Application Research of Frequency Control Technology in Hydraulic Automatic Clamping System

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Abstract. Traditional forms of Hydraulic Clamping System is applied in the Automatic Machining System of machine tool in the past , however its defects are obviously such as relatively complex speed control circuit , large loss of pressure keeping and so on. Aiming at these defects in this paper puts forward a frequency control technology program on the Hydraulic Clamping System, analyzes the principle and application method and the design of the general speed control circuit, propose the calculating and choosing method of the motor speed for the pressure keeping progress. Practical application shows that the automatic clamping system with frequency control technology can simplify the circuit, make the speed control more convenient, and have positive affect on energy saving, noise reducing and cooling in the process of processing and holding pressure.

Introduction

In numerical control machining, using the automatic clamping of the work piece can further improve the automation degree of the machining process, and significantly improve the production efficiency, so the application of automatic clamping mechanism is more and more extensive. In machining automatic clamping system by gas dynamic type, electric type, hydraulic type and the hydraulic automatic clamping system has convenient layout, small volume, clamping force. Traditional hydraulic automatic clamping system is the ordinary AC motor driven oil pump, motor output speed constant to the motor directly regulate output flow of the pump so as to adjust the speed of movement of the cylinder, its governor mainly two: one is by increasing the throttle loop settings to adjust the flow system, namely the throttle; the second is the variable pump volume changes in the way to adjust the flow in the system, namely the volume control. Throttle speed control mode has simple forms, reliable work, low cost, and very low movement speed, etc., but speed loop poor rigidity, loops are relatively complex and not easy to achieve multiple speed regulation; due to the presence of throttling loss and overflow loss, low efficiency and oil temperature rise significantly, affect the system's stability. In the volume control circuit, pump output flow with pressure increasing and decreases, efficiency is relatively high, less heat, but also exists a constant speed and in small flow pump for high speed rotation, noise, depletion, the packing is more obvious. In addition, the hydraulic circuit is more complex and difficult to implement when the clamping process requires some movement changes. In short, the traditional hydraulic automatic clamping system has the defects of the above, it has important significance to overcome these defects.

Application of frequency conversion technology in the automatic hydraulic clamping system, using the advantages of stepless speed regulation performance can reduce energy consumption, can achieve a variety of movement speed of operation process, simple clamping action control, has a good application prospect, the article summarized by means of theoretical analysis and experimental verification, on the application method were studied.

General State and Process Analysis of the Clamping System

Work piece clamping system is an important part of the machine tool processing system, not only to provide sufficient and stable clamping force, but also can according to the requirements of the processing and positioning, clamping characteristics requirements to achieve the corresponding sequence of movements and changes. Fig. 1 is the automatic clamping system diagram, Fig. 2 is a general clamping movement sequence diagram. As Fig. 2 shows, in order to improve the efficiency, the clamping system should has the characteristics of rapid; but in order to protect the work piece, when the clamping body close to the work piece should slow implementation of slow clamping; in the process should keep clamping force; form "fast forward, slowly into the, clamping, stop holding pressure (process), rewind, in situ stop working cycle. The rapid movement of the clamping body has obvious efficiency in the clamping and moving stroke.

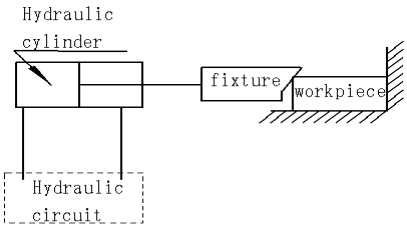


Fig. 1 Schematic diagram of the hydraulic automatic clamping system.

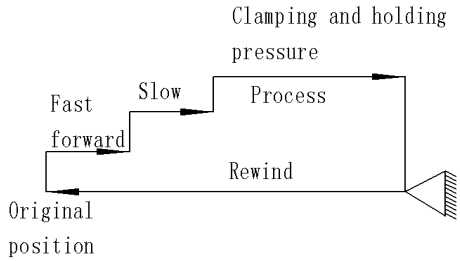


Fig. 2 Automatic clamping working cycle diagram.

