The Development of Numerical Control System of Vertical Rotary Forging Machine

Jian Xiao and Chundong Zhu

Abstract—**Most rotary forging machine can only achieve sequence control, but not monitor current, oil pressure, and displacement. In this paper, we selected Mitsubishi PLC to control the movements of rotary forging machine, while Advantech IPC which integrates with configuration software collect oil pressure, current, displacement signals and monitor the movements of the machine.**

Index Terms—**Rotary forging machine, PLC, configuration software, numerical control system.**

I. Introduction

Rotary forging is a craft of continuous local loading forming [1]. At present, domestic always used relays, PLC and limit switches for controlling rotary forging machine without human machine interface [2]-[4]. This control system defects are simplex and poor interactive. In this paper, the numerical control system selected Mitsubishi PLC and grating sensor to accurately control the movements of the machine. In addition, PLC program can be modified to achieve optimal shaping effect for different machining parts components [5], [6]. Configuration software not only to monitor current, oil pressure, displacement, and other technological parameters, but also has the function of alarm and automatic stop.

II. Numerical Control System

The relationship of rotary forging machine numerical control system shows in Fig. 1. Mitsubishi PLC controls the basic movements and collects some parameter data, while giving most of instructions. IPC collects and analyzes signals of various sensors. Besides, IPC has functions of monitoring, display, alarm, and control. Grating sensor measures the displacement of workbench. Current sensor gathers the main current. Pressure sensor collets the oil pressure of master cylinder. Final, Configuration software analyzes and deals with those data.

A. PLC Programmer of Displacement Signal

Rotary forging machine control segment is mainly controlled by the movement of slider and ejector rod [7]-[9]. The logic movements of machine shows in Fig. 2. Rotary forging machine movements are divided into upward motion of master cylinder, downward motion of master cylinder, upward motion of ejector rod, and downward motion of ejector rod. The master cylinder displacement is measured by the grating sensor and analyzed by the PLC. The delay time of ejector rod can be set by time relay.

In this paper, we select KA300-320 closed grating sensor to measure the displacement of workbench. The pitch of the grating sensor is 0.02mm, and we obtain high precision 5-micron counting pulses after handling in the internal circuit. We select A and B phase photoelectric signal to obtain and judge the displacement of workbench, and then the photoelectric signal are converted into square wave signal [10]. The displacement will be obtained through discriminating and counting square wave signal. KA-300 grating sensor produces 24V square wave signal. Analog and digital inputs are two kinds of input signal of Mitsubishi PLC. The output signal of grating sensor will be input to the internal CPU of PLC for processing. The high-speed counter of PLC is choice to calculate the displacement of workbench.

High-speed counter C251 is part of Mitsubishi PLC to deal with the TTL pulse signal of grating sensor. The high-low A-phase and B-phase signals can be determined by counting increment or decrement of the counter. C251 counts the number of pulse, so we need to convert pulse number into decimal value. PLC program which reads the number of pulse shows in Fig. 3. The 1000 value under C251 represents the grating counted 1000 pulse. We can see that the number of pulse is converted into decimal value in Fig. 4. The final data stored in the D40. The movements of workbench are fast forward, slow forward, and fast backward. The movement is based on the real-time displacement of workbench compared with setup value. The setup values are lower limit, slow forward position, and upper limit, and there are all adjustable.

B. The Acquisition of Current and Oil Pressure Signals

We select MIK series sensor to monitor the main circuit current and oil pressure of rotary forging machine. The characteristics of these sensors are accurate, the result are easy to analyze, and good anti-interference. MIK-DJI sensor shows in Fig. 5. Main circuit wires pass through the 22mm holes of the sensor. The sensor converts main current into 0-10V analogy voltage signal, and then the signal are transmitted to PCI-1711 data acquisition card. MIK-P300 pressure sensor is chose to monitor master cylinder oil pressure. MIK-P300 pressure sensor shows in Fig. 6. The pressure sensor converts pressure into 0-5V analogy voltage signal that can be processed for the PCI-1711 data acquisition card. The card transfer current and oil pressure to configuration software which shows signals for figures and graphs. The PCI-1711 data acquisition card is 12 bit low loss

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card. The card fast deal with displacement signal, current signal, and oil pressure signal. The driver of the card can easy combine the card with configuration software, and it can transmit data to the software to analyze and display charts.

