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Automatic Equipment Design of Intelligent Manufacturing Flexible Production Line Based on Industrial Motorized Spindle

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ABSTRACT

Based on the previous research on the production line automation, this paper carries out further research and further design and development on the basis of the original production line automation equipment. In this paper, the overall design of the automatic production line is carried out, and the various systems in the automatic production line are optimized, and the backward instruments are eliminated, and then some more advanced and convenient instruments are applied. Then, the hardware and software of the automatic production line are studied respectively, and the human-computer interaction module and real-time main control circuit module are redeveloped, and the electric shaft is applied to the automatic production line. Finally, the fuzzy PID controller of the stepping motor is designed. The experiment shows that the fuzzy PID control scheme is better than the traditional PID control scheme. After the rationalization of the system, the quality robustness of proactive planning is improved. Then, the temperature of motorized spindle was tested.

KEYWORDS

Intelligent Manufacturing, Motorized Spindle, Production Line Automation

1. INTRODUCTION

In the United States, Japan and Germany and other developed countries, their manufacturing industry has an absolute advantage in the global structure, such as the Demag Group and the Mazak Group (Grubljesic et al., 2019). Their five-axis equipment is very popular in our country. At present, these developed countries regard machine tool transformation as a new gold industry to promote economic growth, which is a force that cannot be ignored to promote GPD bed transformation in the rapid development period. Due to the rapid development of machine tool manufacturing technology, a large number of high-tech machine tool manufacturing, machine tools are constantly updated, machine tools have become a problem that needs continuous innovation, research and solution, with the rise and fall of the machinery industry, continuous development (Ahmed & Shusen, 2019; Meziane & Taghezout, 2018). After self-transformation, CNC machine tools and production lines can be improved and market demand is high and is gradually forming a new industry. In the United States, the famous recycling companies include Belcher Engineering, Debao Service Group, the American equipment company, etc. US oil depot company established a company in China to carry out business development related to machine tool transformation (Li, Cao, Yang et al, 2018). Germany's machine tool transformation has also made gratifying achievements. More and more enterprises see this big cake and want to share it. In Germany, there are personal workshops and machinery manufacturing enterprises engaged in machine tool transformation. On the other hand, in order to fully transform

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scientific research strength into productivity, some universities and scientific research institutions also participate in this work (Zhang, Li, Wu et al, 2018). These efforts have received strong policy and economic support from the government, as well as special assistance from the federal and state governments. The quality and efficiency of old machine tools has improved significantly since the transformation, such as the regeneration of Nirvana, which can meet all types of production needs; and the price is very attractive. In addition, the second-hand machine tool sales service is also very perfect.

Sixty years ago, manipulators were first developed and manufactured in the United States (Kono et al., 2019). It is mainly used in various fields of automatic production, and its ultimate goal is to achieve driverless production. Industrial robot is a typical robot (Jiang et al., 2017). It can be used in all kinds of occasions, with powerful functions, and can meet the requirements of people's intelligence and adaptability. Because the manipulator has many advantages, there are two outstanding advantages. One is the accuracy and accuracy of the work. The second is efficiency. The second is the ability to finish the work. In recent years, the automation industry has sprung up like mushrooms, and the development of manipulator has been greatly improved. The application of the operator may improve the working conditions of workers involved in engineering and construction, solve the problem of the shortage of jobs in countries with a small population and can be used to build smart, unmanned laboratories (Hamidi & Jahanshahifard, 2018). There are four types of manipulator drive: hydraulic drive, pneumatic drive, electrical drive and mechanical drive (Golovin et al., 2018). Hydraulic transmission a heavy manipulator used to drive a large head. It can not only realize linear motion through hydraulic cylinder, motor and gear rack, but also rotate through rotary cylinder, motor, reducer and gear. Pneumatic transmission components include pneumatic cylinder, piston, air compressor, etc. Its advantages are easy access to air, good maintenance and low price. The disadvantage is small clamping force and large volume. At present, electric drive has not been widely used (Zhang, Wang, & Zhang, 2018). The advantages of electric drive: simple power supply, convenient maintenance, large clamping force, suitable for heavy manipulator. Mechanical transmission is mainly used in some special occasions, belonging to the category of special aircraft. Mechanical transmission generally uses a cam connection mechanism, through this mechanical structure, to perform the planned action. Mechanical transmission has many advantages, in particular: stable, safe and reliable, fast speed of action, low price, high cost efficiency, the disadvantage is not easy to adapt and adapt.