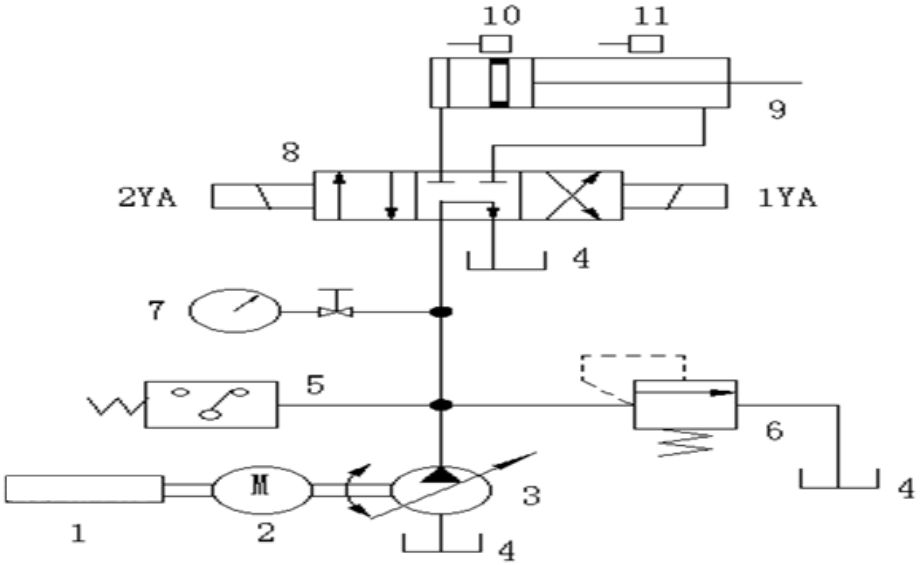
At the same time, in the process of clamping and holding pressure, the flow is not needed in theory, but in order to keep the pressure, the motor and pump need to work. Can also use the accumulator to keep pressure, but the circuit is more complex and it is not necessarily suitable for a variety of functional requirements of the occasion.

The Principle and Advantages of the Application of Variable Frequency Speed Control Technology in the Automatic Hydraulic Clamping System

Application Principle and Method Analysis. As shown in Fig. 2, in order to improve the efficiency but also realize the soft clamping, in the automatic clamping work cycle, from the start, fast forward, fast forward, slow in, slow to enter stop holding pressure to stop holding pressure, rewind, these processes have the speed change, relying on AC frequency conversion technology to realize the automatic adjustment of the motor speed, thus changing the speed of pump, in the clamping movement process realize automatic speed regulation, the pump output flow and system, the working cycle to adapt; In the clamping pressure maintaining process automatically reduce the speed, can effectively reduce the loss of overflow, effectively save energy, effectively reduce the noise and temperature.

Fig. 3 for the use of frequency control technology of the general hydraulic automatic clamping system schematic, figure out a number of auxiliary components.

In the use of variable frequency speed c**o**ntrol technology of automatic hydraulic clamping system, in order to adapt to the action of the automatic clamping system variability, the force and the flow variability and rapid response to ensure system performance and more effectively reduce the energy consumption of the system, still use of variable pump as the pump.



1-Variable frequency controller 2-Frequency conversion motor 3-Oil pump 4-Tank 5-Pressure relay 6-Relief valve 7-Pressure gauge 8-Reversing valve 9-Cylinder 10, 11-Position sensing element
Fig. 3 Hydraulic automatic clamping system circuit.

In this circuit, the sensing element (also can be used as a micro switch) is used as the signal detecting element of the speed change, and the pressure switch is used as the detecting element of the clamping and holding voltage signal. System working process: The working process of the system: when 2YA is energized, reversing valve 8 in left work, variable frequency controller 1 control motor 2 together with 3 pump for high speed, oil by reversing valve 8 arrive at the cylinder 9 and the left chamber, piston rod quickly moves to the right achieve fast forward; Clamping body movement is close to the set position of the work piece, position sensor 11 signal, frequency conversion controller 1 to control the motor 2 to reduce speed and pump 3 speed decreases, reduce the flow, the piston rod to slow down the rate of implementation in slow motion; When the clamping body comes into contact with the work piece, clamping pressure increased to set by the relief valve of the specified value, enters the holding pressure, pressure relay 5 signal, frequency controller to control the motor 2 automatic deceleration to a lower setting value and maintain, maintain the state of pressure keeping, thereby greatly reducing low depletion, avoiding each cycle are required to start the motor and pump. When the work is finished, the operation sequence is: Issued by a machine tool system signal to the valve 4 and inverter 1 - 2YA power-off, 1YA energized, reversing valve 8 turn right, motor and pump 3 for high speed flow increase -- cylinder piston rod quickly back to achieve the action back to the origin position sensor 10 issued signal 1YA power -- reversing valve 8 back to bits, slow down the speed of motor 1 and clamping system into a cycle.

According to the frequency conversion characteristic, the motor speed is proportional to the frequency. The high speed and slow speed of all kinds of state is not necessarily the same, it should be determined according to the actual requirements, and determine the corresponding frequency according to the characteristic of the frequency converter.

