An equivalent flow control system with single-chip computer realizing PWM signals

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ABSTRACT

This paper presents an equivalent flow control system used to crude oil heating furnace. In the system, actuator is a set of electro-hydraulic servo system, and the controller is digital controller in which a Intel 8098 single-chip computer is the core. This paper gives a minute description of sampling, data process, control algorithm, and the realizing method about whole system.

KEYWORDS

Electro-hydraulic Control System, Flow Equivalent Control, PWM

1. INTRODUCTION

The crude oil heating furnace is an equipment in which the crude petroleum oil is heated to separate the mixture of lower-boiling hydrocarbons out of it and retain the stable compositions of crude oil in normal temperature. In the entrance to heating furnace, the oil pipe is often divided into a number of branched heat exchange pipes. Because the characteristic of each heat exchange pipe is different, the discharges in heat exchange pipes often are not obtained equivalent naturally. In the pipe with more resistance, the discharge is smaller and the velocity is lower, and in the pipe with less resistance, the discharge is larger and the velocity is higher. Therefore, the temperatures in every heat exchange pipes are different due to difference of the velocities. If the flame is even in the furnace, the temperature of crude oil is higher in the pipe with lower velocity, and the temperature is lower in the pipe with higher velocity. In the course of time, in the pipe with lower velocity, the paraffin should occurs. This should affect the heat exchange, even trouble, that the pipe is stoped up or is cracked, occurs. Therefore, it is important to keep the flows in every heat exchange...
pipes be equivalent.

To keep the flow be equivalent in every heat exchange pipes, an adjusting system is installed in a heating furnace with four heat exchange pipes, as shown in figure 1.

The flow adjusting equipment consists of four adjusting valves installed in the entrances of heat exchange pipes. As adjusting poppet displacement of the valves, the flows in every heat exchange pipes can be changed, thus keeping the flows equivalent.

The change of poppet displacement of adjusting valve is realized by a set of electro-hydraulic servo system which is controlled by a single-chip computer. In the system, the flow signals $q_i$ ($i = 1, 2, 3, 4$) in the entrance of four pipes and the temperature signals $T_i$ ($i = 1, 2, 3, 4$) in outlets of four pipes are sampled. Then, these signals are compensated and filtered, and after they are processed by a specific control algorithm, the corresponding pulse width modulation (PWM) signals are exported by single-chip computer. The PWM signals are integrated by integrating circuit, so as to obtain continuous analog signals. Then these signals are amplified by servo amplifications and drive electro-hydraulic servo valves. Therefore, the cylinders move so as to change the poppet displacements of adjusting valves. The principle is shown in figure 2.

2. HYDRAULIC CONTROL CIRCUIT

In the system, the hydraulic circuit principle figure is shown in figure 3.

Because in the system the displacement of pistons is very small, and the system is intermittent work, the hydraulic system uses a accumulator as main power, and has a charging pump. The system pressure is watched and controlled by the pressure switch. Working pressure is stabilized by reducing valve. The relief valve is used as safety valve. The pressure in servo valve is switched by directional valve. As the piston of-
ten keeps at a position, hydraulic lock is installed at each circuit so as to make the piston not act in a longer time. The hydraulic locks are switched by spool shut-off valve.

The working principle of the system follows. When the flows $q_i (i = 1, 2, 3, 4)$ or oil temperatures $T_i (i = 1, 2, 3, 4)$ in four heat exchange pipes become to unequivalent, the single-chip computer gives out controlling signals, to turn directional valve and spool shut-off valve on, so that the hydraulic control system can act under the pressure supplied by accumulator. The analog control signals from single-chip computer make electro-hydraulic servo valves act so as to drive the cylinders. Then the poppet displacements of adjusting valves are changed, so that the purpose of change flows is realized. When the flows in the pipes are adjusted to equivalent, the single-chip computer turns the directional valve and spool shut-off valve off, so as to keep the positions until next adjust process.

When the oil pressure of the hydraulic system is below some value, pressure switch turn on, and charging pump starts charging oil to the hydraulic system till the pressure rises to the maximum.

3. SINGLE-CHIP COMPUTER CONTROLLER

3.1. Construction of the Controller

In the adjusting system, the data sample, data process, the realization of control algorithm, etc, all are accomplished by a controller which consists of single-chip computer system. The principle figure is shown in figure 4.

The core of the controller is a Intel 8098 single-chip computer. The chip is a quai-16bit micro-processor. The computer has four channels inner A/D converter which accomplish a converting in $22 \mu s$. Utilizing the HSO (High Speed Output) parts in the computer, more channels PWM signal output can be realized. The computer also have efficient instruction system and flexible timers, so that it is very suitable to use the computer in industry control.

In the controller as shown in Fig. 4, executing and calculating of program are accomplished by a chip of program memory (EPROM 2764,8k), a chip of data memory (SRAM 6264,8k) and 232 bit registers in 8098 single-chip computer. The man-machine interface, for instance display of data and input of control keys etc, are accomplished by a general display/key control IC 8279. Digital value I/O, involving the directional valve control signal, the pressure measuring of hydraulic system, and oil filter resistance alarm etc, uses a chip of programmable general interface 8255 to realize.