There are many choices in the core controller. Such as single chip microcomputer, industrial computer, HLC and so on (Zheng et al., 2018). In recent years, computer control system has produced new ideas. In addition, with the optimization of control algorithm, many new direction control hardware, such as motion control card and logic controller, have appeared (Lakshmanaprabu et al., 2019). The single-chip microcomputer control manipulator is mainly used in the situation of not too high requirements, generally requires communication power supply module. There are still many deficiencies, mainly in the development and design workload, poor load output capacity, poor stability and so on. Its advantages are strong environmental adaptability and low cost. PLC control manipulator can achieve complex control according to the design needs, can meet most of the control needs, and has been widely used (Liu et al., 2018). PLC control has many advantages, which can be summarised as follows: the workload of software and material development is small and the construction of the control system can be completed without spending too much energy in the development process (Naeem, 2021). It has the characteristics of strong output load capacity, safety, stability, reliability, simple maintenance, convenient adjustment and use, strong adaptability to the environment. The disadvantage is that the hardware cost is relatively high. Industrial control computer can be used for manipulator control, with rich functions, strong practicability and excellent performance. Industrial control computer has the advantages of high speed, strong environmental adaptability and high reliability. The disadvantages are heavy workload and high cost.

The development of PID controller has experienced 70 years. It has the advantages of stable and reliable operation, convenient parameter adjustment, simple system combination and good stability. At present, PID control has become one of the indispensable main technologies in industrial production

practice control (Tian et al., 2018). After decades of continuous innovation, PID control technology has completed its own butterfly transformation, forming a large number of improved algorithms (Singh et al., 2019). PID algorithm is the most widely used algorithm in the production process. The algorithm is simple, easy to understand, less adjustment parameters and convenient control. Various improved algorithms can be derived. Especially in the industrial process control, sometimes the situation is complex and complex, it is difficult to find out the temper of the control object, it is difficult to get the mathematical model accurately, which leads to the difficulty to determine the system parameters. The traditional control theory cannot achieve the desired effect. Fuzzy control and traditional control learn from each other, seek advantages and avoid disadvantages, forming this excellent algorithm (Agarwal et al., 2018). Fuzzy control depends on the experience accumulated by experts and engineers who have participated in the control process for a long time. These control experiences are written into the rules (Biswas et al., 2018). When encountering similar control situation, we can refer to the realization to achieve the desired control effect.

This paper puts forward the idea of applying industrial motorized spindle to automatic production line and carries out experiments on it. Based on the traditional automated production line, the paper redesigns, retains the essence of the original automated production line, and changes the backward part into the latest technology. And the segment of the automation material improves, the traditional PID changes to unclear PID and finally the industrial axle drive is added to the automatic production line. Finally, the experimental part compares the traditional PID and fuzzy PID and finds that the opaque PID control system is better than the conventional PID control. Then, the influence of different configuration parameters on proactive scheduling is tested and the temperature of motorized spindle is measured and recorded. Finally, the automatic production line with motorized spindle is compared with the traditional automatic production line. The experimental results show that the production efficiency of the automatic production line with industrial motorized spindle has been greatly improved, and the product qualification rate has also been greatly improved.

