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Research Article

The Review of the Welding Robot's Precision

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Abstract: Welding is an significant link in industrial production, and it is known as the "industrial tailor". However, welding fume, arc light, and metal spatter cause a harsh welding working environment, and the quality of welding has a decisive influence on product quality. Low production capacity, difficult recruitment, and low profits have become drawbacks for the development of the welding field. Combining traditional welding with robots can solve these drawbacks and increase the precision of welding. Welding robots are industrial robots engaged in welding and are mostly used in large-scale manufacturing fields such as automobile manufacturing. Welding robots are divided into spot welding robots, arc welding robots and laser welding robots. In addition, body accuracy and control accuracy are the two main factors that affect the robot welding accuracy. In this case, the sensing technology of welding robot is also essential.

Keywords: Accuracy; Welding; The structure of the welding robot; Sensor

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1 Introduction

1.1 Welding robot

The welding robot, as shown in Figure 1, is defined as a usage of mechanized programmable tools, which completely automate a welding process by both performing the weld and handling the part. The principle of the welding robot is to adjust the voltage, the current, and the gases to melt the solder wire in a constrained temperature. Welding robots can integrate the control system, the sensor detection system, and the mechanical system, as shown in Figure 2.

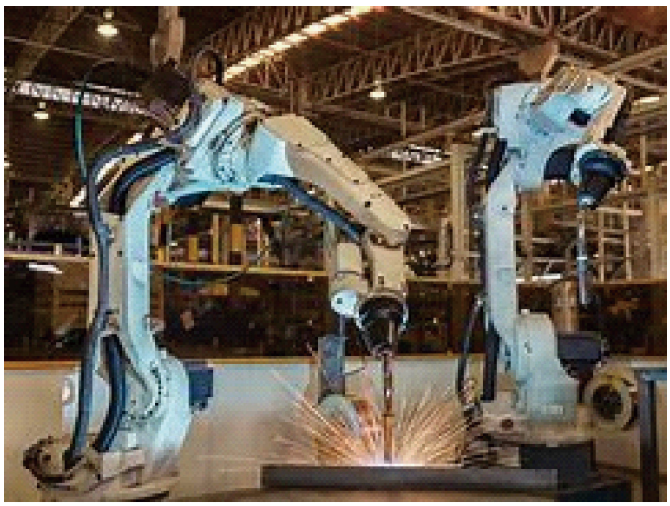

Figure 1. Welding robot

Among them, the control system is a significant part of the welding robot, including memory function, teaching function, connection with peripheral equipment, man-machine interface, sensor interface, position servo function, fault diagnosis and safety protection function. In addition, the control system also has hardware components, control computer, teaching box, operation panel, digital and analog input and output, printer interface, sensor interface, axis controller, auxiliary equipment control and communication interface.

Traditional robot sensors include position sensors, speed sensors, acceleration sensors and other sensors. In addition to these, the welding robot also uses laser sensors, vision sensors and force sensors, and realizes automatic tracking of welds and automatic positioning of objects on automated production lines and precision Assembling operations to improve the robot's operational performance and adaptability to the environment.

The welding robot's mechanical system are basically joint robots, and most of them have 6 axes. The 1st, 2nd, and 3rd axes can send the end tool to different spatial positions, while the 4, 5, and 6 axes solve the different requirements of the tool posture. The mechanical structure of the welding robot body mainly has two forms: one is a parallelogram structure, and the other is a side-mounted (pendulum) structure. The main advantage of the side-mounted structure is that the upper and lower arms have a large range of motion, so that the working space of the robot can almost reach a sphere. Therefore, the robot can be hung upside down to work on the rack to save floor space and facilitate the movement of objects on the ground. However, this kind of side-mounted robot has a cantilever structure on the 2nd and 3rd axis, which reduces the rigidity of the robot. It is generally suitable for robots with smaller loads for arc welding, cutting or spraying. The upper arm of the parallelogram robot is driven by a pull rod. The pull rod and the lower arm form two sides of a parallelogram, and the clamping system of the robot is used to keep the precision of welding procedure in different angles to ensure the quality of welding

In addition ,the motion of each joint (ie each axis) of the welding robot is ultimately attributed to the rotation of the corresponding drive motor of each axis, that is, the rotation of the servo motor; and the robot motor servo system puts forward high requirements, which can be roughly summarized as the following one aspect: high precision, in order to improve production efficiency and demand; wide speed range (ratio of the highest speed and the lowest speed that the motor can provide under rated load), the robot can operate normally within a certain range; low speed and large torque.

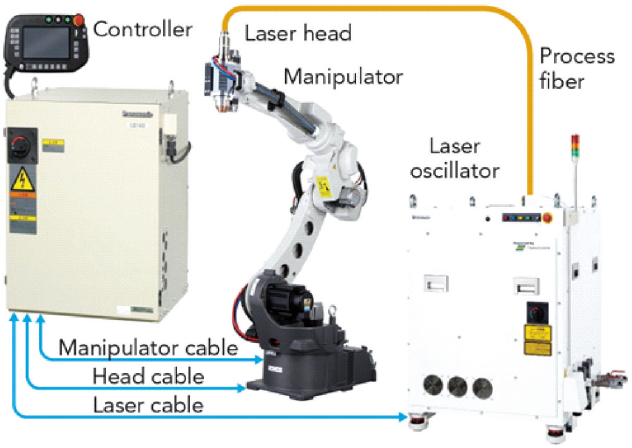

Figure 2. The structure of the welding robot

1.2 The precision of welding robots

The widespread aging around the world, as shown in Figure 4, has led to a shortage of employed population. Because of the lack of human labor, many industries have to use robots to complete tasks. However, it is difficult for robots to have high accuracy. Since most manufacturing industries have high requirements for product accuracy, the requirements for robot operation accuracy will be very high, such as welding robots in the welding industry, and Precision design of the robot is directly related to the quality and production efficiency of production. Therefore, if the accuracy of the robot is not high because the product will be quality and production efficiency without achieving the desired effect and lose a lot of time and money. People must find out the factors that improve this accuracy to save costs and improve efficiency of the production.

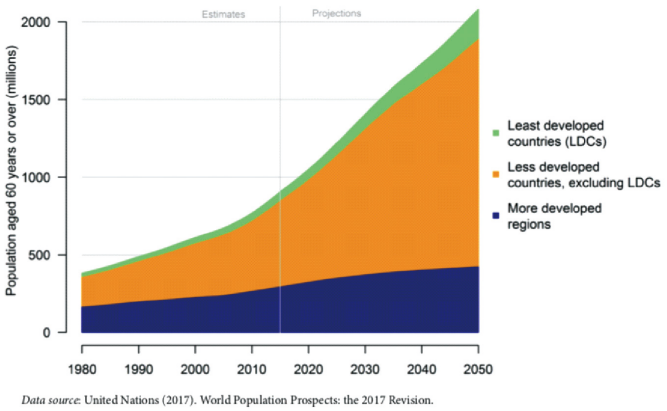

Figure 3. Global aging trend

With the future trend of automated production in the world , as shown in Figure 3, the adoption of welding robots has ensured an increase in productivity on the welding line. It reduces serious work injuries, improves the speed and accuracy of order execution, increases up time, and reduces costs. The automotive, manufacturing, and metal industries have adopted automated welding technology to reduce costs, save time, and improve welding quality. Another advantage of robotic welding is to help reduce the workload of employees and work with them to increase efficiency. The need for welding robots eliminates the need for manpower and ensures excellent operation by effectively and efficiently performing repetitive tasks.

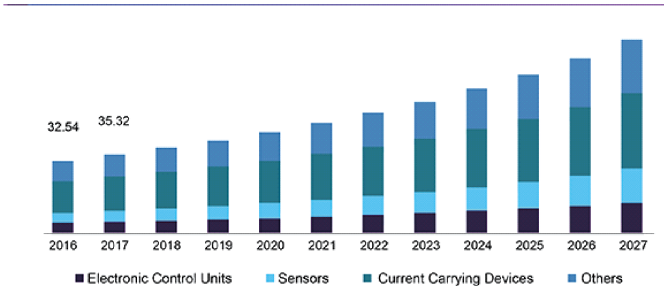

Figure 4. Automotive electronic market size

In addition, the huge investment in robotics research and development activities in various industries encourages the use of new advanced technologies to develop welding robots, as shown in Figure 5. Welding robots can be customized to meet specific requirements, such as online seam tracking and remote monitoring, and effective body structure to improve compatibility with humans through the use of innovative technologies.

