ATLANTIS PRESS
Advances in Engineering Research, volume 154
International Conference on Mechanical, Electrical, Electronic Engineering & Science (MEEES 2018)

Study and Application of Pressure and Flow Control Methods for Ultra-Fast Cooling Water

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Keywords: Cooling after rolling, ultra -fast cooling, Step cooling, laminar cooling, and control strategy.

Abstract. The high-precision control of the special cooling process of the hot-rolled strip steel head is an important means for stable production of the production line and improvement of the finished product rate. It is also a key technical problem for cooling control after rolling. Aimed at the process requirements of different products under ultra-fast cooling conditions and the characteristics of cooling equipment layout after rolling, the hot-rolled strip steel laminar cooling zone has been developed with heads that are not cold, ultra-fast cold heads with weak heads, and pressure-based preloads. The compensated head cold control strategy achieves high-precision control of the special cooling section of the strip head. With the characteristics of flow regulation, ultra-fast and energy-saving high-precision hydraulic control strategies and ultra-fast control methods for cold manifold flow rates have been developed.

1. Introduction

The ultra-fast cold constant pressure water supply system is mainly composed of an inverter booster pump, a diverter manifold, and a cooling water pressure control system. The independent controller controls the water supply pressure and header flow respectively. The frequency conversion booster pump converts normal-pressure cooling water into high-pressure cooling water in real-time to the ultra-fast cold-separated flow collection pipe. Distributary manifolds are equipped with pressure regulating lines and pressure detectors and are connected to ultra-fast cold headers via intermediate lines. The constant pressure cooling water in the diverter collecting pipe is sent to the ultra-fast cooling header in the output roller area through the intermediate pipeline. Each middle pipeline is equipped with electromagnetic flowmeter, pneumatic on-off valve group and pneumatic control valve group.

2. Development of UFC Energy-Saving Hydraulic Pressure Control Strategy

The ultra-fast chilled water system is mainly composed of two parts: a constant pressure water supply system and a header flow regulation system. Controller controls water pressure and header flow.

3. Establishment of UFC Pressure Regulation Efficiency Equation

Under the ultra-rapid cold target pressure (0.85 MPa) process conditions, the influence of the opening degree of the pressure regulating valve group on the overflow flow rate of the pressure regulating pipeline was studied while the relief flow of the pressure regulating pipeline was calibrated. Fig.1 shows the overflow flow curve. The results in the figure show that the overflow flow curve can well match the calibration results, and the fitting accuracy can meet the calculation requirements.

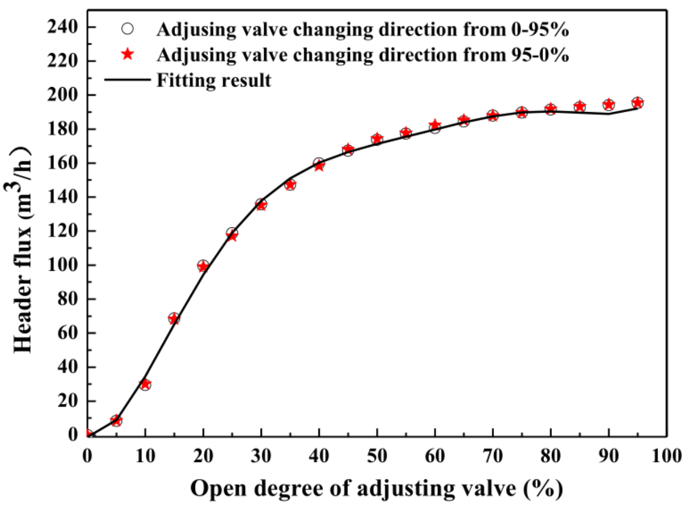


Fig 1. Fitting curve of overflow flux.

Under the ultra-rapid cold target pressure (0.85 MPa) process conditions, the influence of the opening degree of the pressure regulating valve group on the overflow flow rate of the pressure regulating pipeline was studied while the relief flow of the pressure regulating pipeline was calibrated. The pressure-adjustment pipeline overflow flow calibration is fitted with the PAE (Pressure Adjusting Efficiency), which is used to characterize the regulation of ultra-fast cooling pressure controllers.

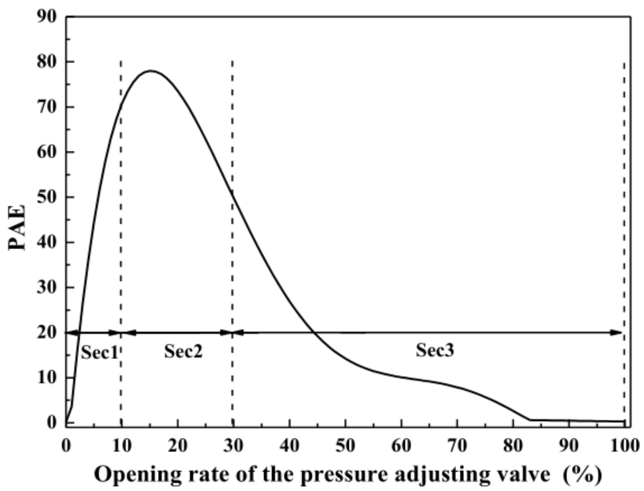


Fig 2. Curve of PAE for UFC.