2. OVERALL SCHEME DESIGN OF AUTOMATIC PRODUCTION LINE

2.1 Automatic Stacking Welding System

There are two ways to automatically stack code (Zhang & Yu, 2018). One is to use the suction head to adsorb the copper strip one by one until it meets the process requirements. This stacking method needs to match a specific product type slot. When the suction head absorbs the copper rod, the initial position of the copper rod shall be kept accurate and the error shall be within the required range.This method has a wide range of applications. It can stack products of different shapes and quantities. However, the accuracy of groove size is required to be higher. A slot needs more time at a time, and the workpiece has more layers. Such as copper bar automatic stacking mechanism limits the stacking of slots and pneumatic components. The stowage mechanism shall be located in the compartment of the evacuation door. The copper cutting rod fell to the limit of gravity. When the number of copper strips reaches a group, the right-angle shackle connected with the pneumatic push rod is pushed from outside to inside until the loose die copper strip is folded along the length and width.

When the pin foil is welded, the positioning accuracy is very high. The copper foil must be sent to a specific position and welded at an angle. Therefore, the six-axis manipulator is selected to transport copper foil, which reduces the position error and meets the requirements of transporting copper box to any position. Copper foil is easy to deform due to gravity during transportation. In order to make the copper foil orderly, the mechanical gripper at both ends of the copper foil should be clamped and fixed, and a gap should be opened at one side of the limit groove. After the copper rods are stacked, the manipulator clamps the copper sheets at both ends of the gap to prevent the copper rods from being clamped by gravity. When the copper rods are stacked orderly by the pneumatic push rod, the manipulator extends through the slot surface opening of the mold to clamp and fix the copper rod.

2.2 Automatic Stamping System

Stamping forming is a flexible connection forming process for copper bars adapted to different working environments (Li, Yang, Chen et al, 2018). The sheared waste is collected in the waste collection box under the punch. The control system of stamping machine consists of two parts: logic control and motion control, which can be integrated into one controller (Lakshmanaprabu et al., 2019). Logic control and motion control can be divided into two kinds of controllers. The transmission structure adopts synchronous belt or screw driven by the same motor. There are two types: manual and automatic. Manual loading and unloading performance is high, there are hidden risks in the operation process. With the continuous improvement of electrical control technology, stamping automation technology has also been rapid development. At present, the master-slave control and rapid feed mechanism of synchronous press are used to greatly improve the production efficiency. In stamping automation equipment, multi axis motion control servo technology is widely used because of its high control performance and fast dynamic response.

2.3 Automatic Bending System

The bending mechanism can be divided into single stroke bending mechanism and multi-stroke bending mechanism (Ji et al., 2018). The typical structure of the single stroke bending mechanism is that the upper die is a V-shaped pressing block and the lower die is a V-shaped groove structure. The workpiece is bent to the required structure through the lower die through the first feeding of the pressing block. The multi stroke bending mechanism is suitable for workpieces with complicated structure. The bending process of workpiece is completed by batch stamping step by step, which has a wide range of applications.

Bending of plate-shaped workpiece refers to the processing of changing the angle of plate or plate. For example, bending plates into V-shaped, UU-shaped, etc., the commonly used bending machine can be divided into two types according to the structure: one is die bending, which is suitable for plate-shaped workpieces with complex structure, small volume and large-scale processing; the other is bending machine bending, which is used to process large-scale structures or small products. The size of the copper bar flexible connection workpiece studied in this project is 160 * 30 * 2mm, the bending mechanism is concave, the shape is simple, and the market demand is large, so single stroke die is selected for bending. After the stamping process of copper bar soft connection is completed, the suction type six axis manipulator will absorb the soft connection from the stamping groove and transfer it to the lower die of the bending machine. If the copper bar is directly placed in the module and the bending die is bent to perform this action, the vibration operation in the medium may change the position of the flexible connection, resulting in the bending part not meeting the required standard. Therefore, it is necessary to place positioning device on the module to make the position of copper rod flexible connection change little (Tan & Gligor, 2019).

2.4 Automatic Casing System

The soft connection of power battery copper rod is made of multi-layer anti corona flat thin copper conductor, and the outer layer is made of extruded insulation layer. Soft connection has the characteristics of low impedance, anti-interference, good reliability, space saving, simple and fast assembly (Lee et al., 2015). As a high-power modular connection structure component, external soft connection needs a layer of heat insulation heat shrinkable pipe to ensure the safety of personnel during installation and prevent the corrosion of acid, alkali, salt and other chemicals on the bus. The automatic production line of copper rod flexible connection casing process needs to use intelligent manipulator instead of manual operation as casing executive part to realize grasping, moving, precise positioning and casing execution of copper rod and plastic pipe.