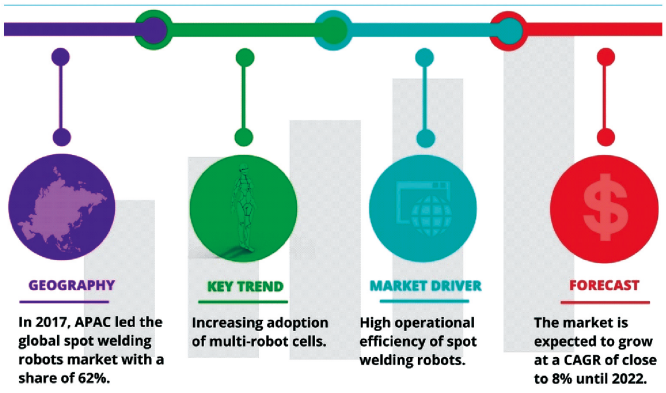

Figure 5. Global spot welding robots market

Moreover, the loss and stagnation of human labor caused by the impact of the global epidemic, as shown in Figure 6, in 2020 will further arouse global attention to automated production. The main reason for adopting multi robot control in industry is the possibility to reduce production cost by having robots working in parallel, especially for low speed processes as arc welding. Other advantages are that multiple robots can be controlled by one controller, which saves floor space, improves collision avoidance performance, and reduces cycle time. Further, in the arc welding is performed by simultaneously from different directions on the same welding object, a symmetrical heat distribution can be obtained. Therefore, the accuracy of welding robots needs to be improved to meet people's required use standards[1-5].

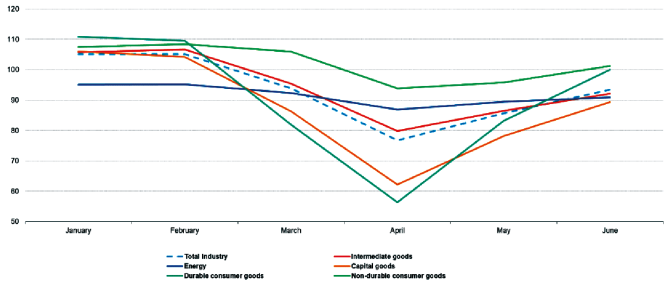

Figure 6. Development of industrial production

2 The welding robots

2.1 The development of the welding robot

In 1949, the United States applied for teaching reproduction technology. This technology established the control technology of most modern teaching robots. The essence of this technology is to first complete the task path by artificially assisting machinery, and the machinery can record the joint rotation angle and other related data can come from the trained. Then in 1959, the United States designed and produced the world's first prototype of an industrial robot. Three years later, the first robot "VERSTRAN" for practical work was produced by the American company AMF. This incident triggered a worldwide boom in the robotic research, so many countries including the United States start to implement corresponding policies to support the research and production of industrial robots. First, the United States continues to invest and accelerate the development of industrial robot applications. Following the United States, the United Kingdom and Germany implemented a subsidy policy for industrial robot research and development, enforced the research and development of industrial robots, and specified positions to greatly accelerate the practical process of industrial robots. Japan has made up for its own development process by introducing mature and advanced technology of industrial robots in the United States, so that Japan now has a pivotal position in the development of industrial robots in the world. Industrial robots are so appreciated because of their long working hours and strong applicability. Among them, welding robots have the highest status, as shown in Figure 7.

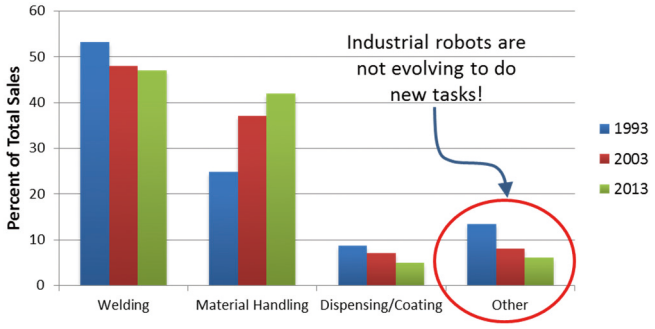

Figure 7. Industrial robot sales in North America

2.2 Key sensing technology of welding robot

Current robots can have a flexible posture and human-like sensory functions are inseparable from the blessing of sensors. Sensors give robots a variety of perception capabilities such as vision, force, touch, smell, and taste. The robot's perception function can also be used to detect the internal working status of the robot itself. By detecting and understanding the position, speed, temperature, load, voltage and other information of each joint, it can effectively ensure and improve the operation and sensitivity of the robot itself.

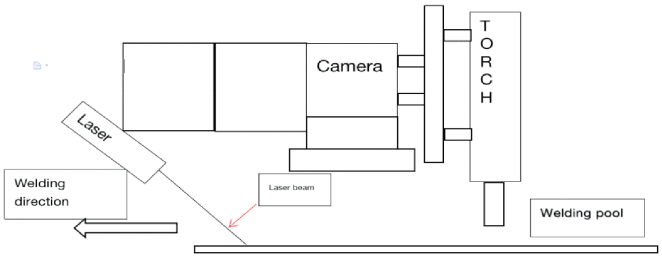

Figure 8. Robot welding structure

The sensing technology of welding robot is mainly divided into two kinds. The visual seam tracking sensor, as shown in Figure8, is one of the foundations of welding robot sensing system. In order to obtain the three-dimensional contour of the welding joint and overcome the interference of the arc during the welding process, the robot welding tracking and recognition technology usually uses active vision methods, such as laser and structured light, to correctly guide the robot welding and follow the actual welding seam to the end of the torch To complete the required trajectory movement. Since the energy of the active light source used is mostly smaller than that of the arc light, the sensor is generally placed at the front end of the welding torch to avoid the interference of direct arc light. The active light source is generally a laser beam scanned by a single-beam or multi-beam laser domain, and the processing is stable, simple, and practical.

Structured light vision, as shown in Figure 9, is another form of active vision welding seam tracking. The corresponding sensor mainly consists of two parts: one is a projector, which uses its radiation energy to form a projection light surface; the other is a photoelectric position detector, often using a surface Array CCD camera. After they are assembled in a certain positional relationship, and matched with a certain algorithm, they constitute a structured light vision sensor, which can perceive the three-dimensional information of all visible points on the projection surface. It can be considered that the trajectory of a spatial weld is composed of a series of discrete points. the density of which is determined according to the needs of control. The origin of the welding seam coordinate system is established on these points, and the sensor measures one welding seam point each time. The pose and the pose heuristic information of unknown weld points can be obtained and the guided robot welding gun completes the tracking of the entire smooth continuous weld. In order to move the welding gun along the weld path, the teaching pendant is used in a traditional robotic welding system. In addition, it is necessary to set welding parameters, start and extinguish the arc, control the shielding gas, and use the robot controller to program smooth welding at the same time. But this often leads to torch positioning errors and unsatisfactory welding quality[5-10].

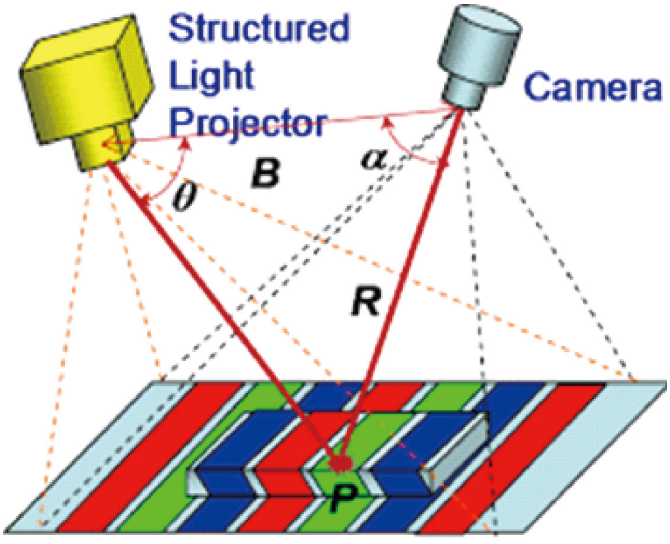

Figure 9. 3D Object in the Scene

3 Precision Analysis of Welding Robot

3.1 Accuracy of the robot body

The body mechanism and high-precision components, high-precision reducer and servo motor play a vital role in the robot. The structure of industrial robot needs to be optimized in the later stage, and the ideal precision and strength can be achieved through continuous optimization design.

When designing the fuselage of a welding robot, it should be noted that the body structure must have sufficient strength, rigidity and stability; structural body is not only to meet the requirements of flexible movement, for example, avoid occurrence and self-locking during design or the problem of jamming, and enough space should be left to install various power lines. The signal line should ensure the safety performance of the robot because the robot is very fast during the welding process. For example, limit switches are installed at the limit positions of each joint of the robot, so that when the robot's work exceeds the working range, as soon as the limit switch is touched, the drive source can be automatically cut off to protect the relevant the safety of people and the equipment[10-13].

