Error Compensation Strategy for Roll Gap of Roller Crusher Based on Adaptive Reference Model

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Abstract. Roll gap between the two rollers of crusher is adjusted constantly to satisfy the particle size of output material. In order to realize convenient adjustment, a roll gap control scheme based on hydraulic technology is designed and optimized in this paper. And an adaptive reference model is applied to compensate synchronous error of the rollers. Then simulation model and algorithm structure are elaborated subsequently. Finally, an experiment platform is built to validate the performance of the proposed approach.

1. Introduction
Roller crusher is widely used to pulverize large size material, such as coal and iron ore, to required granularity. Due its stable and dependable performance, it is applied in many industrial fields such as coal mining, chemical engineering, metallurgy engineering and so on. It is extremely important in industrial production and responsible for the follow-up process. With the development of industry level, the strong demand on higher efficiency of roller crusher is put forward. In recent years, many research institutions and enterprises contribute on optimization and improvement of these machines [1].

How to control the roll gap of roller crusher accurately and ensure the particle size of material is regarded as important issue in daily practice [2]. According to the structure and working principle, the particle size of material after pulverizing is determined by the roll gap of two rollers. Traditionally, the gap is adjusted through changing the thickness of underboarding. Unfortunately, there exist many disadvantages, such as high labor intensity, imprecise control and unable to realize adaptive adjustment for roll gap after wearing, for manual control method [3]. Recently, an automatic control approach through hydraulic transmission technology is applied and achieves good effect [4]. Universal bearing of each roller is connected with piston rod of hydraulic cylinder respectively. The two piston rods are moved synergetically to drive the moveable roller when the gap is to adjust.

In order to realize adaptive and efficient adjustment for roll gap accurately and guarantee the particle size, collaborate and intelligent control strategy for the cylinders of roller crusher should be researched. In this paper, a novel error compensation strategy for roll gap of roller crusher based on adaptive reference model is designed to decrease synchronization error during synchronous moving process of the two cylinders.

2. Control Principle of Roll Gap
The mechanical structure of roller crusher is presented in Figure 1. And the working principle can be summarized as following. Two rollers, the left one in the figure is defined as immoveable roller and
the right is moveable, are rotated in the opposite direction during the crusher working. The immoveable roller is only rotated clockwise, while the moveable is revolved anticlockwise and can be also moved along a straight line. Large coal or iron ore is crushed by the friction with two rollers. The pulverized material is rotated with the roller and discharged under the rack. Generally, the size of the crushed product is determined by the width of discharge gate. And the gate is directly related with minimum roll gap between the rollers. Displacement of two control cylinders is applied to adjust the gap automatically in electro-hydraulic controlled crusher.

It can be seen from working principle of the crusher that the two control cylinders should be keep moving parallelly to ensure the particle size. In order realize the parallel motion, synchronous controlling strategy is essential important to compensate the error during working.

![Mechanical structure of roller crusher](image)

**Figure 1.** Mechanical structure of roller crusher

### 3. Error Compensation Strategy Based on Adaptive Reference Model

In this paper, an adaptive reference model for roll gap of roller crusher is designed to realize error compensation. And the structure of the proposed model is shown in Figure 2. Output displacement $x_{p1}$ of control cylinder is regarded as desired output of the whole system. And control model of cylinder 1 is treated as reference model. The core of cylinder 1 model is Fuzzy-PID controller. Output displacement $x_{p2}$ is compared with $x_{p1}$ to obtain a synchronization error $e$. And the error is compensated to slow-footed cylinder 2. Dynamic response of the slower is accelerated and stability precision is enhanced. So the difference value between $x_{p1}$ and $x_{p2}$ is decreased to obtain efficient system performance.

![Error compensation based on adaptive reference model](image)

**Figure 2.** Error compensation based on adaptive reference model
The core of the reference model is a Fuzzy-PID controller. Structure of Fuzzy-PID can be summarized as following. Real time sensor data is collected and compared with ideal value to obtain deviation value $e$ and its gradient $ec$ [5]. $e$ and $ec$ is detected constantly. Then Fuzzy inference and defuzzy is conducted to optimize three parameters of PID controller online. Dynamic performance is enhanced through the above operation [6-8]. Simulation model of error compensation strategy for roll gap of roller crusher based on adaptive reference model is established as Figure 3.

Fuzzy-PID is established based on Fuzzy rules manually [9]. The proportional coefficient $K_p$, integration coefficient $T_i$, differential coefficient $T_d$, deviation $e$ and deviation ratio $ec$ are adjusted as follows [10-12]:

1. If $e$ is big, $K_p$ should be increased to improve the response speed and decrease $T_d$ to prevent oversize deviation. $T_i$ should be zero to prevent overshoot.
2. If $e$ is medium big, $K_p$ should be decreased to restrain overshoot. $T_i$ and $T_d$ should be medium value to improve response speed.
3. If $e$ is small, $K_p$ and $T_i$ should be increased appropriately. A relatively small $T_d$ is accepted with a big $ec$. And $T_d$ should be increased with small $ec$.

