THE CONTROLLER OF THE GRINDING AND WELDING MANIPULATOR

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ABSTRACT

The low efficiency and inaccurateness always annoys the great hydraulic power station. This paper presents the constitution of the welding and grinding manipulator in order to repair hydraulic turbine guide vane, with the computer directly control and its hardware and software. It emphasizes on the control method based on the position/force control, and also includes the 3-D graphic, based on OpenGL and the data management with database.

IIW-Thesaurus key words: *Manipulators; Welding accessories; Grinding; Controls; Welding.*

1 INTRODUCTION

Because of the vacancy erosion and the wearing, there were great damage of the hydraulic turbine guide vane working in the Yellow River, where the content of soil-sand was the most important all over the world. The hydraulic power station had to spend much money and time on the repairing of hydraulic turbine guide vane. Using the old repairing ways, they took not only much time but also much human labour. The labour strength was very hard, and the work environment was very bad, and it seriously endangered the worker's healthy body. At the same time due to the operation profile's scrambling, the grinding wheel was easy to rotate block and crack [3]. For this reason the manipulator with 5 freedom was designed, it can not only weld along with teach curve, but also complete the auto grinding. The working condition can been greatly changed and the repairing quantity and efficiency can be improved. The controller was based on the position/ force control method and the manipulator was directly controlled by the computer, the artificial proceeds were replaced by the automatically welding and grinding. Its advantage had the convenience of the software, friendly interface, simple operation, high accuracy control, small size of the hardware part, etc.

2 HARDWARE OF THE CONTROLLER

The hardware was made up of the manipulator's mechanism, the circuit of the data gather, the circuit of the pressure examination, the circuit of the position and the speed examination, control circuit of the speed. Hardware circuit was followed as shown in Figure 1.

2.1 Constitution of the manipulator [3]

The manipulator for repairing hydraulic turbine guide vane (Figure 2) was constituted with the grinding part (dc servo motor, deceleration part, grinding part), the shelf (X, Y, Z axis motor), the controller (move controller, grinding controller) etc.

2.2 Principle of the manipulator for the repairing and welding hydraulic turbine guide vane

The manipulator can move along the X, Y, Z axis, and the grinding part can move along the Z direction. When the manipulator works, it will move to the goal position according to the data of the hydraulic turbine guide vane

