DESIGN AND IMPLEMENTATION OF COMPLETELY AUTOMATIC AND CONTINUAL PRODUCTION LINE FOR WATER-IN-OIL (W/O) EMULSION EXPLOSIVE[①]

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ABSTRACT The completely automatic and continual production line for the W/O emulsion explosive is the first example in P. R. China. The assembly line can implement really automatic charge mixing, automatic adjusting charge ratio, automatic adjusting output, automatic packing and so on. Its composition and working principle were introduced briefly, and the automatic control means and strategy for the temperature, the flow, the charge mixing and the charge ratio in continual production process of the W/O emulsion explosive were expounded.

Key words W/O emulsion explosive automatic adjusting charge ratio automatic charge mixing automatic adjusting output

1 INTRODUCTION

Explosive is one of the tremendous energy resources which people often utilize. It is not only used in military purposes, but also used extensively in various sectors of national economic production. Particularly, the W/O emulsion explosive[1], which is developed in the last 20 years, flies its own colors in industrial explosive field and is paid universal attention by explosive specialists for its noticeable performances and characteristics such as safety, reliability, high susceptibility and strong anti-water property. The W/O emulsion explosive items are still increasing continuously[2], they are competitively used in metallurgy, chemical engineering, coal and other mineral resources mining, hydroelectric construction and so on.

However, the W/O emulsion explosive is a new-comer in industrial explosive field after all. Its developing time is not long, and many problems are waiting to be made out and studied[3], in which, the research for the continual and efficient emulsifying facilities, the packing machines, the measure and control system is the key to accomplishing large-scale production of the W/O emulsion explosive and is also a problem which needs urgently to be solved.

The references [2 - 6] introduced particularly the production technology, equipment, items and qualities of the W/O emulsion explosive, measuring methods and so on. This paper will expound the design and implementation of the microcomputer control system for the first continual production line of the W/O emulsion explosive in our country, it can only supply reference for those people who are engaged in explosives or computer automatic production.

2 TECHNOLOGICAL PRODUCTION PROCESS OF W/O EMULSION EXPLOSIVE AND ITS REQUIREMENTS TO AUTOMATIC CONTROL SYSTEM

2.1 Technological production process

The W/O emulsion explosive consists of water-phase (including water, ammonium nitrate, sodium nitrate, ammonium chloride and

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other ingredients), oil-phase (including lubricating oil, compound wax, emulsifier, and other ingredients), and foaming agent (including lubricating oil or diesel oil, sodium sub-nitrate and other ingredients) in an appropriate ratio and technological requirements. Its production includes roughly the four processes as follows[6]:

(1) The water-phase preparation

Water, ammonium nitrate, sodium nitrate and ammonium chloride are added into the water-phase melting tank in an appropriate ratio, heated and stirred until they are all dissolved in water, finally pumped into the water-phase saving tank for being ready to be used.

(2) The oil-phase preparation

Lubricating oil, compound wax and emulsifier are heated and melted respectively in three pre-melting tanks, then flow into the oil-phase mixing tank in an appropriate ratio. The mixture is kept warm till being used up.

(3) The foaming agent preparation

Diesel oil or lubricating oil and sodium sub-nitrate are poured into the foaming agent tank in an appropriate ratio, with being stirred continuously the foaming agent is made ready.

(4) The mixing and packing process

If the three-phase materials are got ready, the oil-phase and water-phase materials can be pumped into the continual emulsifying facilities (the rough emulsifying facility and the fine emulsifying facility) in an appropriate ratio by a gear pump and a screw pump according to the presetting start sequence and time interval. The W/O emulsion is formed under the powerful shearing stress of the emulsifying facilities' curved-leaf wheels. The W/O emulsion is pumped into the mixer via cooling pipes. In the mixer, the W/O emulsion and the foaming agent pumped by a metering pump are compounded into explosive, finally, the explosive is sent to the packers to be packed.

2.2 Technological requirements to automatic control system

(1) The oil-phase and water-phase materials can be automatically charged in the preset weight and ratio. The measuring and controlling error is less than 1 %.

(2) The temperatures of the three oil-phase pre-melting tanks, the oil-phase mixing tank, the water-phase melting and storing tanks can be respectively controlled at their given values. The measuring and controlling error is less than 1 %.