Calculation and Selection of Motor Speed and Energy Saving Analysis in the Process of Holding Pressure. As mentioned above, although the application of variable frequency speed control technology, but in order to achieve better performance, the use of variable pump is still a reasonable choice, so this paper according to the variable pump analysis.

After entering the processing state of pressure keeping, cylinder work no longer need to flow, this is don't need high-speed operation of motor and pump, by electrical control to reduce the motor speed to a suitable value, to achieve energy saving and reducing consumption and noise and oil temperature rise. When the motor work in less than the rated frequency, the output power (frequency corresponding to the rated power) with frequency decreases (is speed decreases)

decreases. Therefore, it is necessary to check nuclear power and the speed of calculation. Therefore, the selection principle of the rotational speed value of the holding pressure process is: ① It is not less than the minimum operating speed required by the oil pump; ② The motor can output power to meet the needs of the working power of the oil pump. That is

$$\begin{cases} n_b \geq n_{\min} \\ P_{mb} = P_m\left(n_b\right) \geq P_{yb} \end{cases} \tag{1}$$

$P_{mb}(n_b)$ express P_{mb} is the functional relationship of n_b, by the properties of the frequency conversion system decided; P_{yb} is the input power for holding pressure oil pump is required to obtain , the unit *kW*.

According to the pump power - speed - flow - pressure relationship, there are

$$\begin{cases} P_{yb} = \dfrac{p_b Q_{0b}}{60\eta_m} \\ Q_{0b} = q_{0b} n_{0b} 10^{-3} \end{cases} \tag{2}$$

combination type (1), (2), pressure maintaining the rotation speed of the motor and pump nb for the calculation of the choices are as follows:

$$\begin{cases} \dfrac{p_b q_{0b} n_b k_s}{6\times 10^4 \eta_m} = P_{mb} \\ n_b \geq n_{\min} \end{cases} \tag{3}$$

Formula (3) suitable for any power speed characteristics of the frequency conversion system.

Generally, the lower limit of the pump speed n_{min} is much larger than the lower limit of the frequency conversion motor, which can not consider the limit of the lower limit of the motor speed.

Energy Saving Principle. According to the formula (3), have to

$$P_{mbs} - P_{mb0} = \frac{P_{mb}}{k_s} - P_{mb0} = \frac{p_b q_{0b}}{6\times 10^4 \eta_m}\left(n_0 - n_b\right) \tag{4}$$

Formula (4) can be turned into

$$\Delta P_{mb} = \frac{p_b q_{0b}}{6\times 10^4 \eta_m} \Delta n_b \tag{5}$$

Thus obtained

$$\Delta W_{mb} = t_b \Delta P_{mb} \tag{6}$$

Among them, ΔW_{mb} is the processing and packing process according to the low speed motor by high speed operation work of the decline is such value difference; t_b is the total pressure processing time. When the packing speed n_b decreased significantly, Δn_b increased obviously to reduce power difference ΔP_{mb} increased significantly, at the same time, running noise and oil temperature rise also decreased significantly. And from the formula (6) that power reduced difference ΔP_{mb} is large, processing security pressure total time t_b is long, motor acting difference is big, energy saving effect is more obvious.

Application Examples and Effects

This example is a company in a CNC milling machine on a part of the design of the automatic hydraulic clamping system using frequency control technology, the system schematic diagram shown in Fig. 3. In the example, the selected variable frequency motor maximum continuous power

of 1.5KW (corresponding to the rated frequency), rated synchronous speed 1500rpm, using variable piston pump, rated capacity 15.8mL/min, mechanical efficiency of 0.94, lower speed 400rpm; determine the work holding pressure of 4MPa, check the pump pressure, displacement characteristic curve was corresponding to the pump displacement is 11.3 mL/r. Preliminary selection of the motor speed n_b = 500(*rpm*), According to the characteristic of the frequency conversion system, the output power of the motor is 0.5kW, and the safety factor of 1.2 is chosen. The above equations of type (3) of the first equation, k_s = 1.25, to meet the requirements, therefore the determination of n_b = 500(*rpm*).

The examples and other similar machine system in traditional hydraulic automatic clamping system are compared, power consumption, noise and temperature of operation decreased significantly, the rough determination, power consumption is reduced about 50%.

Concluding remarks

Compared with the traditional hydraulic automatic clamping system, application of frequency control technology to the automatic hydraulic clamping system, through the electrical control and frequency conversion controller, variable frequency motor automatic control, the utility model has the advantages of convenient clamping speed adjustment, flexible and clamping operation and reliable; Processing speed automatic packing process is reduced, effectively reduce waste, noise and oil temperature, improve the efficiency of the system and to ensure that the stability of the system.

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