Simulation and Analyzing on Model Parameters Effect of BISRA-AGC

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Abstract

According to the control principle of pressure AGC, the control thought and control model of BISRA-AGC were analyzed. By changing the external disturbance of rolling force and sampling time, the BISRA-AGC and Dynamic Set AGC were simulated under the conditions that the position control system was ideal by using GUI. Then, the advantages and disadvantages were analyzed combining the results of simulation, and the intrinsic factors were quantitatively analyzed.

Keywords: BISRA-AGC; model parameters; simulation

1. Introduction

BISRA-AGC made a beginning of using elastic plastic deformation equation to calculate rolled piece thickness, and the following pressure AGC models were developed based on BISRA-AGC. As the simplest pressure AGC, BISRA-AGC only takes the mill modulus into account. So the BISRA-AGC has some disadvantages, such as the elastic-plastic deformation equation was linear which affects the thickness calculation precision of rolled piece. Moreover, the dynamic response characteristics of BISRA-AGC were undesirable without the consideration of mill reduction efficiency compensation \([1]\).

In practice, the parameters about mill and rolled pieces were hardly consistence between the control models and the actual mill. As a result, the system astringency, stability, static error and regulating time

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should be influenced. Based on the control model and algorithm of pressure AGC, the simulation of system dynamic regulation was carried out with Matlab GUI software, and the influence of the system quality with the mill and rolling parameters were also deduced and analyzed with the correlation theory.

**Nomenclature**

| Symbol | Description |
|--------|-------------|
| Δh     | thickness variation; |
| ΔP     | actual force variation; |
| ΔS₀    | roll gap variation; |
| ΔS'    | roll gap regulating variable; |
| S'     | roll gap reference value; |
| APC    | automatic position control; |
| S      | actual roll gap; |
| ΔP_d   | force disturbance; |
| K      | modulus coefficient; |
| M₀     | actual mill modulus; |
| M      | model mill modulus; |
| Q₀     | actual plastic coefficient; |
| Q      | model plastic coefficient; |
| ΔP_s   | force variation with the roll gap variation; |
| ΔPₙ    | force variation in sampling n; |
| ΔSₙ'   | roll gap regulating variable in sampling n. |

\[
A = \frac{Q}{M}, B = \frac{M + Q}{M^2}, C = \frac{M₀Q₀}{M₀ + Q₀}
\]

2. **Sampling simulation and analysis of BISRA AGC**

BISRA-AGC used a calculate thickness as the thickness reference (namely Locked thickness). In the rolling processing, the thickness was controlled under the detection of the incremental signal of the force and roll gap on the delivery side, from which the whole thickness can be controlled under the range of the locked thickness, and the same plate gauge was improved.

The control block diagram of BISRA-AGC was shown in Fig.1. The BISRA-AGC was based on the elastic-plastic deformation equation, the real-time force variation ΔP and roll gap variation ΔS can be detected in the rolling processing, from which the thickness variation can be expressed as
\( \Delta h = \Delta S_0 + \Delta P / M \). In order to make the \( \Delta h = 0 \), the roll gap should be adjusted to compensate the mill spring with the force variation. The roll gap regulation value was expressed as:

\[
\Delta S^* = -\frac{\Delta P}{M} \tag{1}
\]

Fig. 1. Control block diagram of BISRA-AGC

2.1. Regulating process of BISRA-AGC

As the input disturbance, suppose \( \Delta P_d \) was a step signal. Assume the APC was an ideal control system, which means the roll gap adjustment can be finished in one cycle. The adjustment processing was analyzed in the following:

Suppose that the system was on a stable condition without thickness deviation before the external disturbances occurred. At the beginning of the roll force disturbance \( \Delta P_d \) applied on the system, there was no roll gap adjustment, that is \( \Delta S_0^* = 0 \). Set \( n = 0 \), the \( \Delta h_0 \) can be expressed as \( \Delta h_0 = \frac{\Delta P_d}{M} \).

At the first sampling (n=1):

\[
\Delta S_1^* = -\frac{\Delta P_d}{M} \tag{2}
\]

\[
\Delta P_1 = \Delta P_d \left( 1 + \frac{C}{M} \right) \tag{3}
\]

At the second sampling (n=2):

\[
\Delta S_2^* = -\frac{\Delta P_1}{M} = -\frac{\Delta P_d}{M} \left( 1 + \frac{C}{M} \right) \tag{4}
\]

\[
\Delta P_2 = \Delta P_d \left[ 1 + \frac{C}{M} + \left( \frac{C}{M} \right)^2 \right] \tag{5}
\]