(3) The shredder and the screw conveying machine can automatically start and stop in required sequence and time interval.

(4) The mixing and packing facilities can automatically start and stop in required sequence and time interval.

(5) Three-phase flows can be controlled respectively at their given values. The measuring and controlling error is less than 1 %.

(6) On mixing and packing, the production assembly line can stop automatically and warn correspondingly if whichever happens as follows: ① the oil-phase mixing tank or the water-phase storing tank or the foaming making-tank is lack of material; ② there is any breakdown with the mixing and packing units; ③ the charging height in the explosive buffer reaches the limited position.

(7) The production output can be adjusted automatically according to the packers' ability in order that the automation of the whole production assembly line is implemented.

3 FUNCTIONS AND IMPLEMENTATIONS OF CONTROL SYSTEM

The technological process of the W/O emulsion explosive is a rather complex production process of chemical industry. Many technological parameters need measuring and controlling. Thus, the computer system is required to have control and management functions in order to satisfy completely technological requirements and accomplish automation of the entire production line. On considering worse production environment and the requirement to reliability of production, the two level computer monitor-control system[7] is adopted: let IPC-850 (Industrial Process Computer) be management level, and PLC (Programmable Logic Controller) control level. The entire system's basic structure is displayed as Fig.1.

3.1 Subsystem for temperature control

Temperature is a very important parameter in the process of the W/O emulsion explosive production. It can affect directly the quality and output of products[4,6]. For example, if the temperatures of the oil-phase and water-phase materials are properly high, the viscosity of fluid is low, the resistance of pipe is little, the fluid is easy to flow and emulsify, and the basic emulsion is well-distributed. However, if the temperatures are too high, the tendency of the distributed liquid drops, agglutination, amalgamation and exclusiveness are increased at the same time, the stability of the basic emulsion is bad, the storing time of the products is short. It is proved that each of these materials has its own optimum temperature which can guarantee all performance goals of the products so as not to affect the output of explosive. Therefore, it is required that the control system can adjust the temperatures of the lubricating oil, compound wax and emulsifier to given values. The materials are heated indirectly by saturated steam, and the control ways to the temperatures are nearly similar. The composition and working principle are explained, exemplifying the temperature of the oil-phase mixture, as shown in Fig. 2, namely, the value of given temperature, YT_{4r}, is input by keyboard or from the database according to the technological requirement; the actual temperature YT_4 is detected by sensor, transferred into standard signal by converter, sampled by A/D channel, and the feedback temperature YT_{4f} is obtained. By comparative operation of arithmetic in the computer, the temperature error ΔYT_4 is got. Because of heating indirectly, the system's heat inertia is severe, the pure delay is very long, and the random disturbance exists in the working circumstance. Therefore, the intelligent algorithm[8,9] is adopted in order to assure control precision: firsty, the characteristic value (such as the amount, the direction) of temperature error is picked up; secondly, the control signal is computed by inference and algorithm; thirdly, the control signal is output from PLC I/O channels (Y46 and Y47) to adjust electric valve's opening degree by judgement and decision. The on-off ratio control method can reduce the ripple of the controlled temperature in order to guarantee

