize visualization and continuous improvement of the production process
Through the visualization platform of iSMART Factory, real-time monitoring of production progress, quality data and equipment status ensures transparency and traceability of the production process. Using big data analysis technology, explore potential problems in the production process, and continuously optimize production processes and management models through the PDCA cycle (Peças, et al., 2021). Provide data-driven decision support to achieve continuous improvement. Learn from the continuous improvement concept of Toyota Production System, encourage all employees to participate, form a cultural atmosphere of continuous improvement, and constantly pursue excellence.

5. Conclusion and Implications

This study deeply analyzes the root causes of inventory backlog and low production efficiency of SZ Company, and points out key factors such as inaccurate market demand forecasting, limitations of batch production mode, and time differences and uneven production capacity between processes. These problems not only cause capital occupation and waste of resources, but also seriously restrict the market competitiveness of enterprises. Through the investigation of Mazak iSMART Factory project, we found that it successfully built an intelligent production system by integrating cutting-edge technologies such as IoT , big data, and AI, achieved precise control and continuous optimization of the production process, effectively solved the problems of high inventory and low production efficiency, and provided SZ company with a feasible transformation path.
Looking to the future, SZ company should actively adopt the advanced technology and concepts of Mazak iSMART Factory, and implement a comprehensive and systematic improvement strategy from multiple dimensions such as market demand forecasting, production plan adjustment, batch production mode optimization, process balance adjustment, employee skill improvement and production process visualization. By accurately predicting market demand, flexibly adjusting production plans, reducing inventory backlogs. Introducing lean production principles, shortening production cycles, and improving production flexibility. Using Internet of Things technology to monitor process status in real time and achieve optimal resource allocation. Combining intelligent training systems to improve employee skills and build efficient teams. Realizing full transparent management of the production process through a visualization platform, providing solid data support for decision-making. The implementation of this series of measures will help SZ Company significantly improve production efficiency, reduce operating costs, enhance market competitiveness, and ultimately achieve sustainable development and transformation and upgrading.

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