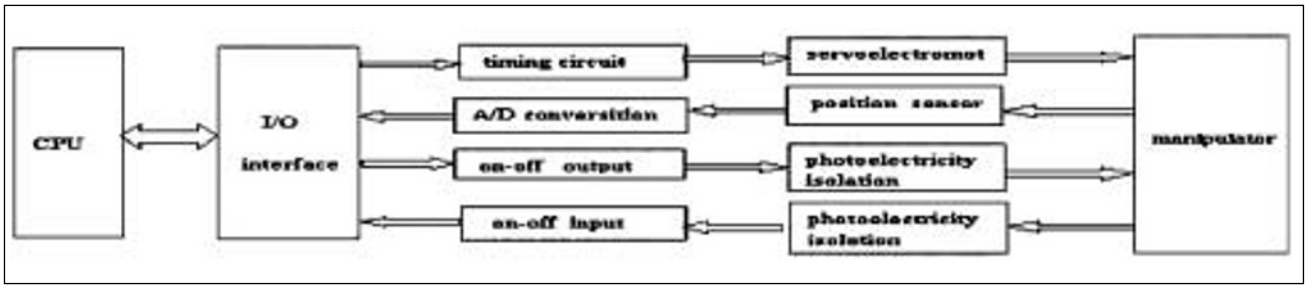

Figure 1 – Hardware circuit principle sketch

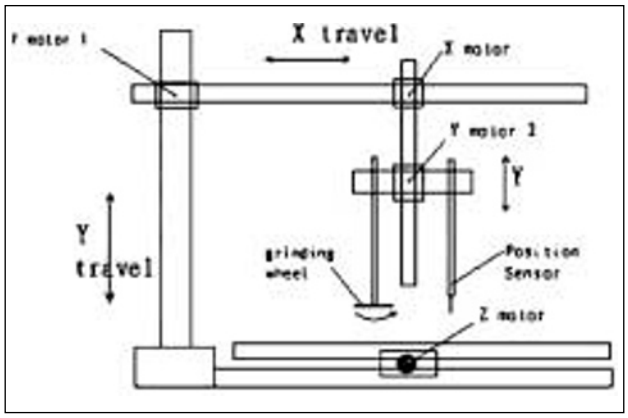

Figure 2 – Welding and grinding manipulator sketch map

to repair. Its movement was decided by the following formula:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [K] \begin{bmatrix} \theta 1 \\ \theta 2 \\ \theta 3 \end{bmatrix} \quad (a)$$

where

X, *Y*, *Z* is the coordinate of the manipulator;
$\theta 1$, $\theta 2$, $\theta 3$ is the angle of the *x, y, z* motor;
[K] is the changing matrix.

2.3 Circuit of the data gather of the hydraulic turbine guide vane

The data gather sensor was a position sensor of resistance style, its principle was like a sliding resistance, constituted by the fixed resistance and the sliding point. The position of the sliding point was controlled by the end point of the machine part, the sliding point would move along with the machine touch, the voltage between the sliding resistance would change with the change of the end point's position. The change of the voltage can be measured by the A/D transducer, then transform the digital data to the position data using a special formula.

2.4 Circuit of the pressure examination

Because the rotation of the grinding part was working at very high speed, the pressure could not be measured with the direct way. And then a current way was used to express the pressure. In this way the pressure could be easily known by examining the current of the grinding part. It was based on the principle that the grinding force was related to the current. When the grinding quantity increased, the grinding pressure would increase too. The energy of working came from the electrical power, in order to balance the energy, the current would increase too.

The moment formula was followed (formula 1), the M (output moment) of the dc servo motor was equal to the sum of the M_r (load moment) and the M_f (the empty wastage moment).

$$M = M_r + M_f \quad (1)$$

Therefore, the moment would increase along with the pressure, at the same time the output moment directly provided by the dc servo motor. Namely (formula 2):

$$M = K_m \times \varphi \times I_a \quad (2)$$

where

K_m is the parameter of the motor,
φ is the electromagnetism flux of the magnetic pole,
I_a is the current of the armature.

The conclusion from formula (1) and (2):

$$I_a = (M_r + M_f)/ (K_m \times \varphi)$$

From here then, the electric current of the dc servo motors' armature would change along with the pressure of the grinding part. So the positive pressure of the grinding part could be fed back through the examination of the current of the armature and the examination was very easily realization. Therefore the identical pressure grinding could be realized by the automatic manipulator. From the above analysis, the manipulator could be controlled to realize the identical pressure grinding through measure the dc servo motors' current of the armature and control the position of the grinding touch point [4]. The theory base was the HUOER domino effect. It was well known that there was the magnetic field surroundings the current, that magnetic field and the electric current's relation could be calculated by AMPER LAW. Using the HUOER sensor to measure magnetic field, it could express the electric current. In this paper this method was used to measure the grinding force by the current sensor. The current was transformed to the binary data by the special circuit, then the computer could accept the data.

2.5 Circuit of the position and the speed examination

For the realization of the profile modelling welding and grinding, it was very important to know the precision position of the manipulator and it was also needed to accurately control it. The position of the manipulator would directly influence the grinding quality. So a close loop was used to realize the position control. Figure 3 illustrates such system. The position was measured by the optical encoder, then the signal was processed by