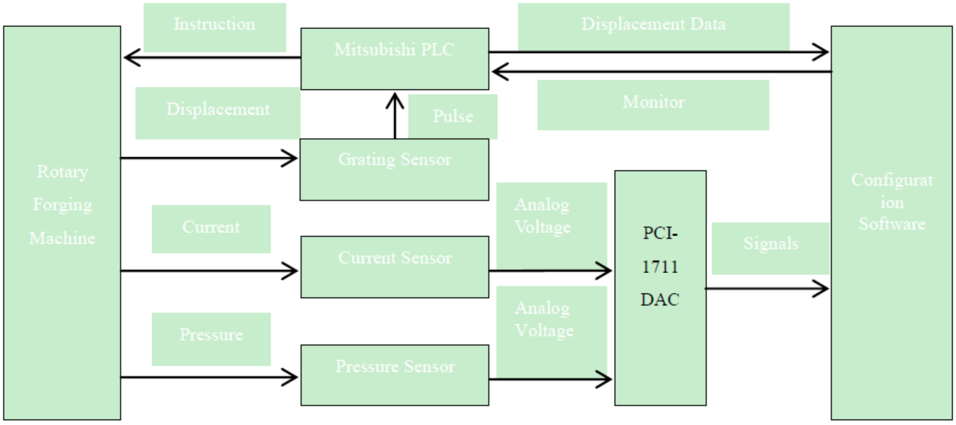

Fig. 1. The relationship of rotary forging machine numerical control system.

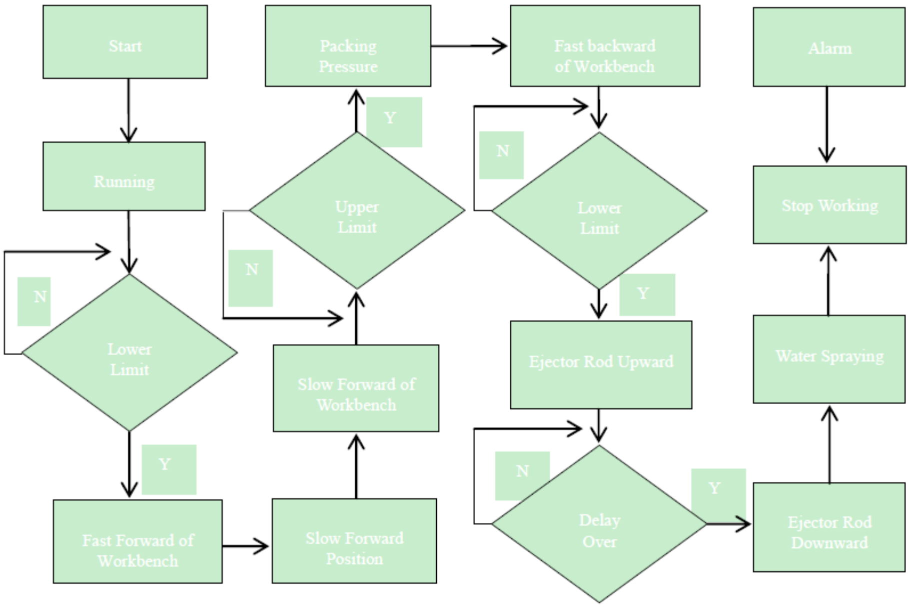

Fig. 2. The logic movements of rotary forging machine.