In analog channels, the input signals are four channels of flow $q_i (i = 1, 2, 3, 4)$ and four channels of temperature $T_i (i = 1, 2, 3, 4)$. Because the 8098 computer have only four channels of inner A/D, a more channels analog switch is used to realize sampling the
q, and \( T_i \) \((i = 1,2,3,4)\) alternately. The analog output signals are the signals which controls the electro–hydraulic servo valve. They are realized by four channels of PWM output through HSO parts in 8098 computer. The PWM signals, after been integrated by integral circuits, change into smooth analog signals. The analog signals can drive the electro–hydraulic servo valves after they are amplified by servo amplifications.

3.2. Data Processing of Sampling Signals

The flow signals \( q_i \) and temperature signals \( T_i \) \((i = 1,2,3,4)\) which were obtained by A / D converting, have to carry out nonlinear compensating and digital filtering.

Flow measure uses orifice meters. The flow \( q \) is calculated by pressure difference \( \Delta P \) between sides of orifice. The expression follows.

\[
q = K \sqrt{\Delta P}
\]  

(1)

Where \( K \) is a coefficient which is concerned with actuating medium and the dimensions of orifice. From expression (1), the relation between \( q \) and \( \Delta P \) is nonlinear. In the fact, sampling signal is pressure difference \( \Delta P \). It have to be calculated with expression (1) to obtain \( q \). In order to ensure the control process real–time, the relation values between \( q \) and \( \Delta P \) are calculated beforehand and put in EPROM. In the process of real controlling, \( q \) values corresponding with measuring \( \Delta P \) are obtained by reading up the table. In the controller, the range of \( \Delta P \) (0 ~ 1.6MPa) is separated equally to 200 parts, 0.08 MPa per–interval. The linear correcting is realized in higher precision.

The temperature measure uses semiconductor temperature sensors. Because the linearness is better, the temperature signals do not been corrected in the controller.

Because distance between control room and worksite is distanter, a large disturb signal exists, though all signals have been converted into electric current source. In the controller, the sample signals are processed with a digital filter. Two step digital filtering is used here. First step filter uses the method of middle value arithmetic average complex filter. After \( n \) numbers of sampling values \( x(i) \) are arranged in the order and the two maximum values and two mimimum values are removed, a arithmetic average value is calculated with remained values.

\[
y(j) = \frac{1}{n-4} \left( \sum_{i=1}^{n-4} x(i) - x_{max} - x_{min} - x_{max-4} - x_{min-4} \right)
\]  

(2)

Where \( y(j) \) is \( j \)th filter value; \( x(i) \) is sampling value; \( x_{max} \) and \( x_{min} \) are maximum and minimum in the \( n \) sampling values.
\[ x_{\text{max}} = \max\{x(i)\} \]
\[ x_{\text{min}} = \min\{x(i)\} \]

\[ x_{\text{max}-1} \text{ and } x_{\text{min}-1} \] are second maximum and second minimum.

The second step filter uses the method of smooth recurrence average filter. The first step filtering values \( y(j) \) are made up a cycle formation, the length is \( m \). A new \( y(j) \) is located at end of the formation, and the first element of the formation is removed. The average value the formation is the filter values.

\[
z(k) = \frac{y(k) + y(k-1) + y(k-2) + \cdots + y(k-m-1)}{m}
\]
\[
= \frac{1}{m} \sum_{i=1}^{m-1} y(k-i)
\] (3)

This method is quick and smooth. Through two step filter, the sample signals are purified, especially the background noise is restrained effectively.

3.3. Control Algorithm and Program Structure

In the system, the flow closed loop is a main loop, and temperature loop is an auxiliary loop.

The purpose of flow closed loop is to keep flows of four pipes tend to equiponderate. Taking average value \( q_{\text{m}} \) of four flow values \( q_i \) \( (i = 1, 2, 3, 4) \) as setting signal, and the error values \( e_q \) between setting value and real sampling value as control signals, the PWM signals can be exported. The block figure is shown in Fig. 5.

![Fig.5 Control algorithm](image)

On normal condition, if flows are equivalent in every pipes, the temperatures are also equal approximately. At this time, the temperature signals are only used as watching signals and not control signals. But, under some unusual condition, that the temperatures of every pipes are not equal though the flows are equal, the temperature closed loop control is necessary. Because the temperature is a kind of slower change value, the control signals have to be both error \( e_T \) and error change \( e_{dT} \). The relation among \( e_T \), \( e_{dT} \) and control value is obtained by reading up table which is calculated preliminarily. The control program is shown in Fig. 6.

The program, in addition to the main structure as shown in Fig.6, have some auxiliary function, for example, super—temperature alarming, trouble alarming, watchdog etc.
4. CONCLUSION

The equivalent flow control system uses a controller in which the single-chip computer is the core. The system has advantages of structure simpler, cost less, the realization of control algorithm more convenient, reliability higher, etc. The property satisfies the using require.

REFERENCES