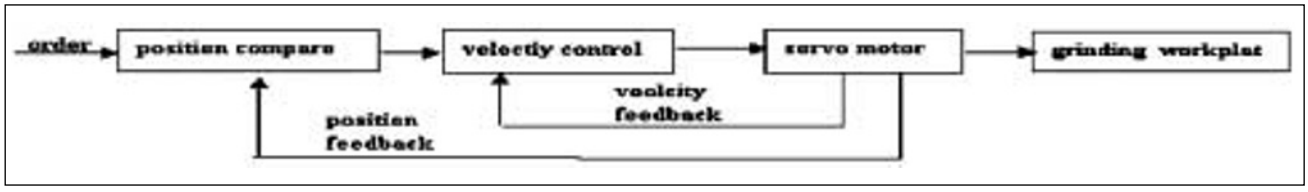

Figure 3 – Control system principle sketch

a circuit. The pulse signal was measured by the counter, the rotation angle can be known. It was transformed to the line displacement. And the manipulator's speed also could be calculated with the displacement within unit time.

2.6 Circuit of the speed controller

To guarantee the electromotor not to strike, lose step, overtake order or surge, contemporary control of the grinding force, the velocity of the manipulator needed be controlled. It must be assured that the velocity starts-up and stops slowly. This was realized through the servo motor's voltage controlling. A stepless timing circuit was designed the centre of which was the use of the DCP (E2POT™ Nonvolatile Digital Potentiometer).

3 SOFTWARE OF THE CONTROLLER

The basic thought of the software was that the control parameter was decided by the original data and the data of the database. After the post-processing stage, the control instruction was output by the computer controller, so the manipulator completed the grinding task. It included the database module graphic module, control module and the failure module.

3.1 Technology realization

Facing object technique was the popular software design method now, it included facing object analysis and facing object procedure. This way solved the problem which could not solve the code's overlap before. Facing object procedure was the design method around real world's concept to organize the model's procedure, it adopted the object to describe the entity of problem space. Visual C++ technology was used to design the controller software of the welding and grinding machine. Its advantage was at the good of the repeated use, the friendship of the interface between the human and computer, the high efficiency.

In general the grinding main parameter was the feed. The transverse feed grinding way last used only at certain speed of the grinding wheel and the smooth move. This method was very simple, but the grinding size was different at different positions, it would bring grinding empty or destroying the grinding manipulator. It was also very dangerous and of low efficiency. In order to improve the state, the equal pressure grinding way was used, namely at the time of grinding, the computer real time measured the pressure and controlled the output parameter, assuring the equal pressure.

When the pressure was larger than the certain one, the controller would make the manipulator move reverse, otherwise move positive. The measure and control of the pressure was the key of the controller. The close-loop control system was followed as shown in Figure 3.

This paper used a force/position blending control method, primarily the force/position axis was chosen, the control type of each joint was certain, and then they were controlled respectively. This design was preceded by the early force control method only based on the force or the position. To realize this kind of project, it required the certain force control axis and the certain position control axis, and the key technique of the transformation from position to force.

Namely examined the position first, the speed was decided by the position, and the force measured was used as the feedback to adjust the speed of the manipulator. The adjustment of the velocity and improvement of the efficient based on the equal force grinding was realized.

3.2 Construction of controller's software (Figure 4)

3.2.1 Graphics module

This module can deal with the data to a certain style and view the true and the ready-repair prototype of the hydraulic turbine guide vane. The control software was programmed at the Visual C++ 6.0 platform and transferred the OpenGL function base. This was due to its easily programming and its quick and simply graphing.