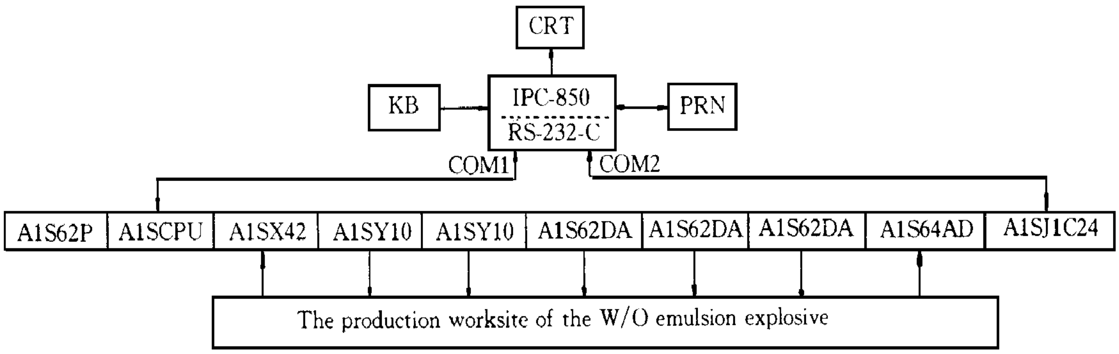

Fig.1 Structure block diagram of two-level computer system

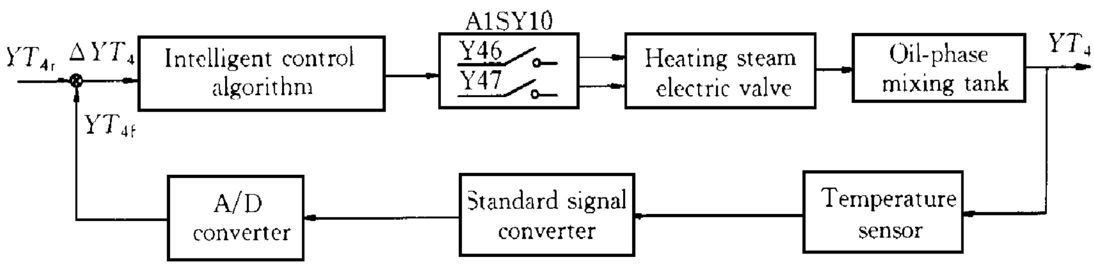

Fig.2 Temperature control principle block diagram of oil-phase mixing tank

control precision.

The intelligent control algorithm is described as follows: let T be the control cycle, t_{on} be the time in which Y46 turns on in a cycle T, and t_{off} be the time in which Y47 turns on in a cycle T. Because Y46 and Y47 can't turn on at the same time (normally, work in turn), $T = t_{on} + t_{off}$. During debugging in worksite, T was selected 120 s so as not to shorten the valve's life because of its frequent operation and in order to assure control precision. The referring and deciding process is shown as Fig.3. Correspondingly, the valve's opening degree and the varying temperature curve are drawn as Fig.4, i.e.

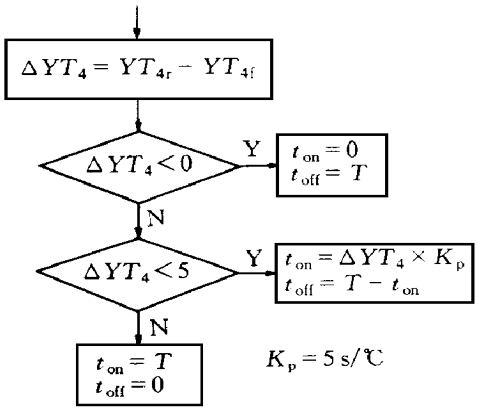

Fig.3 Referring process and control algorithm

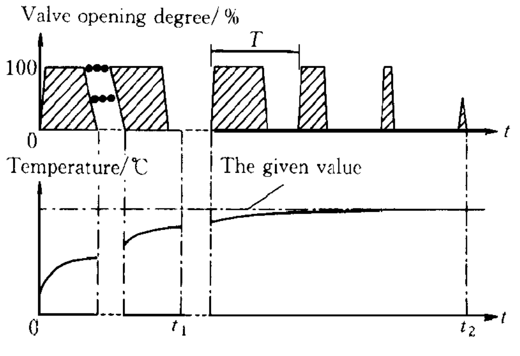

Fig.4 Valve opening degree and temperature curve

(1) During $0 \sim t_1$, $t_{on} = T$, Y46 turns on, Y47 turns off, the heating steam valve is fully opened, and the temperature rises quickly.

(2) During $t_1 \sim t_2$, the on-off time of Y46 and Y47 is controlled, the temperature rise slowly to the given value YT_{4r}.

(3) After t_2, $t_{off} = T$, Y46 turns off, Y47 turns on, until the temperature drifts off YT_{4r}, Y46 and Y47 alternatively work again to assure the temperature is near the given value YT_{4r}, and the absolute error is less than 1 ℃.

3.2 Subsystem for automatic charge mixture

In production of the W/O emulsion explosive, the charges mixing operation is rather strenuous. If the productivity is 1 200 kg/h, eight workers and technicians are needed to charges mixing continually. Because of the worse circumstance (high noise, tensely irritant odor), manual charge mixing is easy to mistake. As a result, the quality of products is low and can't reach the required performance standard. The automatic charge mixing system is designed to reduce workers' labor intensity, guarantee accuracy of charge mixture, and promote automatic degree of the production assembly line.

