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Application of Improved Smith Predictive Control Compensation Scheme In Multi Point Temperature Control System

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Abstract: This paper introduces the compensation principle and function of Smith predictor in the pure lag control system, and analyzes its disadvantages and puts forward the improvement scheme. Constant temperature object is selected in the glass furnace temperature control, using the improved Smith predictor to obtain the successful application of the compensator. Compared with the conventional Smith control, the improved Smith predictive compensation control has the advantage that the KP value of the control object is not needed to be controlled. To adapt to the general industrial production process, there is a pure lag control system, there is a greater value of popularization and application.

Keywords: improved type; Smith predictor; constant temperature control;

I. INTRODUCTION

In the process of industrial production, the time delay system is very common. Due to the existence of the pure lag, it is not conducive to the stability of the closed loop system, so that the quality of the closed-loop system is decreased. Therefore, the pure lag system is always a difficult control system in the industrial process. Studies have shown that process with pure time delay on the control system of the quality effect does not depend on the lag time of the absolute value, but and inertial time constant T (T / T) than the size related, so usually tau / T to measure whether the process with large time delay. Usually when tau; when /T is greater than 0.5, should be used as the delay process, need to use the advanced special control.

Smith predictor is a predictive compensation controller to overcome the large time delay. It in pure lag system closed-loop characteristic equation containing pure lag consequent, in PID feedback control based on the introduced a predictive compensation link and the closed-loop characteristic equation does not contain pure lag consequent, the control quality is improved. On the basis of an improved adaptive Smith predictor, the proposed algorithm is used to adjust the delay time of the predictor on line, which constitutes a parameter self tuning Smith predictor.

II. SMITH PREDICTIVE COMPENSATION SCHEME PRINCIPLE

The size of the object is usually used to measure time delay process and time delay process equivalent time constant T ratio is /T. /T ratio becomes more difficult to control, when /T>0.3 ~ 0.5, become the system with large delay system. In the production process often encountered large pure lag object, to solve this type of object automatic control problems often use Smith estimation compensation scheme, the principle diagram of the control system is shown in figure 1.

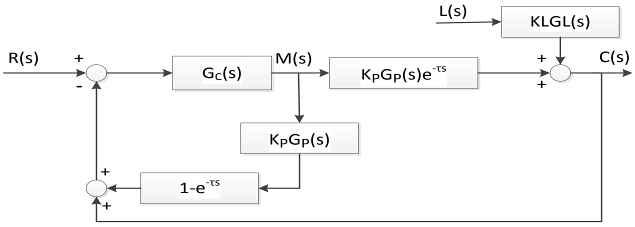

Figure 1 Smith predictive compensation control system diagram

The transfer function of the closed loop system can be derived from Figure 1：

$$\frac{C(s)}{R(s)} = \frac{K_P G_P(s) G_C(s) e^{-\tau s}}{1+K_P G_P(s) G_C(s)}$$

and

$$\frac{C(s)}{L(s)} = \frac{KLGL(s)[1+K_P G_P(s) G_C(s)(1-e^{-\tau s})]}{1+K_P G_P(s) G_C(s)}$$

Obviously, from the above two type, whether the given value change or load disturbance, their closed-loop system characteristic equation KPGP 1+ (s) GC (s) = 0 is the same, and in the characteristic equation does not contain the pure lag factor. This can improve the dynamic quality of the closed loop system by increasing the gain of the regulator GC (s).

But we through the field application that the biggest drawback of this scheme is the mathematical model of process object requirements are too stringent, especially object static magnifying multiples KP values change of regulation effect especially serious when the entire system will have strong oscillations in the, ISE (error square integral) metrics over complete compensation more than 10 times. The reason, the author thinks that when the KP values deviate from the ideal value, caused is the compensation object and the corresponding values for the absolute change, and not like time constant T and pure delay time tau that, as long as the parameter variation range is not big, the result is to be quick and slow response of the compensation object and not cause an imbalance in the system. Thus the Smith compensation scheme, the process object KP value measurement must have sufficient accuracy, and other parameters can be relatively relaxed some of the requirements. But in the actual operation to accurately measure the extraction process the the object of KP is difficult to do, to try to reduce the parameters of the object measured accuracy requirements, and strive to improve the robustness of the system, the author of Smith prediction compensation scheme do the following adjustments.

III. IMPROVED SMITH PREDICTIVE COMPENSATION CONTROL SCHEME

The schematic diagram of the improved Smith predictive compensation control scheme is shown in Figure 2.