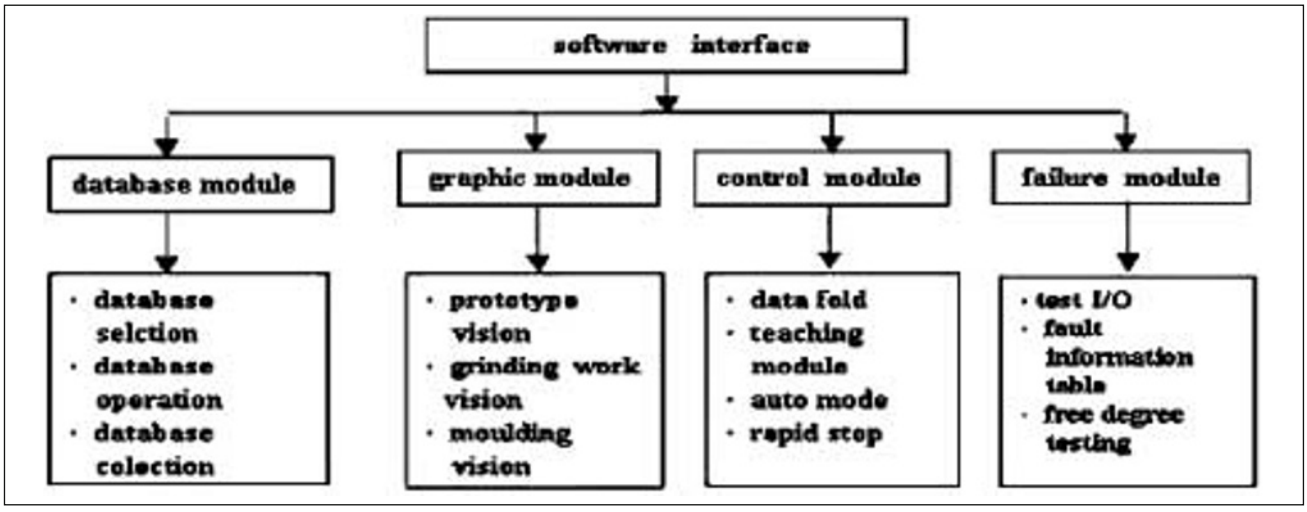

Figure 4 – Control software structure sketch

The OpenGL was an independent and open type of 3-dimension graph standard operation system. OpenGL was an interface between graph and hardware, it included more than 1 000 graph function, we could use them to complete the function of the 3-dimension model and 3-dimension interface. Different from other softwares, the OpenGL provided very clear graph function. Using these function, user could not only use their own data but also the other data fountain. It was transparent to the network, Customer/ Server was its movement mechanism, customers (OpenGL applied procedure) sent out the OpenGL order to the server (OpenGL of inside core) the server then explained and carried out these orders. Generally Customer/ Server run in a single computer, but on the Windows NT platform, OpenGL graphic libraries were encapsulation in the opengl32.dll. Windows NT transfer opengl32.dll. dealing the transfer of the OpenGL function, then transfer winsrv.dll, OpenGLs order again were dealt and sent to Win32 interface of other device drive, finally sent to the graphic order to the vision view drive program.

3.2.2 Database module

Whether the product system or manufacture system, had to establish a unity which could access the data with the information and could analyse the processed system according to the proceeding. The database establishment of the hydraulic turbine guide vane was to transfer the signal from the sensor to the special data, then send these information to the computer. Using the software these information could be viewed and stored. At the same time the hydraulic turbine guide vane standard database had to be established. This paper programmed the database management module with the Visual C++ 6.0. Visual C++ 6.0 provided the program interface to the simple database (Jet Engine) to complicated large database (Oracle). This software adopted the ActiveX Data Object (ADO) (Microsoft) which provided an interface to facing object, with the OLE DB similarly, but connecting more simply and having more extensive characteristics with higher degree of connecting of object. ADO based COM provided the program tool with the VC software. ADO object was similar in the construction to OLE DB, but not depending on the object level of structure. Mostly, user only set up and used the need dealing object. The following object classes constituted the ADO:

– Connection class was used to conjunct with the database, and handle some orders and other business.

– Command class was used to handle the data fountain to deliver the order.

– Recordset class was used to handle the data together, including to obtain and amend the modification data.

– Field class was used to mean the row information of the record concentration, including the row worth with the other information.

– Parameter class was used to transmit the data among the data fountain.

– Property class was used to the other objects property in the ADO of operation.

– Error class was used to acquire the mistake's detail information that took place.

The collection and operation of the database could been completed through these function. In the data gather module dialogue computer was used to complete the data collection of the hydraulic turbine guide vane surface state.