At the third sampling (n=3):

\[
\Delta S_3^* = -\frac{1}{M} \Delta P_d \left[ 1 + \frac{C}{M} + \left( \frac{C}{M} \right)^2 \right] \tag{6}
\]

\[
\Delta P_3 = \Delta P_d \left[ 1 + \frac{C}{M} + \left( \frac{C}{M} \right)^2 + \left( \frac{C}{M} \right)^3 \right] \tag{7}
\]

In the same way, the roll gap regulation and force variation in sampling \( n \) can be deduced as:

\[
\Delta S_n^* = -\frac{1}{M} \Delta P_d \sum_{m=1}^{n} \left( \frac{C}{M} \right)^{m-1} \tag{8}
\]

\[
\Delta P_n = \Delta P_d \sum_{m=n}^{\infty} \left( \frac{C}{M} \right)^m \tag{9}
\]
The convergence condition was $C < M$. When $C < M$

$$n = 0, \Delta \theta_0 = \frac{\Delta P_d}{M_0}$$

When $n \geq 1$,

$$\Delta \theta_n = \frac{\Delta P_d}{M_0} \sum_{m=0}^{n} \left( \frac{C}{M} \right)^m - \frac{1}{M} \Delta P_d \sum_{m=1}^{n} \left( \frac{C}{M} \right)^{m-1} \tag{10}$$

With the summation formation of the geometric progression,

When $n \to \infty$,

$$\Delta \theta = \frac{\Delta P_d}{M_0} \cdot \frac{M - M_0}{M - C} \tag{11}$$

When $C > M$, the system was divergent.

2.2. Introduction of the simulation interfaces

Based on the BISRA-AGC actual adjustment processing, combined with the input parameters, such as the initial external force disturbances, model modulus of mill and rolled piece and so on, the software can draw the thickness variation automatically after each sampling, and the theoretical finally thickness variation can be shown in the left side. The simulation times can be set in the lower left quarter, and the sharper shape can be shown with a narrower step, just as shown in Fig.2.

![Fig. 2. Simulation interface](image)

2.3. System performance analysis of the BISRA-AGC

In the following section, combined with the Matlab GUI interface, the simulation of BISRA-AGC adjustment processing was carried out. According to the practical situation of the hot rolling processing, set $M=1500\text{kN/mm}$, $M_0=1600\text{kN/mm}$, $Q=1000\text{kN/mm}$, $Q_0=900\text{kN/mm}$, and the value of $C$ was 576 kN/mm ( $C = \frac{M_0 Q_0}{M_0 + Q_0}$ ).

Because of $M > C$, the system was convergent. In order to get a clearer simulation result, set the initial external force disturbances $\Delta P_d=1500\text{kN}$, and the sampling number was 10, the sampling step equals 0.1.
The simulation result was illustrated in Fig.3, which shows that the system was stable after the 7th adjustment, and the static error was -0.101mm.

Whereafter, the influence of the model mill modulus on the system adjustment was analyzed. Set $M_0 = 1600 \text{kN/mm}$, $Q=1000 \text{kN/mm}$, $Q_0 = 900 \text{kN/mm}$, by changing the value of $M$, the simulation comparison of system adjustment with the different $M$ could be obtained. During the simulation, the sampling number was set at 20, and sampling step was set at 0.1, and the simulation results were shown in Fig.3. According to the simulation results, the conclusions were obtained as following: the static error was relative to the deviation between $M$ and actual value, the greater deviation, the greater static error. The greater $M$, the less adjustment times, and faster convergence, from the Eq.10, the system condition of convergence was $M > C$, otherwise it can result the status of fig.3, and the dynamic adjustment of BISRA AGC has no relationship with the $Q$, which provides a facility for the adjustment.

From the simulation results of Fig.3, even if the system was under in ideal condition (that is $M = M_0$, $Q = Q_0$, and system static error was zero), the system reached stable condition through 5-6 adjustments at least. A faster convergence means more static errors, on the contrary, the adjustable speed can be influenced by the requirement of system accuracy. Therefore, the BISRA-AGC can not meet the demand in both accuracy and efficiency.
With a gain factor $K$, and the adjustment of $M$ can be taken into account with $K$, which can make the system more adjustable.

![Control schematic diagram of improvement BISRA-AGC](image)

Fig. 6. Control schematic diagram of improvement BISRA-AGC

### 3. Conclusion

Combined with the regulating process of BISRA-AGC deduced with the theory, a deeply analysis of the domination principle of BISRA-AGC was carried out. Using the simulation software made by GUI tools of Matlab, the system performance was analyzed, and the influences of mill modulus to the system performance were obtained, which verified the correctness of the theory formula. The limitation of BISRA-AGC was also discussed, and the improvement approach was put forward. Based on the improvement approach, the thickness control system would be improved.

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