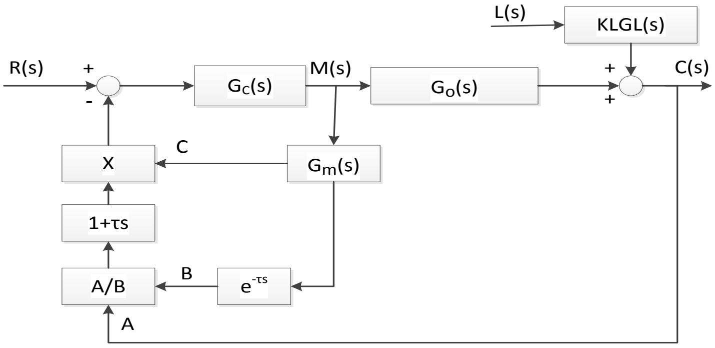

Fig. 2 block diagram of improved Smith predictor

In the Figure 2, $G_O(s)= K_P G_P(s) e^{-\tau s}$

$Gm(s) = K_P G_P(s)$

The system is characterized in that the original Smith compensation scheme in object go (s) a output and compensation model output B subtraction was renamed to phase in addition to the original model GM (s) output C and a and B compensation deviations from additivity change C output and the recognizer output multiplication. Identified here is (1 + taus) is a link ahead, ahead of time constant and pure delay time constant tau equal. It is mainly from the signal will be leading role. When the model GM (s) EUI taus and real object dynamic characteristic go (s) exactly equal, namely go (s) = GM (s) EUI taus, figure 2 divider output is always 1, the recognizer output is 1 when Figure 2 is transformed for the equivalent system of Figure 3.

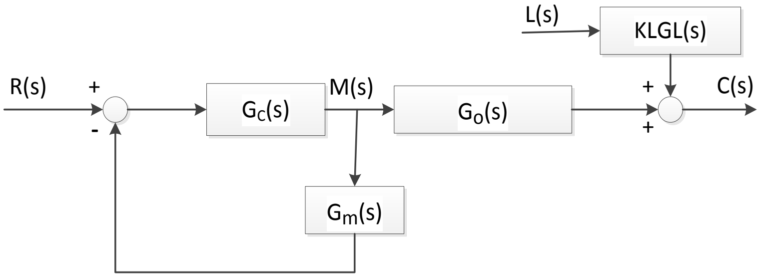

Fig. 3 the complete compensation equivalent system block diagram

From figure 3,

$$\frac{C(s)}{R(s)} = \frac{G_C(s)}{1 + G_C(s)G_m(s)} G_O(s) = \frac{G_C(s)G_m(s)}{1 + G_C(s)G_m(s)} e^{-\tau s}$$

Type GO (s) = Gm (s) e- s, if L (s) = 0, the representation of the system and the original Smith compensation scheme of the same. When there is a deviation between the model and real object dynamic characteristic, the system shown in Figure 2 will play the role of adaptive. As seen from the compensation principle, if the generalized object magnification coefficient change, should be the object predictor model magnification also can produce the same changes completely, so that it can achieve the ideal compensation. Now generalized object of KP increases to KP+ delta K, and assuming the other parameters unchanged, figure 2 A / b = (KP+ delta K) / KP and due to the status recognition (1 + taus) in differential taus doesn't work, identifying the output device is (KP+ delta K) / KP, this value and GM (s) multiplying the output of the input to the controller as the feedback, because of the product of the decision to transfer function.

$$\frac{K_P + \Delta K}{K_P} Gm(s) = \frac{K_P + \Delta K}{K_P} K_P G_P(s) = (K_P + \Delta K) G_P(s)$$

Therefore, the amount of feedback also increases the delta K, this is achieved in the new conditions of the complete compensation. When the KP is reduced to the generalized object (KP- K), apparently had the same effect. In addition, the differential effect of the identifier is actually a dynamic compensation. It obtains a signal to identify the change trends and the direction of change of B A/. For example, if a K is increasing with time, the compensation lines offer pre compensation. The change of the B A/ ratio and the role of the identifier can be compensated by the change of the pure time delay of the generalized object. It can be seen that the identification circuit can be equivalent to a variable coefficient KV amplification link, KV depends on the difference between the real characteristics of the generalized object and the predictor model. When the output of the model is less than the output of the generalized object, divider output increases, which is equivalent to identifying circuit kV increases, so that the system still compensate. Vice when the model output is greater than the output of the generalized object (s) go, due to the decrease of the divider output, which is in kV decreases and achieve the ideal compensation. Figure 4 shows the schematic diagram of this kind of analysis.