The oil-phase mass of three ingredients and the water-phase mass of two ingredients are weighed respectively by electronic balances. Lubricating oil, compound wax and emulsifier are poured one by one into the oil-phase mixture tank via electric valves; water and ammonium nitrate are put one after another into the water-phase melting tank via electromagnetic valve, the screw conveying machine and shredder. The block diagrams of the system structures and the control algorithm are about the same, exemplifying the weighing control system of oil-phase mixture tank, the working principle is illustrated as Fig.5.

The total mass of desired oil-phase materials is input by keyboard, the computer can calculate the needful mass of each material according to the charge ratio of three ingredients. If the oil-phase charge mixing is permitted, three kind of materials (lubricating oil, compound wax and emulsifier) are poured into the tank and weighed in turn by the output points of AISY10 module controlling corresponding electric valve.

Because the discharging pipe is large in diameter (6 cm), the distance from the discharging

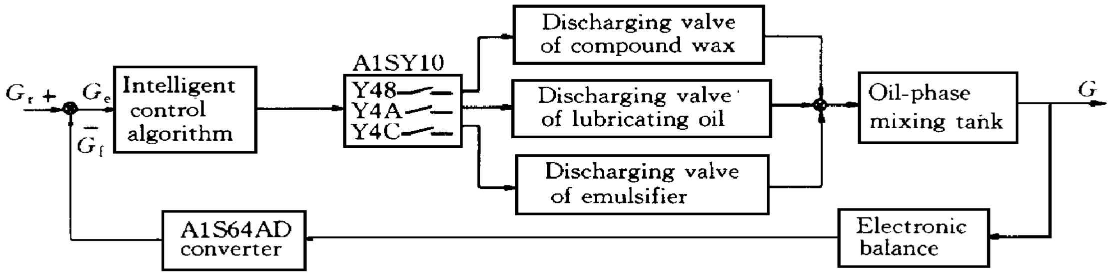

Fig.5 Principle block diagram of oil-phase automatic charge mixture system

valves to oil-phase mixing tank is long, in such case, the remainder in the pipe will influence the mass of oil-phase in a while even if the discharging valve is closed, and the amount of remainder is indefinite as a result of the influence of the material temperature, the flow and the liquid height of three pre-melting tanks, the following means are taken in order that charge mixture is quick and accurate.

On condition that G_r is the given value of the mass, G_f is the detective value, $G_e = G_r - G_f$ is the error value.

(1) If $G_e > 10$ kg, the opening degree of the discharging valve is set on 100 %;

(2) If 3 kg $< G_e \leqslant 10$ kg, the opening degree of the discharging valve is set on 20 %;

(3) If $G_e \leqslant 3$ kg, the discharging valve is closed.

The practical result proves that the mentioned-above weighing and controlling means enables charge ratio error to be less than ±1 %, and accord with technological request.

3.3 Subsystem for charge ratio control

As above-mentioned, the W/O emulsion explosive is formed when three-phase materials are mixed and emulsified according to technological charge ratio strictly. For this reason, whether the charge ratio is accurate or not will directly affect the quality of product[5]. In this system, the charge ratio control is accomplished by controlling respectively the flows of oil-phase, water-phase and foaming agent.

The oil-phase and the water-phase materials are conveyed separately by screw pump and gear pump which are driven by two sets of alternating current speed-adjusted system. Therefore, the control of the flows of oil-phase and water-phase may be transformed into the adjustment to the frequencies of the converters. The foaming agent is conveyed by metering pump, hence, the control of the flow of foaming agent is transformed into the regulation to the stroke of the metering pump. The flows adjusting principle of three-phase materials and control algorithms are nearly same. The working principle is expounded in the example of the control to oil-phase flow. The structure block diagram of control system is illustrated as Fig.6.