There is a relative displacement between the plastic tube and the copper rod during the treatment of the copper bar lining. In order to carry out the automation of this process, two operators are needed

to complete the treatment of the housing. One manipulator is used to fix and move the plastic pipe, and the other is used to position and move the copper rod. When the plastic pipe passes through the copper rod, the movement track of the plastic pipe is a straight line, which can be operated by a three-dimensional manipulator. The copper rod can be fixed and moved easily by using three-dimensional manipulator. Domestic manipulator mainly focuses on manipulator control cutting, mainly driven by electric and hydraulic. Manipulator is an indispensable part of the automatic production line of copper sleeve flexible connection technology.

3. HARDWARE DESIGN OF AUTOMATIC PRODUCTION LINE

3.1 Human Computer Interaction Module Circuit Design

The human-computer interaction module mainly realizes the communication between human and computer, including hardware platform, operating system and application software (Devi & Easwarakumar, 2017). In order to make the human-computer interaction module more applicable, which is used as the hardware platform of the human-computer interaction module. The whole human-computer interaction module is divided into two parts, one is the core board part, which mainly includes CPU, memory and power supply, and leads out the pins on the CPU; the other part is the peripheral circuit part, which can be added to the required module as required:

1. **Core board circuit:** The core function module of small PC is packaged on small-sized ECB board. The core board can be used not only as an embedded processing board, but also with other application processing boards, which is convenient for scientific research and development. Compared with other core boards, the core board also has cost advantages.
2. **Peripheral module circuit:** Peripheral module circuit mainly includes LCD module circuit, USB interface, Ethernet interface, SD card interface and can and RS485 communication interface circuit. The selected LCD part mainly displays the current status and parameters of the whole device (Kitouni et al., 2018), USB interface realizes data replication and program upgrade, and RS485 interface communicates with man-machine module and real-time main control module.
3. **LCD module circuit:** Human computer interaction module LCD screen has the characteristics of ultra-thin, light weight, small size, low power consumption. LCD module has signal transmission circuit, backlight circuit and power supply circuit. Considering that the LCD module used in industrial control field needs to improve the anti-interference ability, the signal transmission adopts differential line transmission. This transmission mode takes advantage of the advantages of differential signal, avoids the interference in the transmission process, makes the signal received by LCD more complete and the display screen more stable.

3.2 Design of Real Time Main Control Circuit Module

The core of hardware architecture of real-time main control module is cortex m3. 144 pin, 120m main frequency and internal integrated floating-point operation unit, which can quickly process corresponding algorithms and a large number of real-time data calculation tasks. The real-time main control module also includes servo motor module, which is used to control the rotation of stereo library; the switch signal detection module receives external signals, such as buttons, sensors and alarm signals (Parada et al., 2018); RS485 bus communication module is used for man-machine data transmission; CAN bus module is used for data communication with actuator module; The power supply module provides power for all functions of the real-time main control module to ensure normal operation; the reset circuit can reset the MCU; the debugging interface can be used for program recording and online debugging:

1. **Servo motor differential hardware circuit design:** The real-time main control module uses PWM module to generate pulse to adjust the speed and position of servo motor. In order to reduce the interference of external signal (Wei & Ho, 2019), the pulse signal of servo motor adopts differential control signal. These pulses are electrically isolated by high-speed optocouplers. The single ended signal PG generated by the differential chip am26ls31cd is converted into the signal P +, P - to control the speed of the servo motor ‘.
2. **Can communication hardware module design:** The main control module and the actuator module communicate in real time through CAN bus (Al-Momani et al., 2018). The transmission speed is usually 500K baud rate. Each frame of data has CRC check and other frame error measures to reduce the error probability and improve the stability of communication. Differential circuit enhances the anti-interference ability of the system, has priority and arbitration ability, and greatly ensures the correctness of data communication.
3. **Switch detection module design:** The number of switches mainly includes start, stop, sensor and alarm. When the start switch is pressed or a simple yarn is detected by the sensor, the input is at low level, the lamp in OPL is on, and the diode in OPR is on. At this time, the opot end is also at a low level. Through this state, the corresponding judgment can be made. The optical coupler is used to judge the single chip microcomputer, the single chip microcomputer, and the sensor is isolated to avoid the damage of the large current outside the system to the single chip microcomputer.