Software with an integrated display interface is needed to deal with all information of rotary forging machine. We select configuration software to complete interface setup and data processing. Configuration software is compatible with many hardware devices which are external devices of configuration software [11]. The external devices of this system are Mitsubishi Fx2N PLC and Advantech PCI-1711 data acquisition card. The core part of data exchange between Mitsubishi PLC with Advantech data acquisition card is variables database of configuration software.

C. The Monitoring of Configuration Software

Master interface of configuration software shows in Fig. 7. The buttons of switch interface are the master-control interface, alarm window interface, real-time curve interface, history curve interface, database interface, reporting interface, and exit interface. The functions of numerical control system are setting parameter, displaying working status, giving alarm, collecting data, and transferring parameters. The parameters which can be set in this numerical control system are slow forward position, lower limit, upper limit, and delay time. Configuration software directly establishes communication with Mitsubishi PLC to monitor the displacement of workbench. The software reads and displays the displacement from the PLC data registers D40. The displacement can be processed to obtain displacement-time curve and analyze relevant process parameters. Current and oil pressure signals are also transmitted to configuration software, and then the software displays relevant values and real-time curve.

The numerical control system not only implements function of auto control, but also monitors the melding process of rotary forging machine. Monitoring process also includes alarm and pre-procedure. Configuration software integrates powerful industrial control function and supports alarm module. For the melding process of the machine, alarms are produced by IPC which receive abnormal signal from each sensor. There are appropriate PLC procedures to alarm and automatic stop. The functions of alarm and event log are special and necessary modules in configuration software. It also conforms to reliability principle of the development of numerical system. The alarms of the program include variables alarm, operation alarm, user login alarm, and work alarm. Operators can set maximum or minimum limit values for these variables in the alarm interface. The system will monitor and alarm these variables according to these new limit values. Alarm information will be displayed in the alarm interface, when these variables exceed limit values. The information also contains the actual values for checking alarm records.

These signals of numerical control system are workbench displacement signal, current signal and oil pressure signal. Therefore, the alarm groups are main workbench displacement, current, oil pressure. We select overage alarm to monitor the three parameters. For example, workbench displacement is a range of value. There are two limit switches on lower and upper limit position to play a protective role. The lower and upper limit of alarm should be corresponding with the limit position of displacement. Limit switches play a role of pre-warning. The alarm interface includes real-time alarm window and historical alarm window. Real-time alarm window mainly displays the information of real-time alarm and confirm alarm, and the information will disappear from the window as soon as alarm reset. Real-time alarm window only displays recent alarm unless new alarm appears. Historical alarm window displays all alarm information in this system.

Fig. 3. Reading TTL pulses.

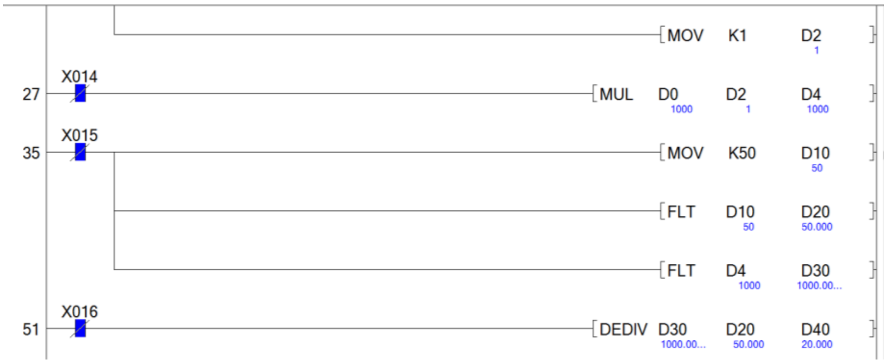

Fig. 4. TTL pulse signal converted into displacement

Fig. 5. MIK-DJI sensor.

Fig. 6. MIK-P300 pressure sensor.