The analysis and selection of materials, as shown in Table 1, is one of the important steps in the design of the robot body. Most of the robot rods e are parts that move frequently. On the one hand, it requires a high speed when working. Therefore, the material of the rod is preferably a light material to reduce its own weight and inertial force; on the other hand, because the robot is often at a high speed. In the state of reciprocating motion, it is bound to be accompanied by vibration, and the welding work requires good stability and high precision, that is, the material of the robot should have the characteristics of high rigidity and good vibration resistance. Comprehensive considerations, the robot rod determines the material with higher specific strength. The higher the specific strength of the rod material, the higher the strength of the rod under the same weight. After analyzing the properties of various materials commonly used at present, it is found that among the materials that conform to the robot motion rods, the hard aluminum alloy has the better performance, so it is used as the manufacturing material of the robot motion rods, such as the robot arm wrist; The base and waist of the welding robot play an important role in the overall working stability of the robot, good anti-deformation ability, high strength and so on. Compared with commonly used materials, it is found that alloy structural steel has better performance in these aspects and can satisfy. Therefore, alloy steel is selected for the material of the base and waist[13-15].

Table 1. The analysis of different materials

Material	$E/\times10^5$ MPa	$\rho/\times10^3$ kg/m^3	$(E/\rho)/\times10^7$ m^7/s^7
40Cr	2.10	7.80	2.70
LY12	0.72	2.80	2.60

3.2 Control Precision

In the improvement of the accuracy of welding robots, the second most important factor is the control accuracy of the robot. The control system of welding robot is composed of several parts, including memory function, teaching function, connection with peripheral equipment, man-machine interface, sensor interface, position servo function, fault diagnosis and safety protection function. The high precision control part includes: link cable, transformer, cable, end device hand grab, power switch, stop button, power supply, main board, servo amplifier and so on. The control accuracy ensures that the robot can run accurately, and it can also make up for the error of the body accuracy. Therefore, the robot control accuracy is significant. The wire feeding control system and gas mixing control system of the welding robot, as well as the voltage and current control system directly determine the quality of the welding workpiece of the welding robot, the servo motor control system and the driving system determine the stability of the welding robot. The sensor control system determines the safety and stability of the robot operation, and at the same time improves the stability of welding[15-17]. Therefore, improving the stability of the control system determines the accuracy of the welding robot. It has been found that model-based control (Sciavicco and Siciliano, 2000) is very significant in robotics, which can meet the contradictory requirements of performance improvement and cost reduction.

Continuous development for more complex kinematics and dynamic models, more complex multiple-input multiple-output (MIMO) control scheme, a greater change in static and dynamic model parameters, increasing the level of noise and interference, more low mechanical Intrinsic frequency and expanded non-linearity. Even if a large amount of academic research has been conducted in all these areas, a large amount of applied research is needed to further improve the model-based robust control of industrial robots[18-25].

4 Conclusions and discussions

The application of welding robot technology has strongly promoted the progress of world industrial technology. Especially welding robots play an extremely significant role in high-quality and efficient welding production. This paper mainly focuses on the development of welding robots, the analysis of welding robot accuracy, and the research overview of improving the overall accuracy of welding robots. The conclusion points out that the robot welding accuracy is mainly affected by the body accuracy and control accuracy. Among them, the development of sensor technology plays a key role.

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Research Article

Design and Application of Intelligent Diagnosis System for three Pumping Stations of Stamping Automation

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Abstract: This paper focuses on the maintenance of automotive stamping automation equipment. Through long-term self-study and accumulated experience, we independently developed a process monitoring system based on the three pumping stations of clutch, tension pad and lubrication in the stamping automation production line, which is used for real-time monitoring and diagnosis in the automatic production process without stopping the machine, and for the detection of oil temperature change, high-pressure pipeline leakage and oil return pipe In this paper, the improved case has strong practicability, low development cost, and has been recognized by peers in terms of cost efficiency improvement, which is easy to be popularized.

Keywords: Intelligent diagnosis; HMI process monitoring; Stamping automation; Hydraulic lubrication system

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1 Research on current situation of equipment

Through the investigation and study of the on-site stamping automation equipment, five problems are found.

(1) With the influence of seasonal temperature changes, the oil temperature of pump station also changes. In summer, the high temperature will burn the sealing ring of pipeline, in winter, the temperature is low, the response speed of compressor is delayed, and the operation performance of equipment is unstable all year round.

(2) The oil level inspection can only be roughly observed by observing the glass tube of the connector. Between the maximum value and the minimum value, the default is that the liquid level is normal, and the hidden problems can not be found artificially.

(3) The welding seam of high-pressure pipeline cracked in random state, and the hydraulic oil leaked quickly. Only when the leakage reached the minimum liquid level requirement of the program, the system would be shut down automatically, and it was too late when the personnel found out.More than 30 barrels of hydraulic oil are wasted, and the direct economic loss caused by each leakage is more than 60000 yuan[1-2];

(4) The oil return pipeline of slide block is often blocked by foreign matters, which leads to that the lubricating oil can not return to the oil tank normally, and the liquid level of the lubricating pump station is low. If the lubricating oil is added blindly with the liquid level of the oil tank as the reference standard, the oil will overflow directly after it flows back to the oil tank, resulting in cost waste and environmental damage;

(5) Due to the factors of labor cost, it is impossible to arrange personnel to be on duty all the time, and the traditional inspection, spot inspection, maintenance and other methods can not achieve effective monitoring(Figure 1).

Figure 1. FAW Volkswagen Chengdu stamping workshop

2 Make a plan

In view of the five uncontrollable problems found in the survey, we conducted special research and discussion, and finally worked out the following five countermeasures to overcome the above five technical difficulties;

The original temperature control valve of water-cooling analog quantity on the pump station is improved to digital water-cooling on-off valve. The cooling program is written with S7400 PLC. When the oil temperature is higher than 45℃, the first cooling valve is opened; when the oil temperature is higher than 50℃, the second cooling valve is opened; when the oil temperature is lower than 45℃, the second cooling valve is closed; when the oil temperature is lower than 40℃, the first cooling valve is closed; When the temperature is lower than 35℃, the heating function will be started automatically. Thus, the temperature is fixed at the optimal temperature of 40℃ - 45 ℃.

Liquid level inspection improves the traditional physical inspection method to HMI digital quantity and histogram display. Based on the visual diagnosis interface of "three major pump stations monitoring system" independently developed by windows, the liquid level height of dirty cavity, clean cavity and heat conduction cavity of pump station is displayed in real time by histogram respectively. The normal liquid level is green, the alarm liquid level is yellow and the shut-off liquid level is red; The current liquid level value is displayed on the top of the histogram in real time, and the data acquisition update cycle is 500ms[3];

Through the real-time monitoring and acquisition of the liquid level value, it can be realized in S7400 In the PLC program, the preset liquid level standard value is used to follow and compare with the current liquid level value in real time. Once the following error is detected to exceed the allowable range, the system will consider it as an abnormal state and immediately require the equipment to shut down after circulating shutdown. The HMI diagnosis interface will display the word leakage and highlight to remind the maintenance personnel to check and confirm in time;

By using the powerful data management function of SQL Server database, the monitoring system of three major pumping stations archives the collected data in real time, and tries to call, read and check the stored data through the trend, so as to easily check whether the oil return in the pipeline is normal and whether there is oil return blockage without shutdown.

Maintenance personnel can browse the process status data of a certain day, week, month and year by moving the mouse in the center console regularly without being on duty, so as to provide reliable reference data for equipment maintenance.

3 System function

3.1 After opening the software, it will automatically enter the radar scanning interface of the system.

It is divided into four parts: the first section: the system login window displays the current login user name, developer information, system time and FAW Volkswagen logo. The second section: Corresponding to the control unit function button, the safety control unit is used to divide the area, whole line area, destacking area and press area. The third section: The middle radar area is the main window area, displaying the corresponding function window. At the bottom of the window is the functional unit, which is divided according to the functional areas. The menu and submenu functions are developed for each functional area. Click the corresponding functional module with the left mouse button, and the main window will immediately switch to the diagnosis display of this area(Figure 2).

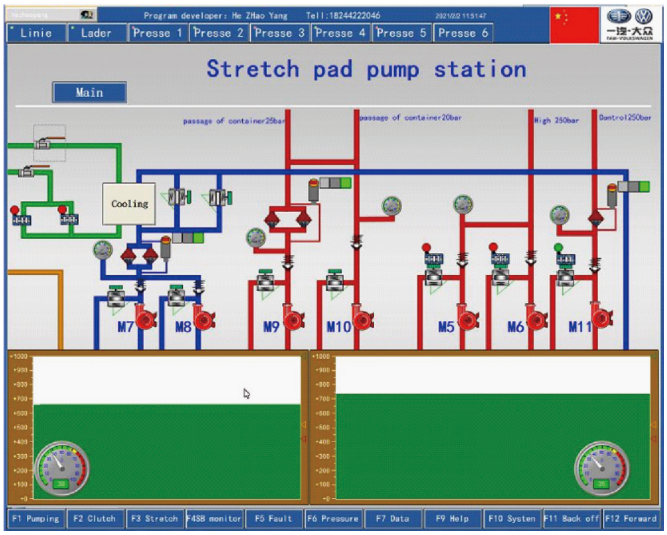

Figure 2. Remote oil system monitoring

3.2 Click the user button in the upper left corner of the main window with the left mouse button to open the login interface

For the sake of operation safety, in order to use the intelligent diagnosis system of stamping automation, it is necessary to apply to the maintenance management department for login permission in writing, and obtain the personal user name and password before login. After successful login, you can operate the corresponding functions of the software. Otherwise, when you click the function button, the system will automatically prompt you that you have no right to access. It is forbidden to do any page switching check on the system.