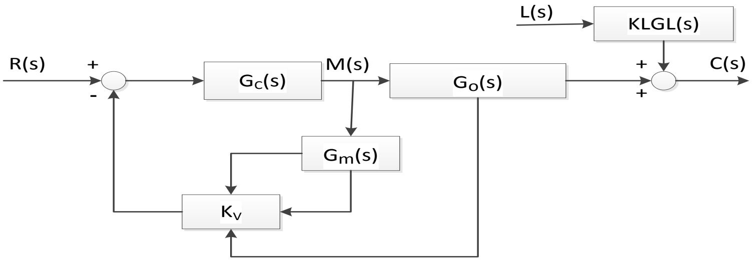

Fig. 4 equivalent system of incomplete compensation

IV. APPLICATION EXAMPLES

The workpiece is heated to a certain temperature before rolling in the steel rolling shop. Figure 5 shows one of the heating section temperature control system. Before using the conventional PID control, due to the pure lag and parameter variable control ability is insufficient, it is difficult to achieve the ideal control effect; also used pure lag compensation Smith, heating furnace of pure lag compensation, system control quality greatly improved, however, due to the heating furnace object description model characteristics, resulting in in fact can not be sufficiently accurate mathematical model, the pure lag compensation control quality is seriously affected; here the use of improved Smith compensation scheme can not only overcome the pure time delay effects on control system, and the model is not accurate for certain amendments. So, with variable gain adaptive compensation, achieve good control quality.

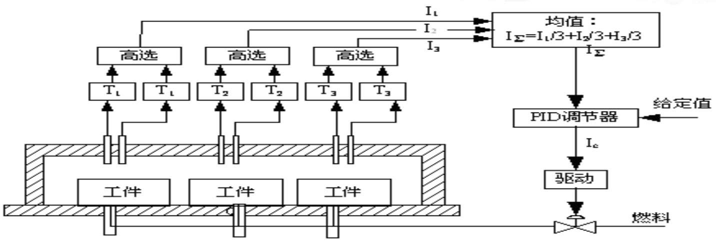

Fig. 5 temperature control system of heating furnace

In the picture, six sets of temperature transmitter, three high value selector, one adder, one PID regulator and one electric converter system are used. The system transfer function for the output of the heating furnace temperature is obtained by using the step response identification:

$$G_1(s) = \frac{T(s)}{I_m(s)} = \frac{10e^{-60s}}{120s + 1} °C/mA$$

Temperature measurement and the transfer function of the transmitter is:

$$G_2(s) = \frac{I_{\sum}(s)}{T(s)} = \frac{0.106e^{-20s}}{10s + 1} °C/mA$$

System transfer function:

$$G = G_1(s)G_2(s) = \frac{1.06e^{-80s}}{(120s + 1)(10s + 1)}$$

As $10s+1=e^{10S}$, therefore can be simplified as:

$$G(s) = \frac{1.06e^{-90s}}{120s + 1}$$

With Simulink in MATLAB drawing simulation diagram as follows:

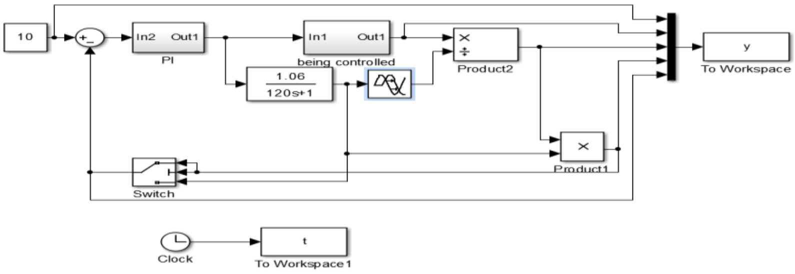

Fig. 6 block diagram of system simulation Simulink

Dual ramp function is used to simulate the disturbance, and the amplitude of the controlled object is changed (minimum 0.795, maximum 1.272). Simulation results are:

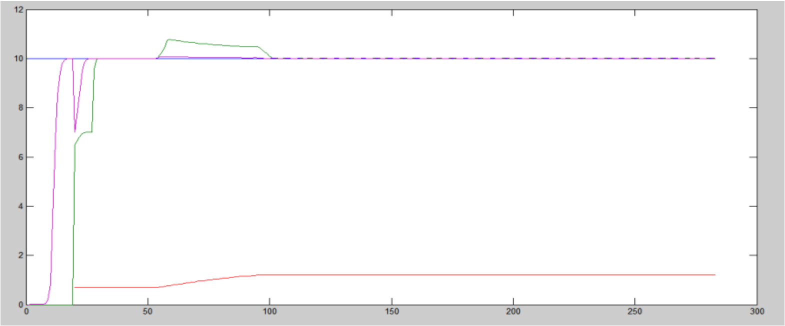

Fig. 7 simulation results

It can be seen from the figure, although be to know the amplitude of the object has changed greatly (minimum 0.795, maximum of 1.272) and large delay system model is not accurate in the estimated the improved compensation control mode, the system output and not too much volatility.

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