When the pressure control valve group opening is 15%, the flow regulation efficiency reaches a maximum of 78.03. Combining the regulation efficiency curve, the area where the opening degree of the pressure regulating valve group is less than 10% is called the pressure regulation area (Sec1), and the area where the opening degree of the pressure regulating valve group is 10 to 30% is called the rapid response area (Sec2). The area where the opening degree of the pressure regulating valve group exceeds 30% is called a boosting area (Sec3).

4. Development of Optimal Pressure Control Strategy

In order to reduce the pipeline pressure load and ensure the boosting efficiency before the ultra-fast cold variable frequency booster pump is up-converted, the opening degree of the ultra-fast cold pressure control valve group is maintained in the boost pressure zone. When the up-converted signal is delivered, the ultra-fast cold pressure open-loop controller adjusts the pressure regulating valve group from the boosting zone to the quick response zone. When F4 is loaded, it enters into the scope of the pressure closed-loop controller. At this time, the pressure control valve group is in the quick response zone, has sufficient regulation efficiency, and can achieve high-efficiency decoupling control with booster pump up-conversion process to increase the ultra-fast cooling pressure. Increase the rate. When the frequency conversion booster pump is used for stable water supply, the opening degree of the pressure regulating valve group is about 10% in combination (5.3), which is at the edge of the voltage regulation zone.

5. Research on Flow Control Method of Ultra-fast Header

Before the ultra-fast cooling system is put into use, the ultra-fast cooling header flow needs to be calibrated. According to the literature, when the opening degree of the flow regulating valve group changes from small to large and from small to large, the flow curve of the header does not coincide. In order to eliminate the influence of the regulating valve group's regulating direction on the manifold flow control, the manifold flow rate was set to 0%-95% and 95%-0%, respectively. The results in the figure show that the FAE curve is similar to the trend of the PAE curve, and the FAE reaches its maximum value when the opening of the ultra-fast cold header flow control valve group is 14%. Due to the non-linearity of the FAE, when the ultra-fast cold header control valve sets have different initial opening degrees, the same adjustment amplitude will produce different flow adjustment results, fully considering the high-precision control of FAE as ultra-fast cold header flow. Effective means. The the FAE curve is shown in the following figure:

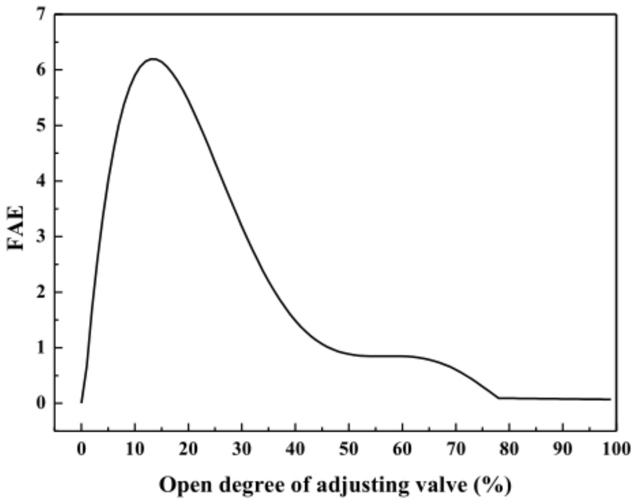
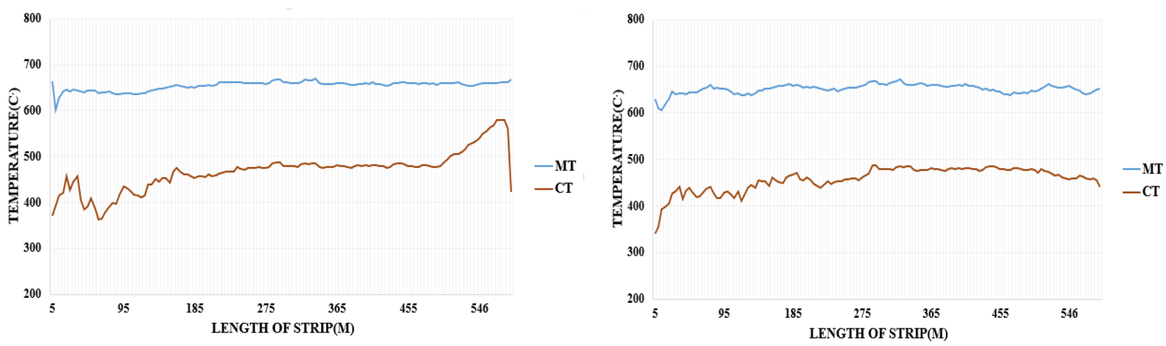


Fig 3. Curve of FAE for UFC header.