The real-time curve interface and history curve interface of this system all includes current-time curve, pressure-time curve, and displacement-time curve. The curves transformed from real-time or historical data can reflect change trends of parameters. The real-time curve can be rapidly displayed according to the change of variables, and it cannot check the records. The historical curve can check records and play an important role in later process, equipment inspection, data review, and regularity summarization.

Configuration software has powerful compatibility. This is mainly due to the database functions. The software not only can access the database on the IPC, but also can share own database [12]. The database operation of configuration software is relatively complex. The software collects real-time data through sensors and lower computer, and then these data will be converted into decimal numbers or charts. These are real-time feedback of the scene, and operators can adjust process parameters according to the results of the display. Configuration software counts and analyzes displacement current, oil pressure, and other processing parameters. Tables and figures transformed from those data are stored in upper computer. These historical data are important basis for the system to generate status and control process.

In this configuration software, report forms record the changes of sensors values, and those are important record of melding process. We can calculate, convert, analyze, and print the data. Report data are stored in the database in order to increase its stability. The software can directly edit the data in database. The database function is more flexible than huge editing software and reporting systems. These data need store stability and change occasionally, and report system cannot meet these requirements. We chose Microsoft Access database and Office Excel to process data which are related to system information. The configuration software has function of accessing ODBC database. It not only can read data from the external database, but also write data into the external database. The stability of the external database makes data storage guaranteed.

Configuration software has its strong application on the network function. The data in real-time operational status of the machine can be shared and accessed on the internet. Besides, it make possible for remote monitoring [13]-[14]. Sharing on the internet largely strengthen the integrity of the numerical control system.

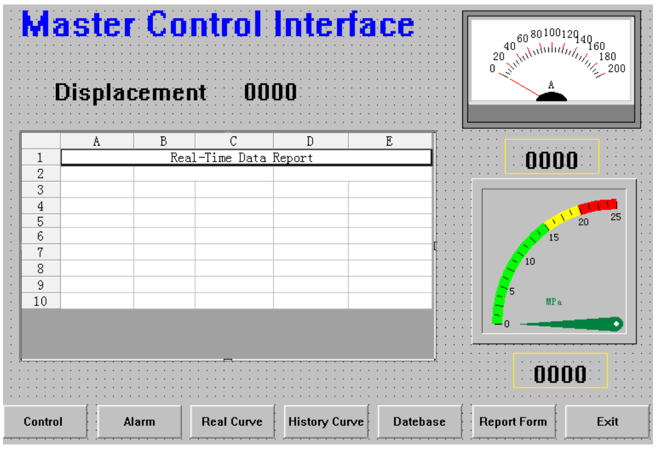

Fig. 7. Master control interface.

III. Conclusion

With the improving of hardware and the intelligent software, the industrial automation intelligent computer will be more and more widely applied in the field of manufacturing. Intelligent computer will perform stable with expert system and PLC control system. It will be the benchmarking of future machinery manufacturing, and greatly improving the production efficiency. In this paper, the numerical control system of vertical forging machine combined Mitsubishi PLC with IPC to realize normal operation of the machine. The machine meets the requirements of production and experiment.

We compiled PLC procedures of rotary forging machine and completed the movement of the machine. Besides, pulse number is converted into decimal value which is easy to obtain workbench displacement. The control interface and function interfaces of configuration software can display workbench displacement, main current, oil pressure and corresponding graphs and process parameters. These data can be converted into corresponding graph and parameters to improve process of rotary forging. In addition, the alarm system assures safety of the melding process of rotary forging machine.

The numerical control system also needs further research. According to different parts processing, the contact area and pressure between swinging head with work piece are the important factors of the forming, so the system needs to add pressure sensors and alignment sensors to monitor pressure of contact positions. The system has realized the basic movement functions and database functions. In order to conform to the intellectualization and of development production machinery, we can establish expert system on the basis of database system in the further, and it can set different process parameters according to different work piece. We can also add a small local area network equipment to adapt the digital and highly efficient of the manufacturing machinery, engineers can realize real-time monitoring and management in the office.

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