3.3 Application of Motorized Spindle

1. **Works flow of motorized spindle:** The fixed spindle stator and high-speed rotating spindle rotor constitute the electric energy rotating mechanism of the motorized spindle. The stator of the main shaft converts the potential energy provided by the outside into electromagnetic energy and drives the rotor to move. When the rotor cuts off the magnetic induction line, the electromagnetic energy is converted into kinetic energy to drive the spindle rotor to rotate. The air gap distance between stator and rotor is very important. After activation of the stator, the vacuum air provides an electromagnetic connection between the rotor and the stator to ensure the final power output. The distance of air gap determines the performance of motorized spindle. The mechanical efficiency of motorized spindle mainly depends on the bearing. The synchronous speed n of an asynchronous motor is related to the number of poles P. the speed is changed by changing the frequency of the current flowing into the spindle. At the same time, the angle encoder inside the spindle and the driving control equipment form a closed-loop structure. By changing the output frequency of the output driver, the electrodeless speed regulation function of the motorized spindle can be realized. The direction of the alternating magnetic field is controlled by changing the phase sequence of the current entering the stator of the spindle, so as to control the rotation direction of the spindle. In the whole working process, the traditional PID is replaced by fuzzy PID, and a series of experiments are carried out.
2. **Temperature characteristic quantity of motorized spindle:** When the motorized spindle is running, due to the electromagnetic loss of the motor winding and the friction of the bearing, a lot of heat will be generated, which will lead to the temperature rise of the motorized spindle, and then affect the accuracy of the bearing. Therefore, the temperature rise balance temperature of motorized spindle are important performance indexes of motorized spindle. In addition, during the operation of motorized spindle, its heat production and processing conditions will also change, such as load, speed, etc. The motorized spindle with different heat conduction and surface heat dissipation elements is a multi-factor coupled temperature field. The temperature rise of the spindle is generally defined as the temperature change in the temperature sensitive area of the motorized spindle when the external temperature is less than the spindle temperature.

In practical engineering applications, the outer ring of the front bearing of the motorized spindle is usually taken as the typical temperature rise measurement area.

Generally speaking, the main shaft sound power does not represent the objective sound power, including the spindle sound power.

Sound power represents the energy generated by sound in unit time. The specific calculation method is as follows:

$$W = \int_{s} I \cdot dS \tag{1}$$

where s is the curved surface area of sound propagation, I sound intensity, and W is the sound power.

The sound intensity (I) represents the energy contained in the sound, in w / m2. The calculation formula is as follows:

$$I = \frac{P^2}{\rho c} \tag{2}$$

where C is the sound velocity, P is the effective sound pressure, and P is the density of the propagation medium.

3.4 Design of Fuzzy PID Controller for Stepping Motor

Fuzzy rules are mainly composed of fuzzy linguistic variables, membership functions of linguistic variables and the establishment of rules:

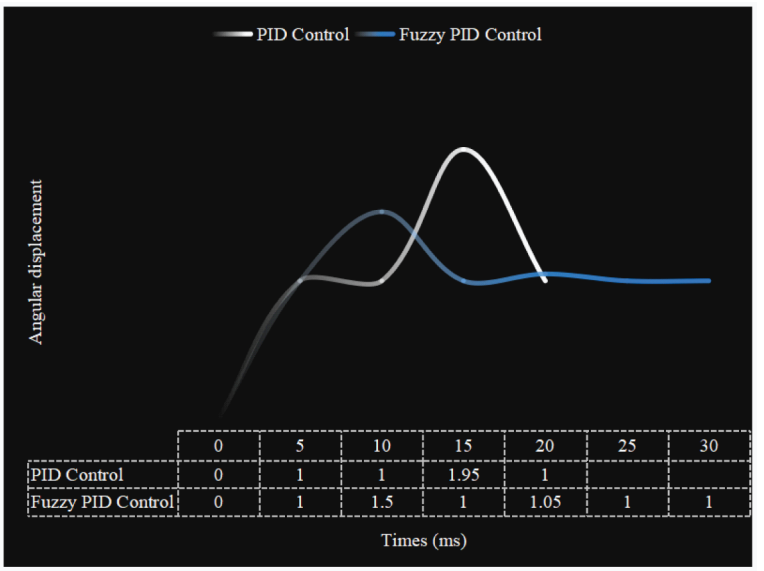
1. In the design of fuzzy PID controller, deviation E and deviation rate EC are used as input and motor control pulse as output. K_R, K_D, K_I are the output of fuzzy controller. A stepper motor control system with position feedback is constructed. A photoelectric encoder is added to the stepper motor. The actual measured value $C\left(T\right)$ of the controller adopts the pulse number collected by the photoelectric encoder.
2. According to the need of control, the domain of each input and output variable is defined as E, EC domain: $\left\{-3,-2,-1,0,1,2,3\right\}$, ΔKP, ΔKI, ΔKD, domain: $\left\{-3,-2,-1,0,1,2,3\right\}$. A PI parameter setting algorithm based on fuzzy comprehensive reasoning is used. Let the AAA sampling time be $K_P\left(k\right) = K_{PO} + \Delta K_P\left(k\right)$.
3. Some membership functions are linear some are nonlinear. The representative linear membership functions include trigonometric function and trapezoidal function, while the representative nonlinear membership functions include Gaussian function, normal function and Cauchy function. Whether the membership function is linear or not can be ignored. The maximum membership degree of the intersection of adjacent fuzzy subsets plays a key role in the control effect, that is, the size of its inner product is the key to the control effect. According to the common membership function form in fuzzy control theory, the variables E, EC, K_R, K_D and K_I are determined.

4. RESULTS AND DISCUSSION

4.1 Traditional PID and Fuzzy PID

Shown as Figure 1, the fuzzy PID control scheme has the advantages of fast step response, fast angular displacement, small overshoot and no steady-state error. The control accuracy of Diagonal displacement reflects the control accuracy of stepping motor. This shows that the control scheme can make the closed-loop system with displacement feedback have the characteristics of high adjustment accuracy, fast response speed and negligible overshoot. Compared with the traditional PID control, there are oscillation error and steady-state error. The fuzzy PID control scheme is better than the conventional PID control scheme.

Figure 1. Traditional PID and Fuzzy PID Control of Stepping Motor Control Simulation Curve



	0	5	10	15	20	25	30
PID Control	0	1	1	1.95	1		
Fuzzy PID Control	0	1	1.5	1	1.05	1	1

4.2 Influence of Different Configuration Parameters on Proactive Scheduling

Show as Figure 2, the robustness of the solution is improved by 8%, 2.5%, 1,95% respectively, and the quality robustness is improved by 6.7%, 10.99% and 35% respectively compared with the assembly scheme with deterministic problems. At the same time, with the increase of resource preparation time, the total number of customer trips and buffer time of active planning decrease. This is because under the same deadline, under the premise of quality robustness, the resource preparation time is larger, and the buffer time of active planning allocation is smaller, which makes the improvement of robustness index less. In the same way, with the increase of resource preparation time, the total travel time between customers in the activity planning group is reduced, and the uncertainty interference is reasonably prevented. The work arrangement of the assembly group is to ensure stability, and the activity plan and quality are improved, and the robustness is more obvious.

4.3 Electric Spindle Temperature Measurement Test

Shown as Table 1, it shows the change of velocity with time.