D After the flow deviation control module receives the measured flow F mea, it takes the difference from the target flow F set to obtain the flow deviation e (k). The parameter setting module records the current opening degree of the manifold flow control valve group in real time, and uses this as the input, combined with the flow deviation e(k), and on-line tuning gain parameters such as F P and F I. The PI controller uses the adjusted gain parameters to calculate the correction amount of the current control valve group opening and sends the calculation result u (k) to the actuator to realize the closed-loop control process of the manifold flow.

6. Integral Time Optimization

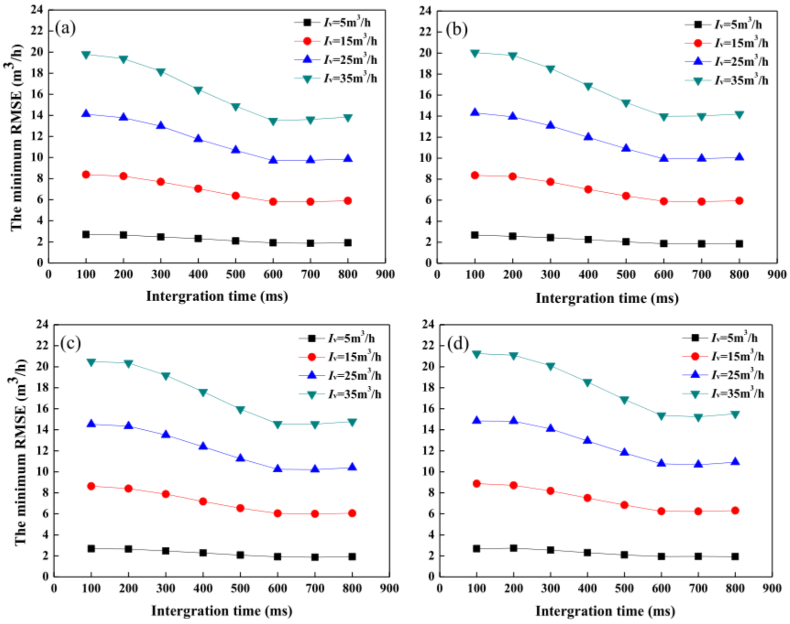
Using the simulation model, the optimization of the integration time was first studied. The integration time, as the cumulative period of system deviation, plays a crucial role in eliminating steady-state errors and improving system stability. In order to ensure the optimality of the parameters, the optimal integration time for the initial opening of the ultra-fast cold header flow control valve group was 15%, 25%, 35%, and 45% respectively. The amount of interference I v was 5 m 3 /h, 15 m 3 /h, 25 m 3 /h and 35 m 3 /h, calculation results.



(a)Before Integral time optimization (b) After Integral time optimization

Fig 4. MT and CT curves

With the automatic feedback control, the system runs stably and reliably. At present, this process is used in double phase steel, complex phase steel, part of high strength container and beam steel. The temperature of the rolling process, MT and CT control precision is high, and the temperature and performance uniformity in the direction of strip length are ensured.



(a)15%; (b)25%; (c)35%; (d)45%

Fig 5. 10 The minimum RMSE of flux under different initial opening rates.

When the flow control valve group has the same initial opening degree and the integration time is in the range of 100~600 ms, the minimum RMSE decreases with the increase of the integration time, and the decrease amplitude increases with the increase of the interference amount. The flow regulation valve group also follows the above rules under different initial opening degrees. Because the longer the integration time, the sensitivity of the integral term decreases, which is not good for the stability of the system. Therefore, 600 ms is the optimal integration time of the PI controller for the current flow.

7. Summary

Combining with the adjustment characteristics of the ultra-fast cooling pressure control valve group, the pressure adjustment efficiency evaluation method was introduced, and the pressure regulation efficiency was divided into a boost pressure zone, a quick response zone, and a voltage regulation zone. Combining the boost process of the ultra-fast cold dynamic water supply with the pressure regulation efficiency zone, the high-pressure regulation efficiency in the rapid response zone is fully utilized to achieve efficient decoupling control of the ultra-fast cold-frequency variable frequency booster pump and the pressure controller. In the process of increasing the ultra-fast cold header, the moderate pressure regulation efficiency of the voltage regulation zone is fully utilized to ensure the precision of pressure control, and the consumption of ineffective cooling water is further reduced, and finally an energy-saving and high-precision pressure control process is finally realized.

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