3.3 Click the F1 pump station button at the bottom of the window / directly press the shortcut key F1 - > to pop up the menu lubrication pump station, clutch pump station and stretching pad pump station.

Each submenu is followed by a > symbol, which means that there is a next level submenu in the current menu, including motor / pump top, oil circuit control and temperature and liquid level submenu. Put the mouse over the corresponding menu to highlight it. After clicking, the active window will automatically activate Live menu information. If the pop-up dialog box shows that there is no corresponding permission, it indicates that the current login permission assignment is low, and the higher permission option cannot be opened. (in order to ensure the security and prevent the data from being changed by mistake, some buttons need expert permission to enter. You can apply for account authorization in writing.)

3.4 Click F1 pump station - > select oil temperature and oil level in the pop-up menu, and the following activity information will be automatically displayed in the activity window, respectively displaying the real-time value of oil temperature and oil level of clutch dirty cavity and clean cavity, the real-time value of oil temperature and oil level of stretching pad dirty cavity and clean cavity, the real-time value of oil temperature and oil level of lubrication station dirty cavity, clean cavity and heat conduction cavity, the state of each cooling valve group, and the temperature heating state of each pump station.

Alarm status information lamp. The green display is normal, the Yellow display is warning, and the red display is alarm off. The process data of each control area is connected through the oil temperature / level curve below to view the historical data in real time. The data value can be recorded every 500 ms, and any data storage time can be set according to the needs. The 200GB hard disk can store data for 10 years.

3.5 Oil temperature, liquid level and heating curve

Click this button to open the temperature and oil temperature recording curve. Through the curve, we can analyze and judge the blockage of oil return pipeline, pipeline leakage, oil channeling, use verification of analog temperature control valve after repair, cooling effect analysis of IO temperature control valve, etc(Figure 3).

Figure 3. Global monitoring of three pumping stations

4 Fault diagnosis

Click the "oil temperature and oil level curve" button, the process data will be displayed in the active window, and the name of the current data recording area will be displayed in the title bar of the window. Select the corresponding recording curve, corresponding recording time and window range value according to your needs, and click OK to display the analysis in the historical record data window[4-5]. White dirty cavity temperature, red clean cavity temperature, green clean cavity liquid level and blue dirty cavity liquid level can be quickly diagnosed by dragging the window scroll bar or clicking the record operation button in the toolbar. Such as pipeline leakage, blockage, the flow between pumping stations and other hidden equipment failure(Figure 4).

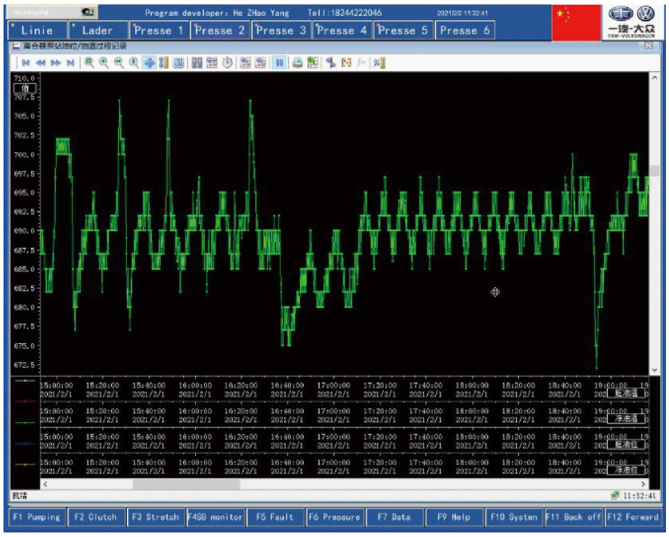

Figure 4. Equipment history process diagnosis

5 Summary

Before the system: It is not accurate for maintenance personnel to inspect the glass tube of the connector to check the liquid level, and it can not effectively control such problems in time. After the development of the system, four hidden problems were diagnosed in just three months. (1)The oil return pipeline is blocked (cloth, cotton and hemp, raw tape, etc.) 3 times; (2) It is diagnosed that the leakage of the seal causes the oil migration between the lubrication pump station and the clutch pump station;(3) It is diagnosed that the cooling system of the pump station is unstable; Improved to digital cooling solenoid valve; (4) It is diagnosed that the oil temperature is abnormally low due to the stuck core of the cooling valve; After the system was developed, it was recognized by departments and workshops. It was awarded the first prize of company level Youth Innovation and creative project, the second prize of energy conservation and emission reduction, the first prize of efficiency improvement, the talent of improvement and the key person. It also applied for the national software copyright registration certificate of the people's Republic of China;

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Journal of Electronic Research and Application

Research Article

Analysis of the Reliability Model of the Tool Magazine Subsystem in the Processing Center

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Abstract: Tool magazine is an important part of a processing center. Tool magazines have the advantage of reducing work parts turnover, handling, and storage time. In addition, some research shows that the use of tool magazine in machine tools in the machining center can make the cutting time utilization rate of machine tools 3-4 times higher than that of ordinary machine tools, and has better machining consistency, thus improving processing accuracy and processing efficiency, shortening the production cycle. Therefore, the reliability, efficiency and accuracy of the tool magazine have a crucial impact on the stability of the machine tool. Therefore, the reliability analysis of CNC machine tool magazine is considerably important. In view of this problem, this paper puts forward that the reliability model of the tool magazine is established after the parameter estimation and hypothesis test, and then the maintainability model of the tool magazine is built, it ends with the fault analysis of the tool magazine.

Keywords: Tool Magazine, Processing Center, Reliability, Repairability, Failure Analysis

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1 Introduction

CNC machines are the basis of manufacturing industry, so the reliability of CNC machines research become important in the past decades[1]. Tool magazine, as one of the important components of high-precision machine center, it's failure time, maintainability, and reliability will directly affect the quality of CNC machines[2]. In the past, researchers have shown that the Weibull distribution plays an extremely important role in the application of reliability estimation of any product[3], such as Lai Chin[4], have discussed the Weibull distribution and its application. The current mainstream method is to use the least square method of the two-parameter Weibull distribution[5,6] to perform in depth study. In this paper, the reliability model is established based on the Weibull distribution, and then the maintenance model of the tool magazine is carried out by using the logarithmic normal distribution of the variable 'time', and with the inspiration of failure analysis on tool magazine carried out by Zhongsong Zhang[7], this paper discusses the failure analysis of the tool magazine[8]. With the above consideration, this paper introduced the two-parameter Weibull distribution into the reliability analysis of the tool magazine [9,10].

2 Build a subsystem system reliability model

Based on the failure time of a processing center, the reliability model of key components is established. Tool magazine, in my case. Table 1 shows the cumulative running time of the tool magazine, failure time, t_i.

Table 1. Failure time of tool magazine

i	t_i (h)	i	t_i (h)	i	t_i (h)
1	12	11	211	21	394
2	45	12	234	22	417
3	54	13	237	23	557
4	54	14	259	24	565
5	61	15	266	25	591
6	63	16	271	26	729
7	70	17	274	27	769
8	92	18	296	28	944
9	96	19	346	29	1044
10	104	20	372		

2.1 Parameter estimation of the reliability model

Based on previous studies on the reliability of any processing centers, we know that the cumulative fault distribution functions of processing centers are subject to the Weibull distribution, so tool magazine should follow the same distribution as well.

The two parameters Weibull distribution function is:

$$F(t) = 1 - exp[-\left(\frac{t}{\alpha}\right)^{\beta}], \qquad t \geq 0 \tag{1}$$

In the function (1) the parameters are as follow:

α—scale parameter α >0;

β—shape parameter β >0;

The corresponding reliability function:

$$R(t) = exp[-\left(\frac{t}{\alpha}\right)^{\beta}], \ t \geq 0 \tag{2}$$

2.2 Least squares method with respect to Y

After deciding the reliability model of the machining center obeys the Weibull distribution in the previous section, it is necessary to estimate the parameters of the Weibull distribution model. When estimating the parameters of the Weibull distribution model of the machining center, the regression line is often directly fitted in the y direction. Keeping this rule, we can perform a linear regression model with respect to y. The symbol in the article are defined as follow:

$l_{xx} = \sum_{i=1}^{n} x_i^2 - n\bar{x}^2$, $l_{yy} = \sum_{i=1}^{n} y_i^2 - n\bar{y}^2$,

$l_{xy} = l_{yx} = \sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}$, $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$,

$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$

Estimation of least square method with respect to y

The linear regression model respect to y

$$y=a+bx+\varepsilon \tag{3}$$

In the equation: a, b—regression coefficients;

ε—deviation.