Figure 2. Change ΔD Improvement Trend of Robustness Index

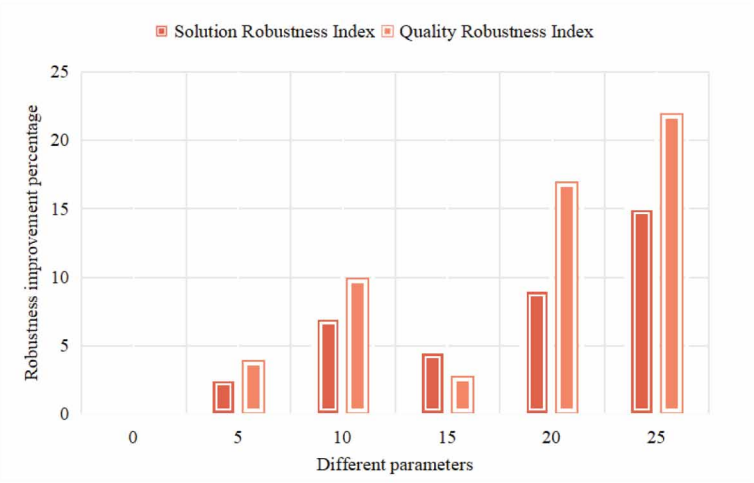
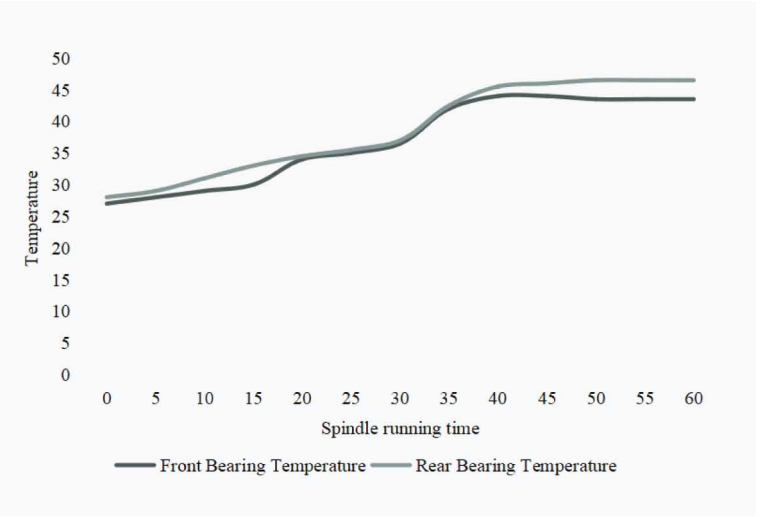


Table 1. Speed times table

Time/min	Speed/(r/min)	Time/min	Speed/(r/min)
0	2050	21	10050
9	2050	24	15050
12	4050	27	20050
15	6050	.....	.....
18	8050	60	20050

Show as Figure 3, the initial temperature of motorized spindle is about 26.5 °C. In the clean preheating stage, the temperature increases evenly, and the motorized spindle runs at 205 / min. After that, in the protection acceleration phase, the motorized spindle increases 205 or 8-20 minutes every 3 minutes / min, which is consistent with the spindle temperature fluctuation from 2 O5 or / min to 1005 or / min. In the 20-26 min fast acceleration stage, the shaft speed increases to 505 years or every 3 minutes / min. when the speed changes, the spindle temperature rises rapidly from ioo5 or 2005 / min / min. The balancing time of the hot front bearing motorized spindle is about 39 minutes, the average equilibrium temperature is 44.5 °C, and the thermal balance time of the rear bearing is about 44 minutes. The average equilibrium temperature is about 47.5 °C, and the spindle is in good condition within this temperature range. The test platform is used to measure the bearing temperature of motorized spindle. The measurement results can reflect the temperature trend of the spindle stably and accurately. Temperature sampling channel and sampling frequency can be selected for testing. The sampling data can be displayed in real time in the software. After sampling, the temperature can be saved and recorded. The temperature acquisition accuracy can reach 0.01 °C and meet the design requirements.