4 CONTROLLER MODULE

Control module was the core part of the software, and the welding and grinding process was its main function (see Figure 5). It included the transfer of the data, the part of the teaching, automation control and rapid stop. The transfer of the data was to make the basic control data according to the grinding workpiece data and the standard work data. The part of the teaching used the former teaching box to realize the hand control grinding, namely realize the equal force grinding control in the Z orientation and the manual control in the X, Y orientation through teaching box. Automatic part would automatically calculate the target work data at the basis of the database. The surface appearance data was the data based on the manipulator plot system and the target order data was the data based the hydraulic turbine guide vane plot system the origin of which was a certain point of the hydraulic turbine guide vane. So we must transform the two data into a unified plot. The process of control module used two close-loop control systems which used the position feedback to realize the exactitude position, and used the force feedback to realize the force control close loop, the grinding stability and reliability could be guaranteed, avoiding the wheel rotate block and crack phenomenon. The controller computed the control quantity according to these two close loop, sent out the manipulator order through a connecting electric circuit, completed the manipulator control.

5 CONCLUSION

This controller of the grinding and welding manipulator was based on the Windows system, and adopted the position/ force cooperation control system. Graphic tech-

Figure 5 – Control software operation interface

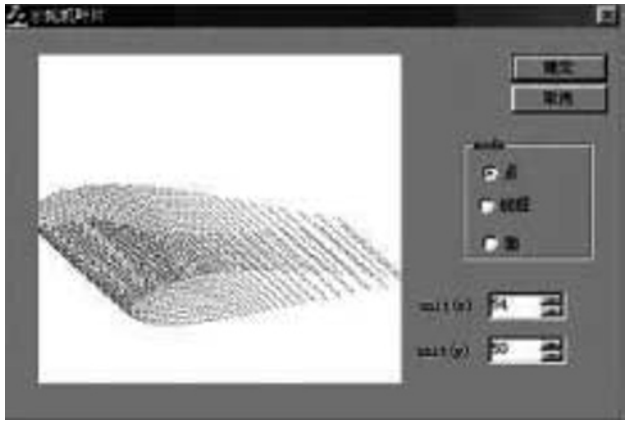

Figure 6 – Hydraulic turbine guide vane graphic

nology, database technology, computer control technology was utilized in this design. Its interface was friendly, it had the well expansibility, agility and economy.

(1) This manipulator could complete 400 × 800 mm^2 space curve superficial welding and grinding.

(2) The final error precision between target data and machining data was smaller than 0.3 mm.

(3) It could realize the hydraulic turbine guide vane 3-D entity graph (see Figure 6).

(4) It had the multi-control function of automation or hand control etc.

REFERENCES

[1] Wang Xijing, Chen Shujin: Applied study of the teaching-playback method for the vacuum electron beam welding, China, Journal of Welding 2002.1, 45-48.

[2] Wang Xijing, Xu Zhenqing, Li Chunxu: Teaching of Manipulator for repairing hydraulic turbine, China, Journal of Gansu University of Technology, 1999.1, 16-19.

[3] Wang Xijing, Wang Xuewu: Trajectory Control of the arc-welding manipulator for repairing hydraulic turbine blade, China, Journal of Gansu University of Technology. 2000.3, 8-11.

[4] Wang Xijing, Zhang Ruihua, Li Heqi: The study of grinding plane system for hydraulic turbine adjustable blade's repairing, China, Journal of Gansu University of Technology, 2000.12, 5-8.

[5] Wang Xijing, Li Heqi, Zhang Ruihua: Development of strip auto-overlaying and auto-grinding set for repairing hydraulic turbine guide vane, China, Large Electric and Hydraulic Turbine, 2000.9, 42-45.

[6] Wang Xijing, Li Heqi, Zhang Ruihua: Auto-positioner and control system for repairing hydraulic turbine guide vane, China, Journal of Gansu University of Technology, 2002.3, 15-18.

[7] Wang Xijing, Ou Zengqiu, Zhang Zhongke: Analysis of arc welding manipulator teaching and playback error and dispel measure, China, Electric Welding Machine, 2002.6, 26-28.