The corresponding least square constraints

$$Q_y = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (y_i - a - bx_i)^2 = min \tag{4}$$

In the equation: Q_y—sum of squares of deviation;

ε_i—the ith sample deviation.

When the derivative of Q_y with respect to a is equal to 0 and the derivative of Q_y respect to b is also equal to 0, Q_y hence reach it's minimum. Consequently the estimation of A, B can be:

$$\begin{cases} \hat{B} = \frac{l_{xy}}{l_{xx}} \\ \hat{A} = \bar{y} - \hat{B}\bar{x} \end{cases} \tag{5}$$

Since we know the two parameter Weibull distribution function.(1), then we can perform linear transform the equation(1) and get:

$$\ln\ln\frac{1}{1-F(t)} = -\beta\ln\alpha + \beta\ln t$$

Let $y_i = lnln\frac{1}{1-F(t_i)}$ and t_i represents ith failure point when sorting time from small to large. And x_i=ln t_i , A=-β lnα, B=β. Take y_i=lnln $lnln\frac{1}{1-F(t_i)}$ x_i=ln t_i back into equation 5 we will be able to get A, B. But before we do any calculation, we need to make an estimate on F(t_i). Normally we will use median ranks to estimate(t_i), so $\hat{F}(ti) \approx \frac{i-0.3}{n+0.4}$. Finally, we conclude that $\hat{\beta} = \hat{B}, \hat{\alpha} = exp(-\hat{A}/\hat{B})$.

Because the sample size n>14 for the tool magazine with fault data, the y-direction parameter estimation method can be directly used. Based on the above discussion, in combination of the cumulative failure time data of the tool magazine (table 1), we get the result of β=1.047013, α=342.31388.

2.3 Hypothesis testing of reliability model

2.3.1 Linear correlation test

The liner correlation coefficient is

$$\rho = \frac{l_{yx}}{\sqrt{l_{xx} \cdot l_{yy}}} \tag{6}$$

If |ρ $|\hat{\rho}|>\rho_{\alpha}$, we would assume that the correlation relationship between x and y is significant. ρ_{α} is the

critical value of correlation coefficient ρ, which can be found out by the table, or it can be calculated by approximate formula. In this paper, the approximate formula is used to take the level of significance α=0.1, hence

$$\rho_\alpha = \frac{1.645}{\sqrt{\upsilon - 1}} \quad (7)$$

Because there are 29 failures in the tool magazine, the failure time distribution of the tool magazine is hypothetically tested by the correlation coefficient method when v is 29. Using equation (6) we get $\hat{\rho}$ = 0.9837073 and ρ_a =0.311. sinceρ $\hat{\rho}$ >ρ_a , we can get the conclusion that x and y have a strong correlation, so the failure time of tool magazine should follow Weibull distribution.

2.3.2 Hypothesis test for distribution model

We will perform Kolmogorov-Smirnov test to check the failure time distribution function that we obtained above is correct. The main concept is that if the hypothesis is true then D_n should be small, otherwise the hypothesis will be false if D_n is large.

If the distribution function derived from the estimated parameters meets the following conditions, then we can conclude that the parameters that are estimated are reasonable.

$$D_n = \sup_{-\infty<x<+\infty} |F_n(t) - F_0(t)| = max\{d_i\} \le D_{n,\alpha} \quad (8)$$

In the equation above,

$F_0(t)$ — the original hypothetical distribution function.

$F_n(t)$ — the empirical distribution function with n samples.

$D_{n,\alpha}$—critical value.

d_i as stated below:

$$d_i = max\left\{F_0(t_i) - \frac{i-1}{n}, \frac{i}{n} - F_0(t_i)\right\} \quad (9)$$

The tool magazine hazard function is then calculated as $F(t) = 1 - exp[-\left(\frac{t}{342.31388}\right)^{1.047013}]$, then we will now perform Kolmogorov-Smirnov test. We get D_n =0.105712, with significance level of 0.1, $D_{n,\alpha}$= 0.302683. Because $D_n \le D_{n,a}$, the hypothesis tests are accepted.

Table 2. Hypothesis test values

$F_0(t) = 1\text{-}exp[-(\frac{t}{\alpha})^{\beta}]$	$\frac{i-1}{n}$	$\frac{i}{n}$	d_i
0.026151	0	0.034483	0.026151
0.104641	0.034483	0.068966	0.070158
0.125933	0.068966	0.103448	0.056967
0.125933	0.103448	0.137931	0.022485
0.142338	0.137931	0.172414	0.030075
0.146997	0.172414	0.206897	0.059899
0.163194	0.206897	0.241379	0.078185
0.212875	0.241379	0.275862	0.062987
0.221692	0.275862	0.310345	0.088653
0.239116	0.310345	0.344828	0.105712
0.44397	0.344828	0.37931	0.099142
0.481262	0.37931	0.413793	0.101952
0.48596	0.413793	0.448276	0.072167
0.519267	0.448276	0.482759	0.070991
0.529451	0.482759	0.517241	0.046693
0.536607	0.517241	0.551724	0.019365
0.540852	0.551724	0.586207	0.045355
0.570927	0.586207	0.62069	0.049763
0.632695	0.62069	0.655172	0.022477
0.661464	0.655172	0.689655	0.028191
0.684154	0.689655	0.724138	0.039984
0.706349	0.724138	0.758621	0.052271
0.812759	0.758621	0.793103	0.054138
0.817567	0.793103	0.827586	0.024464
0.832392	0.827586	0.862069	0.029677
0.89362	0.862069	0.896552	0.031551
0.906881	0.896552	0.931034	0.024154
0.948316	0.931034	0.965517	0.017282
0.963232	0.965517	1	0.036768

In conclusion the reliability model of tool magazine follows Weibull distribution, it's shape parameter is 1.047, scale parameter is 342.3138. The failure time distribution function of tool magazine F(t), probability density function f(t), reliability function R(t), and failure rate function λ(t) , can be represented as follows:

$$F(t) = 1 - exp\left[-\left(\frac{t}{342.3138}\right)^{1.047}\right] \quad (10)$$

$$f(t) = \frac{1.047}{342.3138}\left(\frac{t}{342.3138}\right)^{0.047} exp\left[-\left(\frac{t}{342.3138}\right)^{1.047}\right] \quad (11)$$

$$R(t) = exp\left[-\left(\frac{t}{342.3138}\right)^{1.047}\right] \quad (12)$$

$$\lambda(t) = \frac{1.047}{342.3138}\left(\frac{t}{342.3138}\right)^{0.047} \quad (13)$$

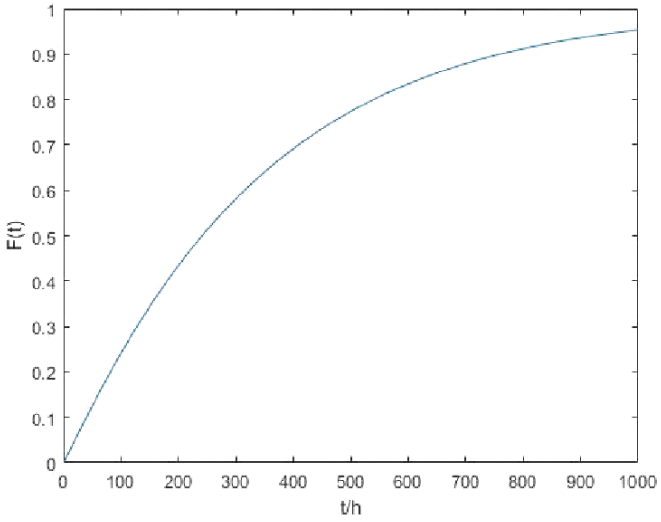

Figure 1. F(t)-failure time distribution function

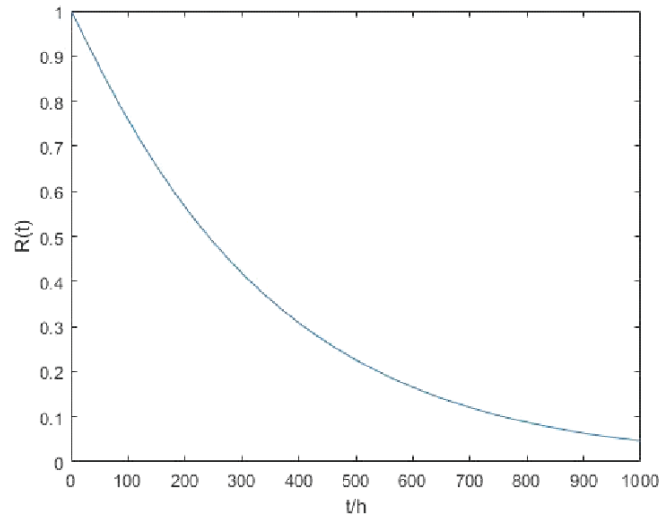

Figure 2. R(t)-reliability function

2.4 Reliability evaluation of tool magazine

Mean time between failure (MTBF), is a measure of how reliable a product or component can be, it is measure as the time between each failure. MTBF is then used to represent the average working time without any faults, which the mathematical expectation E(t) of the failure interval time, t.

