The Effect of Parameters on PI Control for Hydraulic Looper Control in Hot Rolling Mill

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Abstract. In this paper, the influence of PI controller on hydraulic looper control was analyzed, especially the effect of proportional coefficient $KP$ and integral action time. The PI controller can adjust the stock and tension of the strip according to the deviation between actual value and set value. At the same time, the PI controller has many parameters, such as proportional coefficient, integral action time. The effect of parameters on the output of PI controller was analyzed and tested by programming. The influence law of proportional coefficient is that with increasing the proportional coefficient, the output of PI controller increases and the trend is significant. And the influence law of integral action time is that as the integral action time increases, the output of PI controller decreases. At first, the trend of decrease is remarkable and then weak. This analysis can be used to deepen the understanding of PI controller, then give a positive effect on hydraulic looper control in hot rolling mill, to get an efficient and effective controlling result.

1. Introduction
The influence of hydraulic looper control on the quality of rolling product is significant. The hydraulic looper can affect the tension of strip during rolling process. Zhang et al.\textsuperscript{[1]} conducted experiments to analyze the effect of hydraulic looper control on tension of the strip and then check the precision of the strip. It shows that a large tension can result in a narrow size of the strip. The set tension of F6 hydraulic looper is 10.8 MPa, and the max tension reached 19.5 MPa. And the proper tension should be set as 10 MPa according to the experience. So the enlargement of tension leads to the narrow head width. Ji et al.\textsuperscript{[2]} analyzed the problems of traditional hydraulic looper control system. A soft touch method was employed to make a better touch of hydraulic looper on strip. A good control of hydraulic looper can benefit the thickness deviation. Especially, the high precision of hydraulic looper control can enhance the quality of strip head and tail. Li et al.\textsuperscript{[3]} used a new hydraulic looper control system to replace the old one. An effective and efficient calculation method is useful to perform a more accurate hydraulic looper angle and tension. It is successfully employed in the hot strip mill plant in Baosteel. Zou et al.\textsuperscript{[4]} investigated a hydraulic looper control system which is used for hot strip mill. They explained that the interaction of strip stock and strip tension is harmful to the tension control of the hot rolled strip. So the effort was devoted to the control algorithm. Zhong et al.\textsuperscript{[5]} developed an innovotive nonlinear control scheme to be traced. Then it can be used to affect the hydraulic looper and tension system in the hot strip rolling process. The simulation of this method is conducted and showed effectiveness. Zhong and Wang.\textsuperscript{[6]} developed the sliding model control of hydraulic looper-tension,
aimed to make a stable control of hydraulic looper in hot rolling process. This model is a nearly linearized model. This solution is well-known to its simplicity characteristics and robustness. The simulation of this method is also better than the conventional ones.

The related references conducted investigation on the hydraulic looper control, however, limited paper focused on the effect of parameters of PI controller on the output of PI controller, which is significant to the hydraulic looper control. In this paper, the influence of parameters on the output of PI controller related to the hot rolling data was investigated. The algorithm was also programmed to make a quantity test.

2. Application of PI controller
This paragraph follows a section title so it should not be indented. PI controller is generally used in the hydraulic looper control in hot strip rolling process. In level 1, the PI controller can be used to adjust the deviation of set value of strip stock and target value. In the strip tension control, the PI controller was also employed to make a precision control. The PI controller is in the stock and tension function part. The PI controller is used for stock and tension calculation and adjustment. This function block is in the HLC control program. By searching the level 1 in HLC control program, the PI control block can be got. The control cascade can be generally made to a three stage with the help of PI controller, that is position--speed--torque. At the same time, it can also be set to a relatively short stage. A two cascade of parameters can also be set, that is position--torque in terms of strip tension control. The important parameters such as proportional coefficient KP, integral action time TN and sample time TA, can affect the result of PI controller effectively. And the output of controller in the plan traditionally is generated and limited to the rang between +1 and -1, in terms of servo valve opening in a normalized calculation.

3. The algorithm of PI controller
The algorithm of PI controller is important. And it can be used to explain that how the PI controller deals with the input value and output value. And it also illustrates the relationship of these different parameters. The algorithm of the PI controller used in this hot strip mill is illustrated in the following part. Based on the algorithm of PI controller, the code was programmed for analysis. The specific algorithm of PI controller is illustrated as follows:

\[
Y_n = Y_{n-1} + KP \cdot \left[ (1 + TA/TN) \cdot YE_n - YE_{n-1} \right]
\]

where, \( Y_n \) is the value from Y in sampling interval n; \( Y_{n-1} \) is the value from Y in sampling interval n-1; \( KP \) is the proportional coefficient; \( TA \) is the sample time that is configured according to the function block and it is related to the sampling times; \( TN \) is the integral action time; \( YE_n \) is system deviation, that is derived from the former function block in sampling interval n; and \( YE_{n-1} \) is system deviation, that is derived from the former function block in sampling interval n-1. The former function block calculates the deviation between set value and actual value and transfer the result to this block. For example, in the stock calculation part, the system deviation \( YE \) is the deviation between set value of stock and actual value of stock. The algorithm was programmed to evaluate the effect of parameters on the output of the PI controller. A small segment of the whole program is given as follows:

\[
Dy=Kp\times[(1+TA/TN)\timesYE\ (i)-YE\ (i-1)]
\]

\[
y \ (n)=y(n-1)+Dy
\]

End.

4. Results and discussion
The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used. After programming the algorithm, the effect of process parameters, that is proportional coefficient and integral action time, on the output of PI controller was analyzed. The results were drawn and shown in the following part. And the discussion was given.
In this part, the effect of TN on the output was analyzed. The value of KP is set as a constant value of 500. And the TN is varied from 4 to 40000. The values of TN is chosen as 4, 40, 400, 4000, and 40000. After a new TN value was given and changed in the code, the code was run with this new value, and the result is generated and drawn in the above figure. It can be seen from the figure that with increasing the time, the output value is increased in a straight line. At a constant time value, the output value decreases with the increase of the TN value from 4 to 4000. When the time is 100 and the TN value is 4, the output value is about 6.6e7; and when the time is 100 and the TN value is 40000, the output value is about 2e7. As is shown in this figure, the output value firstly decreases sharply and slightly. Especially, when the TN is from 400 to 40000, the change of output value is insignificant.

In this section, the value of TN is set as a constant value of 40. And the KP is varied from 50 to 1000. The values of KP chosen are 50, 125, 250, 500, and 1000. After a new KP value was given, the code was run, and the result is drawn in the figure. It can be seen from the figure that with the increase of time, the output value is increased in a straight line. At a constant time value, the output value increases with the increase of the KP value. When the time is 100 and the KP value is 50, the output value is about 2.5e6; and when the time is 100 and the KP value is 1000, the output value is about 4.75e7.
5. Conclusion
1) According to the above calculation, it can be concluded that with the increase of the proportionality coefficient KP, the output of PI controller becomes slow; and with increasing the integration constant TN, the output of PI controller deceases significantly.
2) According the comparison between proportionality coefficient KP and integration constant TN, the regulating ability of proportionality coefficient KP is more prominent than integration constant TN. So, it is advised that during the adjusting period, the proportionality coefficient KP should be adjusted firstly, and the integration constant TN should be adjusted secondly.

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7. Reference
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