![Figure 3. Simulating model of synchronizing error compensation](image)

4. Experiment

In order to validate the proposed error compensation strategy for roll gap of roller crusher based on adaptive reference model, an experiment platform was established as Figure 5. Some key parameters
of control cylinder were listed in Table 1. A step signal with amplitude of 30mm was selected as input signal during the experiment process. Response curve and comparison between experiment curve and simulation curve were presented in Figure 6.

![Experiment platform](image)

**Figure 5.** Experiment platform

![Response curve and synchronous error curve](image)

(a) System response curve  
(b) Synchronous error curve

**Figure 6.** Response curve and synchronous error curve

**Table 1.** Key parameters of hydraulic cylinder during experiment

| Name  | Diameter of cylinder D/mm | Radius of cylinder d/mm | Travel of cylinder L/mm |
|-------|---------------------------|-------------------------|-------------------------|
| Cylinder | 63                         | 45                      | 200                     |

In this paper, maximal synchronous error, adjustment time and stable synchronous error were applied to validate performance of the system. 500 times simulation was conducted. And the final average result was presented in Table 2.
Table 2. Result of the experiment

| Parameter Value | Maximal synchronous error /mm | Adjustment time /s | Stable synchronous error /mm |
|-----------------|-------------------------------|--------------------|-----------------------------|
|                 | 0.270                         | 0.179              | 0.0018                      |

It can be seen from the experiment result that congruency between the simulation result and the experiment result was high. Performance of the roll gap control system of roller crusher with error compensation strategy could satisfy the actual requirement.

5. Conclusion

In this paper, mechanical structure and control principle of roll gap of roller crusher were shown to present the adjustment process of the gap. Then Error Compensation Strategy for Roll Gap of Roller Crusher Based on Adaptive Reference Model was introduced to realize convenient adjustment. In order to test the effectiveness of the proposed approach, an experiment and some simulations were conducted subsequently. Finally, the proposed method achieved the maximal synchronous error of 0.270mm, the adjustment time of 0.179 seconds and the stable synchronous error of 0.0018, which proved its superiority.

6. References

[1] Fang X. Development Status of Crusher and Requirements for Its Use in Coal Handling System [J]. S P & BMH Related Engineering, 2017(2): 5-9.
[2] Han Y. Application of Four-tooth Roller Crusher in Circulating Fluidized Bed Boiler [J]. Gas & Heat, 2017(05): 9-11.
[3] Yu P., Wen X. Y. Design of monitoring and control system for double toothed-roll crusher based on PLC [J]. Mining & Processing Equipment, 2018, 46(7): 40-42.
[4] Choi J. Tracking Control of Hydraulic Excavator Using Time Varying Sliding Mode Controller with Fuzzy System[J]. Advanced Science Letters, 2012, 15(1): 78-82.
[5] Pradhan P, C, Sahu R K, Panda S. Firefly Algorithm Optimized Fuzzy PID Controller for AGC of Multi-Area Multi-Source Power Systems with UPFC and SMES[J]. Engineering Science & Technology an International Journal, 2016, 19(1):338-354.
[6] Petković D, Shamshirband S, Anuar N B, et al. Input Displacement Neuro-fuzzy Control and Object Recognition by Compliant Multi-fingered Passively Adaptive Robotic Gripper[J]. Journal of Intelligent & Robotic Systems, 2016, 82(2):177-187.
[7] Luo Q.Z., An A.M., Zhang H.C., Meng, F.C. Non-linear performance analysis and voltage control of MFC based on feedforward fuzzy logic PID strategy [J]. Journal of Central South University, 2019, 26: 3359-3371.
[8] Bejarbaneh E.Y., Bagheri A., Bejarbaneh B.Y., Buyamin S., Chegini S.N. A new adjusting technique for PID type fuzzy logic controller using PSOCSALF optimization algorithm [J]. Applied Soft Computing, 2019, 85: 105822.
[9] Petković D., Shamshirband S., Anuar N. B. Input Displacement Neuro-fuzzy Control and Object Recognition by Compliant Multi-fingered Passively Adaptive Robotic Gripper [J]. Journal of Intelligent & Robotic Systems, 2016, 82:177-187.
[10] Liu C., Peng J.F., Zhao F.Y., Li C. Design and optimization of fuzzy-PID controller for the nuclear reactor power control [J]. Nuclear Engineering and Design, 2009, 239: 2311-2316.
[11] Bennoufi A., Saadi S. Type-2 fuzzy logic PID controller and different uncertainties design for boost DC-DC converters [J]. Electrical Engineering, 2017, 99: 203-211.
[12] Wang Y.Z., Jin Q.B., Zhang R.D. Improved fuzzy PID controller design using predictive functional control structure [J]. ISA Transaction, 2017, 71: 354-363.