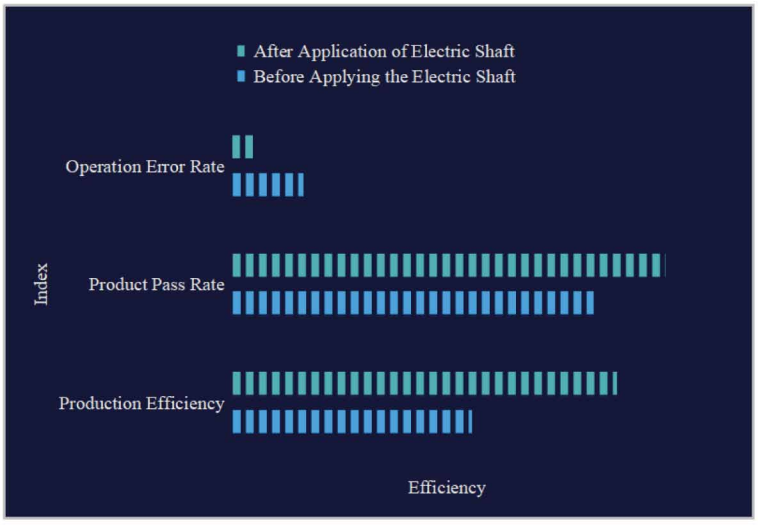
Figure 3. Temperature rise curve of motorized spindle bearing



4.4 Effect Comparison Before and After Application of Electric Shaft

Shown as Figure 4, after using motorized spindle, the error rate of the production line is greatly reduced, the product qualification rate is significantly improved, and the production efficiency is also greatly improved. Therefore, the application of electric shaft has an important impact on the development of automatic production line.

Figure 4. After Comparing the Performance of the Production Line before the Application of Electric shaft



5. CONCLUSION

With the departure of German industry, made in China was born in 2005. In the early stage of the development of China's manufacturing industry, there are problems of low level of industrial automation and insufficient productivity. The traditional production line is mainly manual, which greatly reduces the production efficiency. Therefore, the development of an automated and digitally integrated production line is of great importance for improving product efficiency and overall production efficiency. In order to ensure the sustainable development of the Chinese industry, the Chinese industry is actively responding to the call of the state and upgrading traditional automation of the production line.

With the continuous progress and high-speed development of electric drive technology, the motorized spindle which can realize zero drive emerges as the times require. Due to the structural characteristics of motorized spindle, the speed of spindle has a qualitative leap. The birth of motorized spindle has a great influence on the machining ability of CNC machine tools, especially aluminum alloy machine tools. This paper designs the overall scheme of the automatic production line and optimizes each system in the automatic production line. Then the automation and software of the production line are applied to the production line. Firstly, the traditional PID and fuzzy PID are compared. The fuzzy PID control scheme has the advantages of fast step response, fast angular displacement, small overshoot and no steady-state error. Compared with the traditional PID control, there are oscillation error and steady-state error. The fuzzy PID control scheme is better than the conventional PID control scheme. The bearing temperature of motorized spindle is measured by the test platform. The measurement results can reflect the temperature trend of the spindle stably and accurately.

Temperature sampling channel and sampling frequency can be selected for testing. The sampling data can be displayed in real time in the software. It can be saved and recorded after sampling. The temperature acquisition accuracy can reach 0.1 °C and meet the design requirements. Compared with the assembly planning under deterministic problems, the proposed active planning can reasonably prevent uncertain interference, ensure the stability of assembly team works arrangement, and significantly improve the quality robustness of active planning. Through the investigation, it can be seen that the error rate of the production line after using the electric shaft is greatly reduced, the product qualification rate is greatly improved, and the production efficiency is also greatly improved. Therefore, the application of electric shaft has an important impact on the development of automatic production line. This experiment redesigns the hardware and software system of the automatic production line, improves the automation degree of the automatic production line, reduces the labor degree of the workers, effectively improves the production efficiency and product quality, and has important practical significance for promoting the automatic production line.

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