Estimated MTBF of tool magazine:

$$MTBF = \int_0^{\infty} tf(t) = \alpha\Gamma\left(1 + \frac{1}{\beta}\right) \quad (14)$$

$$=342.31388 \times \Gamma\left(1 + \frac{1}{1.047013}\right) = \ 333.7443(h) \quad (15)$$

3 Maintainability modeling of tool magazine

After analyzing the reliability of the tool magazine in the processing center, the maintenance of the tool magazine needs to be studied. Even if the reliability of the tool magazine is high and the failure rate is low, the credibility level of the tool magazine is obviously not high if it is difficult to repair after a failure or requires a longer repair time. The establishment of maintainability model is the key to quantitative research on the maintenance of the system, and also to lay the foundation for further research on the degree of maintenance impact, so this section will study the maintainability model of the tool magazine in the processing center.

In this paper, we performed a field test and monitored 7 tool magazines for 7 different processing centers, the repair time data obtained as shown in Table 3.

Table 3. Repair time data

Group	Repair time	Number of times appeared	Frequency
1	0.5	10	0.3448
2	1	7	0.24137
3	1.5	6	0.20689
4	2	3	0.103448
5	3.5	1	0.03448
6	5.5	1	0.03448
7	7.5	1	0.03448

3.1 Parameter estimation of maintainability model

If the natural log of repair time t, lnt follows normal distribution, then the distribution function of repair time follows logarithmic normal distribution.

Hence the probability density function of logarithmic normal distribution is:

$$m(t) = \frac{1}{\sigma t\sqrt{2\pi}}{}^{-\frac{1}{2}\left(\frac{\ln t-\mu}{\sigma}\right)^2} \tag{16}$$

In the equation: μ—the mean value of lnt; 0.088

σ—the variance of lnt; 0.732

The integral of logarithmic normal distribution is:

$$M(t) = \int_0^t \frac{1}{\sigma x\sqrt{2\pi}}{}^{-\frac{1}{2}\left(\frac{\ln x-\mu}{\sigma}\right)^2}\, dx \tag{17}$$

Using the maximum likelihood estimate method to estimate μ, σ^2 parameters for the maintainability model. The basic idea of maximum likelihood estimate is that if a parameter has the greatest probability of a sample observation occurring, we will then use this value as the true value of the parameter estimate. Assuming that the observed machining center repair time, t_1, t_2, $\cdots$ t_n is a sample from a population of the normal distribution of the number of pairs, then the function will be written as:

$$L(t;\mu,\sigma) = \prod_{i=1}^n m(t_i) = \prod_{i=1}^n \frac{1}{\sigma t_i\sqrt{2\pi}} exp\left(-\frac{1}{2}\left(\frac{\ln t_i-\mu}{\sigma}\right)^2\right) \tag{18}$$

Take the natural log of both side:

$$\ln L\,(t;\mu,\sigma) = -\sum_{i=1}^n \ln t_i - \frac{n}{2}\ln(2\pi\sigma^2) - \sum_{i-1}^n (\ln t_i-\mu)^2/(2\sigma^2) \tag{19}$$

The corresponding maximum likelihood estimate equation will be:

$$\begin{cases} \frac{\partial \ln L(t;\mu,\sigma)}{\partial \mu} = \frac{1}{2\sigma^2}\sum_{i=1}^n 2(\ln t_i-\mu) = 0 \\ \frac{\partial \ln L(t;\mu,\sigma)}{\partial \sigma^2} = -\frac{n}{2}\frac{2\pi}{2\pi\sigma^2} + \frac{1}{2\sigma^4}\sum_{i=1}^n (\ln t_i-\mu)^2 = 0 \end{cases} \tag{20}$$

The parameters of logarithmic normal distribution will be:

$$\begin{cases} \hat{\mu} = \frac{1}{n}\sum_{i=1}^n \ln t_i \\ \hat{\sigma}^2 = \frac{1}{n}\cdot\sum_{i=1}^n (\ln t_i-\hat{\mu})^2 \end{cases} \tag{21}$$

Under the premise that the repair time for tool magazine is subject to logarithmic normal distribution, by using equation(21) we will then get estimated $\hat{\mu}$ =0.08804, $\hat{\sigma}^2$ =0.535963, $\hat{\sigma}$=0.732095.

Hence the maintainability model function M(t) is:

$$M(t) = \int_0^t \frac{1}{0.732\sqrt{2\pi}}\cdot e^{-\frac{1}{2}(\frac{\ln x-0.088}{0.732})^2}\cdot dx$$

Probability density function of maintainability model m(t) is:

$$m(t) = \frac{1}{0.732t\sqrt{2\pi}}\cdot e^{-\frac{1}{2}(\frac{\ln t-0.088}{0.732})^2}$$

Unrepairable model function G(t) is:

$$G(t) = 1 - M(t) = 1 - \int_0^t \frac{1}{0.732x\sqrt{2\pi}}\cdot e^{-\frac{1}{2}(\frac{\ln x-0.088}{0.732})^2}\cdot dx$$

Repairable rate function u(t) is:

$$u(t) = \frac{m(t)}{1-M(t)} = \frac{m(t)}{G(t)} = \frac{\frac{1}{0.732t\sqrt{2\pi}}\cdot e^{-\frac{1}{2}(\frac{\ln t-0.088}{0.732})^2}}{1-\int_0^t \frac{1}{0.732x\sqrt{2\pi}}\cdot e^{-\frac{1}{2}(\frac{\ln x-0.088}{0.732})^2}\cdot dx}$$

The graph of maintainability model function M(t), probability density function of maintainability model m(t), unrepairable model function G(t), repairable rate function u(t) are shown below.