In Fig.6, YQ_r is the given value of oil-phase flow which is calculated according to the productivity and the charge ratio. The system is

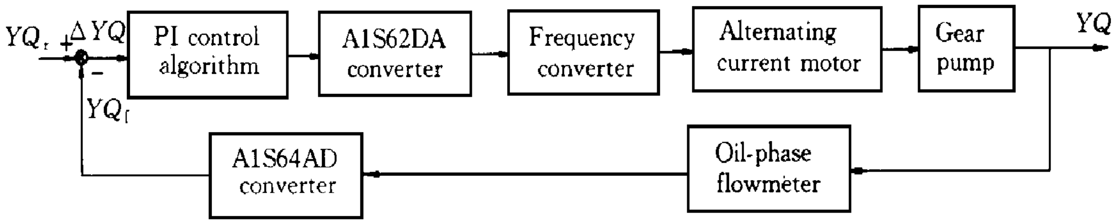

Fig.6 Control principle block diagram of oil-phase

put to use in opening loop at the beginning. The output current (via D/A channel in the module AIS62DA) is determined by the given value of the flow. After 15 s of working in such way, the flow displayed on the flowmeter is nearly stable and comes close to the given value, but it does not accord with the demand of precision. The main factors which affect the precision are the temperature of fluid, the viscosity of fluid, the resistance of pipe, the leak and the reflux of the gear pump, and so on. So it is necessary to make further improvement on the control precision that the opening loop control is replaced by the closed loop proportion integral (PI) control algorithm[10]. The running results show that the control strategy is successful and effective. It can not only start the system quickly, but also make its output (YQ) track its input (YQ_r) rapidly, avoid the harm about which the an integral saturation brings because the integral algorithm is applied to the controlled object with evident inertia and pure delay, and make the control precision accord with the technological requirement to charge ratio.

3.4 Subsystem for production output adjustment

The most outstanding characteristic of the microcomputer monitor and control system is that the output can be adjusted automatically according to the capacity of packer, which make the whole production assembly line work automatically and most efficiently. The way is described in detail as follows.

The pressure buffer is installed in front of the packer. The height of buffer is defined as six levels. A proximity switch is fixed at each level. Its action is controlled by the height of charging (explosive). When the buffer is empty, the six proximity switches are all opened, otherwise, they are closed. The ON-OFF states are detected by the module AISX42.

In the beginning, the whole system runs at the rated capacity of packer, after ten minutes, the computer decides whether to increase or decrease output in terms of the states of proximity switches:

(1) If the proximity switches are all opened, the output is increased progressively by 4 % each five minutes;

(2) If only one proximity switch is closed, the output is increased progressively by 2 % each five minutes;

(3) If two proximity switches are closed, the output is increased progressively by 1 % each five minutes;

(4) If three proximity switches are closed, it shows that the production facilities work at an optimum output neither increased nor decreased;

(5) If four proximity switches are closed, the output is decreased progressively by 2 % each five minutes;

(6) If five proximity switches are closed, the output is decreased progressively by 4 % each five minutes;

(7) If six proximity switches are all closed, the entire mixing equipment is stopped except the packer(s) until the height of explosive in buffer descends to normal position.

The maximum variation of output increased or decreased can't be beyond a half of the rated output. It is mainly restricted by the full scale of flowmeter, the conveying capacity of pipe and the working ability of the other apparatuses, such as screw pump, gear pump, metering pump and so on. The interval (five minutes) of increasing or decreasing output is decided on the basis of the flow in pipe, the capacity of buffer and debugging in worksite. If it is too long, the output can't be adjusted in time so as to make the height of charging in buffer too high, result in accidents, and affect normal production; if it is too short, the output is regulated frequently so as to disturb stable running of equipment, particularly, make the flows of three phases ripple heavily, result in wrong charge ratio, consequently, waste or substandard product rate goes up. All these are not desired in the system.

The running result indicates that adjusting output as the mentioned above means not only guarantees the product quality, but also enables the assembly line to work fully.

4 CONCLUSIONS

The system has been put into production in a chemical plant. The running results indicate that it achieves completely the goal of design and accords with the requirement of safety and reliability. It includes automatic operation, manual operation, control, management, warn, chain lock, and other functions. The operation and maintain are very easy. The performance of product is excellent. It greatly improves the productive ability of the W/O emulsion explosive in our country, brings about economic and technological benefit in business and society, and sets the scene for the system design of the W/O emulsion explosive continual and automatic production.

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