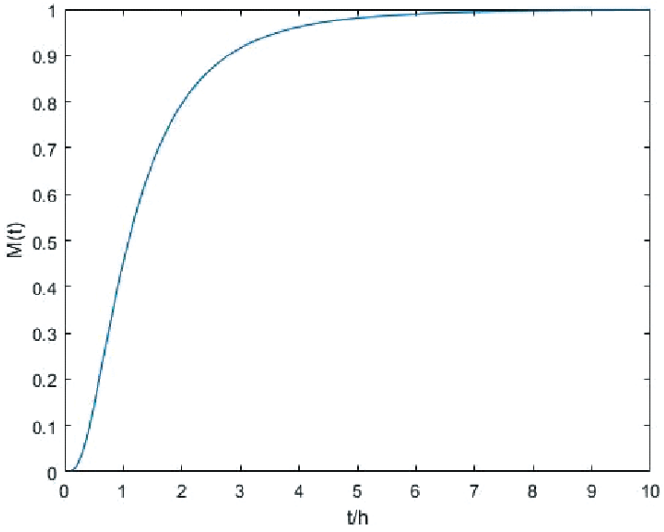

Figure 3. Maintainability model function

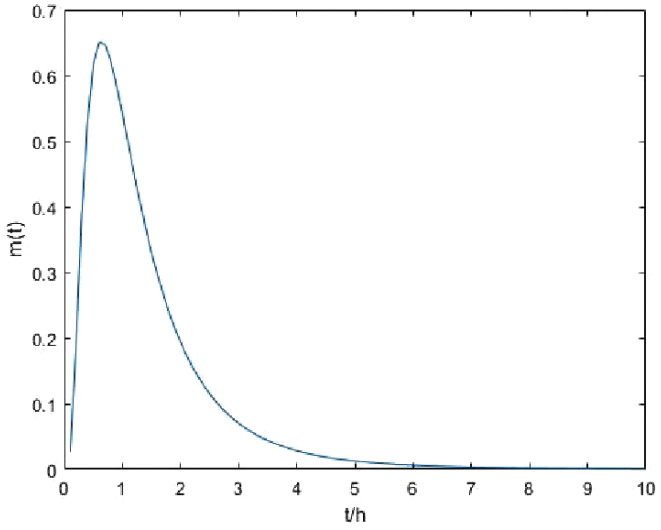

Figure 4. Probability density function of maintainability model

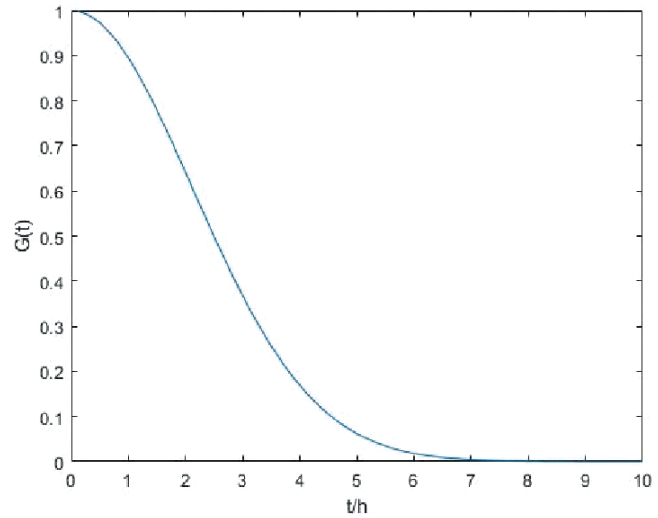

Figure 5. Unrepairable model function

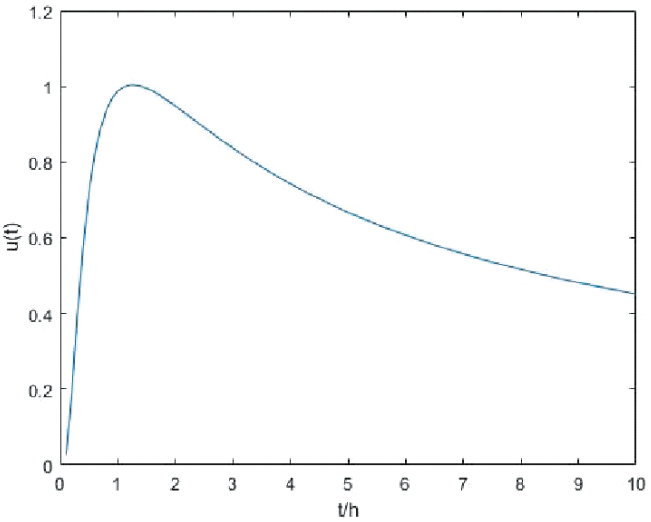

Figure 6. Repairable rate function

3.2 Maintainability evaluation of tool magazine

Mean time to repair (MTTR)

The observed MTTR is:

$$MTTR = \frac{1}{n}\sum_{i=1}^{n} t_i \tag{22}$$

In the equation: n— the cumulative maintenance frequency of tool magazine is n=29;

t_i—the i th repair time

Hence we obtained the observed average repair time MTTR=1.5h.

The equation for estimated MTTR value would be:

$$MTTR = \int_0^{\infty} tm(t)dt = exp(\mu + \frac{\sigma^2}{2}) \tag{23}$$

By doing the calculation above, we obtained MTTR=1.423h, which is close to our observed value.

4 Fault analysis of tool magazine

In this section we perform a fault analysis of the tool magazine. The most frequent failure mode of the tool magazine is the tool magazine offset (71.41%). From the tool magazine failure type frequency graph (Figure 3) and the failure mode frequency table (Table 3) fault types occur most often are dissonance types. Also, from the tool magazine fault cause frequency table (Table 4), and the fault cause frequency graph (Figure 4), the analysis shows that the main causes are parts damage (28.57%) and eelectronic component malfunction (28.57%).

Table 4. Tool magazine failure type frequency table

Codes	Failure type	Failure mode	Number of time occurred	Frequency
0407	Dissonance	TM Dissonance	5	71.43%
0501	Functional	Moving parts failure	1	14.29%
0503	Functional	Trans position not accurate	1	14.29%

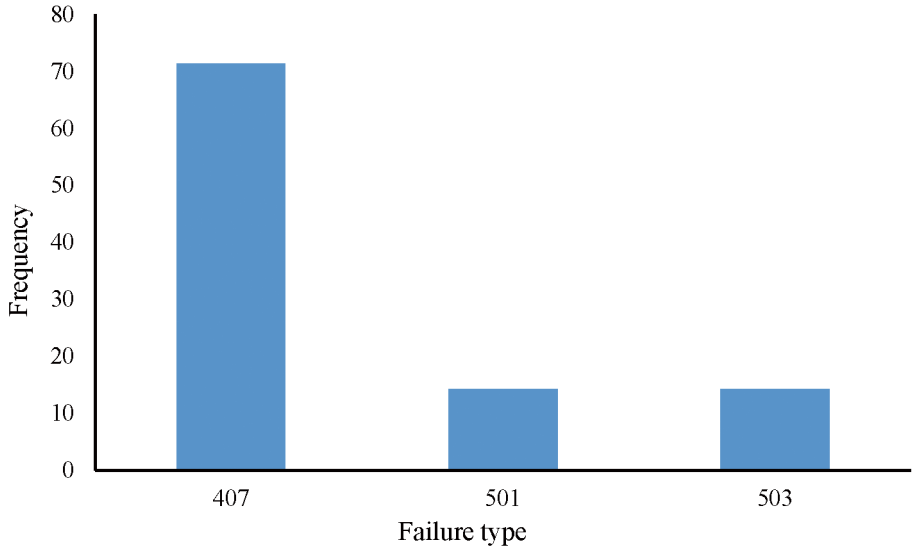

Figure 7. Tool magazine failure type frequency graph

Table 5. Tool magazine failure cause frequency table

Codes	Cause	Number of times occurred	Frequency
33	Electronic component malfunction	2	28.57%
34	Parts damage	2	28.57%
31	Misoperation	1	14.29%
22	Drifting	1	14.29%
36	Improper adjustment	1	14.29%

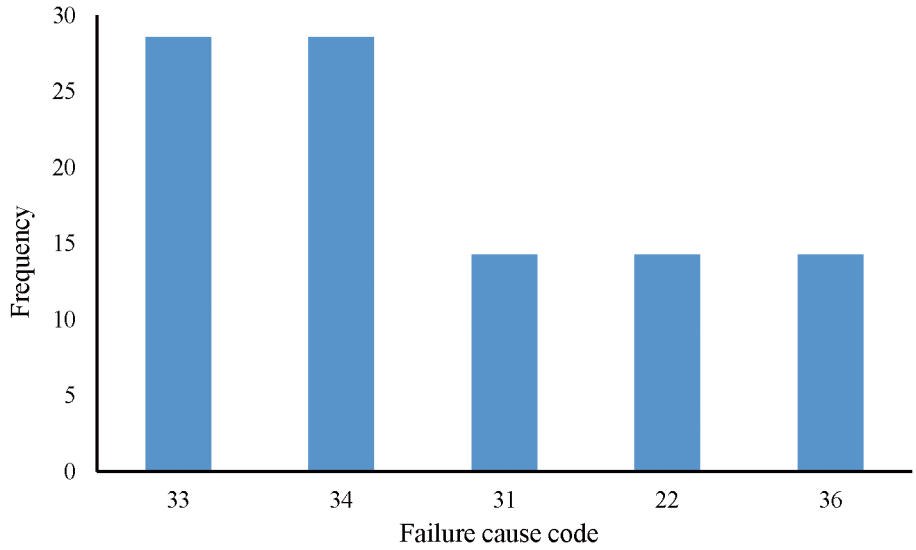

Figure 8. Tool magazine failure cause frequency graph

5 Conclusion

This paper focuses on the modeling and evaluating reliability and maintainability model of the tool magazine in the processing center, and the failure analysis. In the reliability model parameter estimation, the fitting of the least square method in reliability model is discussed, and by using the linear regression fitting we conclude a reasonable parameter for Weibull distribution. According to the conclusion, we obtained β =1.047 (shape parameter) and α =342.313 (scale parameter) for the reliability modeling of the tool magazine. As we discussed in the maintainability modeling of tool magazine section, if the natural log of t follows the normal distribution, then the repair time should follow logarithmic normal distribution as well. Then we used maximum likelihood estimate method to the parameters for maintainability model distribution. The parameter estimation of the maintainability model is obtained, μ =0.088, σ^2=0.536, follow by the evaluation of maintainability of tool magazine. Finally, the failure analysis of the tool magazine is carried out and found that the tool magazine dassonance fault mode is the most frequent, at 71.43%, the main cause of which is the electrical components failure and parts failure.

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Research Article

Application Strategy of Big Data Processing Technology in Intelligent Transportation

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Abstract: With the rapid development of China's society and economy, the process of urbanization has been accelerated, and the transportation system has become more complicated, especially the frequent occurrence of traffic accidents, traffic congestions, and environmental pollution. In the context of the rapid development of Internet technology, digital technology, artificial intelligence technology, etc. We apply them to traffic management as effective ways to improve China's traffic operation management. Based on big data processing technology, this paper discusses its application strategy in intelligent transportation, in hope of serving as a reference.

Keywords: Big data; Processing technology; Intelligent transportation

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1 Introduction

The so-called intelligent transportation technology is intended to yield its ideal effect in traffic management, and it needs the support of a large amount of collected and aggregated data. At this stage, our society is gradually moving into the era of big data, and the collection and sorting of traffic data is more reliable and accurate. With the help of big data processing technology for traffic data processing, storage, display and sharing, it will give full play to the high efficiency, visualizability and other advantages of big data technology, explore the application strategy of big data technology in traffic operation management, promote the implementation of emerging technologies in the field of transportation, and improve the standard of traffic management technology.

2 Overview of Related Theories

2.1 Big Data Processing Technology

The big data described in this paper is based on the aspects of data volume, which has the characteristics of large storage capacity, rich varieties, and fast processing etc. The comparison of traffic big data with traditional traffic data has the following characteristics: Firstly, traffic big data has a large amount of information and a wide range of sources, which can reflect its good long-term and extensiveness in the process of data storage; Secondly, the data processing speed is fast, and the traffic conditions control has a strong timeliness, and the current high-precision data processing technology is required in data processing; thirdly, in terms of the nature of the traffic data itself, it has the characteristics of very strong spatiality and practicalness. Therefore, the data generated later has certain practicality and significance of reference; fourth, the active application of the current relatively advanced computer, sensing and other science and technology can quickly realize the application and improvement of intelligent transportation technology.

2.2 Intelligent Transportation

Simply speaking, intelligent transportation is the use of current advanced automated control, electronic sensing, computer and other technologies to manage traffic information. Compared with the traditional traffic technology in the past, it takes big data processing technology as the foundation to

promote the refinement of intelligent transportation hardware, actively apply current advanced science and technology to give full play to its advantages in transportation, so as to build various operation modes such as data collection, data analysis and data feedback specifically for the transportation system. It has the functions of monitoring and predicting dynamic traffic data, which further improves the application efficiency of traffic data, and at the same time promotes the entire transportation system to yield better operating efficiency. In addition, through the use of current advanced high-tech and related machinery and equipment, it can quickly transmit and process a large amount of data information, use traffic big data to build a safety model, analyze and evaluate the safety of transportation systems, and improve the safety of transportation operations.

3 Big Data Processing Technology in Intelligent Transportation

In intelligent transportation, the application logic of big data is mainly embodied in the three stages of data collection, processing and application. The data flow logic is shown in Figure 1.

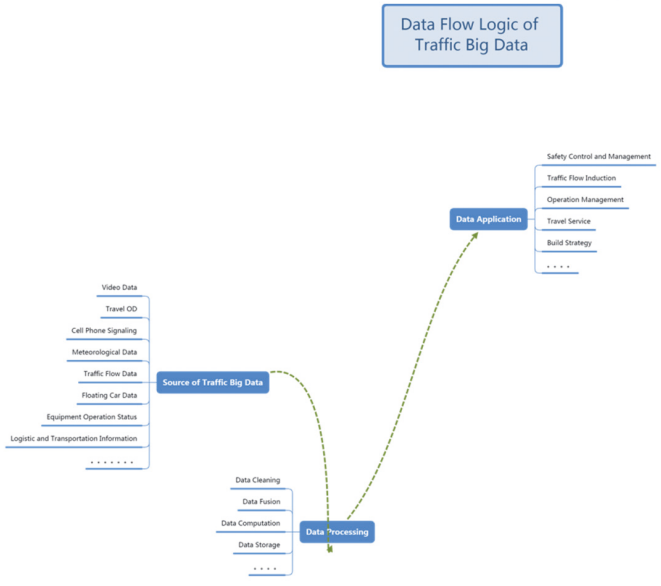

Figure 1. Big Data Processing Technology in Intelligent Transportation.

Below we will focus on introducing data collection, data processing, data analysis, and data sharing in our data logic.

3.1 Data Collection

Applying big data processing technology to intelligent transportation, information collection is mainly done through multi-dimensional and multi-source data, mainly including the self-built data collection system of the transportation system and the shared data collection of other industries in the society. The self-built system mainly includes vehicle flow speed, time, video, OD and other parameter information collected by sensors such as induction coils, microwave radars, and video image acquisition equipment[1]; the data shared by other industries in the society is mainly influential data for transportation operational control,, such as meteorological data collected by meteorological units, mobile phone signaling data collected by communication operators, and logistics information collected by transportation companies. In the construction of intelligent transportation systems, various data affecting traffic operation and management should be fully collected to provide data support for traffic management and control strategies.

3.2 Data Processing

Data processing in intelligent transportation can be roughly divided into data cleaning, data fusion, data computation, and data storage, etc. Its biggest feature is that it can implement distributed or centralized data processing according to the source of the data and the management and control objectives of the platform and process irregular data and information by adopting intelligent and standardized cleaning and storage. For example, through the cleaning and fusion of road junction video data, radar data, geomagnetic data, and data such as floating cars on road segments, traffic signal timing and traffic accident detection etc. are carried out. It can also use the fusion processing of historical traffic data and real-time data for the prediction of traffic conditions.

3.3 Data Analysis

Traffic data analysis is to study the collected and processed data with appropriate statistical analysis methods, extract information closely related to traffic control, and display the degree of impact of various data on traffic in visual forms such as tables and graphs. In this way, the current traffic state, accident information, traffic operation and maintenance requirements, traffic control strategies, etc. of the traffic section can be analyzed; data mining technology can also be used to specifically analyze the data information in a certain traffic section in combination with current advanced AI, neural network and other technologies to judge the future

traffic conditions.

3.4 Data Sharing

Big data processing technology is the foundation of intelligent transportation system, which can realize the data sharing function between it and other systems, and further enhance the value of transportation data and the scope of data services. During data collection and analysis, the system will call the corresponding processing port according to the data request, service type and other requirements of related users, carry out data analysis and processing, transmit the processed data to each application system to satisfy the data application requirements of different users, complete data sharing, and effectively ensure the practicability of data.

4 Application Strategy of Big Data Processing Technology in Intelligent Transportation

4.1 Application in Traffic Safety and Smooth Flow control

Through the use of big data processing technology, it can effectively collect health status information of traffic infrastructure, information of traffic flow conditions, drivers' driving habits, and traffic accident information, etc. to formulate corresponding emergency plans for accidents, bad driving behaviors, and various traffic accidents, etc. based on collected and analyzed data, and at the same time improve the standardization of driving behaviors of drivers and passengers through safety warning and traffic control and management strategies[2]. For example, under the state of traffic jam, using real-time collected traffic flow data, historical periodic traffic data, and surrounding road network traffic flow data to conduct traffic guidance in advance can improve the smooth flow of roads; under the state of accident, through the detection of accident information, timely release of early warning on accident information, and control and give early warning to upstream vehicles can reduce the human and financial losses caused by accidents.

4.2 Traffic Operation and Maintenance Management Application

In traffic operation, the specific analysis on traffic passage construction planning, road section traffic operation methods, management and control strategies, etc., based on road network traffic volume data, OD data, regional economic and industrial distribution data in traffic big data, etc., provides executable, high cost-performance ratio operation strategies for traffic operations. At the same time, based on the data fusion of service time, life cycle, equipment health status and other data of various facilities in the transportation operation process, a reasonable and reliable maintenance plan is formulated for each facility in the transportation system, and the input and output of the transportation operation are compared and analyzed to provide data support.

4.3 Convenient Mass Travel Information Service Application

The convenient travel information service for the masses in the transportation system is realized by relying on the information sensor network. On the whole, the position sensing equipment of vehicles, stations, and parking lots etc. in the transportation system can provide effective information for the transportation service centers. In addition, combined with the current advanced cloud computing, data mining and other technologies, it can provide the traffic information that the transportation department needs anytime, anywhere, so that people can choose their own travel mode according to the actual traffic conditions when traveling, and avoid the disruptions caused by unplanned travel[3]. From the aspects of the traffic information service system, it can provide timely and accurate information about relevant traffic sections, effectively avoiding problems such as uneven traffic flow and poor travel experience etc. For example, after the data collection and data fusion of GPS information, floating car information, and road traffic status etc, the navigation system provided by map operators for drivers and passengers will bring a good experience to travelers selecting travel modes and travel routes.

5 Conclusions

In conclusion, applying big data processing technology to transportation is the only way for the transportation industry to develop under the background of high-tech development. Through in-depth research and mining of traffic big data, more and more application demands and scenarios are bound to emerge in the transportation industry, and

the so-called intelligent transportation must also be implemented along the application of various emerging technologies. Research units and personnel in the transportation industry should increase the exploration of big data in the transportation field, and study in-depth the application of big data technology in intelligent transportation to meet people's needs for safety, convenience, and comfort in transportation systems.

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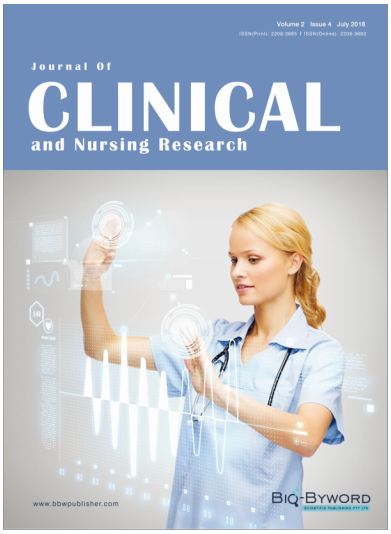

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