# Novel ARM-based Gauge Control System with Fuzzy PI Controller

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***Abstract***

*To minimize the longitudinal strip thickness error in the hydraulic cold rolling industries and improve traditional AGC control scheme on this problem, we put forward a secure gauge control system based on Advanced RISC Machines (ARM) and intelligent PI control strategy. The traditional automatic gauge control (AGC) scheme depended on personal experience about the parameters. The new gauge control system decreases the longitudinal strip thickness error via fuzzy control and ARM-based computing. Besides, this new system can be smaller than the traditional AGC system, and so is much easier to transport. The Fuzzy control scheme can increase the robustness of the ARM-based gauge control system against some disturbances. The Matlab-based experimental simulations show that our secure gauge control system with Fuzzy control and ARM is better than the traditional one.*

***Keywords:*** *Gauge control system; ARM; fuzzy PI controller; longitudinal strip thickness error; AGC system.*

## 1. Introduction

The automatic gauge control system, named as AGC, has been adopted widely in the hydraulic cold rolling industries. It is well known that the hydraulic cold rolling mill consists of screw-down system, backup roll, work roll and all kinds of sensors. The screw-down system, which generates power, is made up of cylinder, servo valve and the sensors of pressure and position. With pressure sensors, the feedback control of pressure comes into being. In like manner, with position sensors, the screw-down system can accurately track the cylinder's position. Neither position nor pressure control of the screw-down system can be directly used to control the thickness error of sheet strips.

In order to realize these control objectives, it is no doubt that the current gauge of sheet strips should be measured and the error signals should be used to correct the actual output of the computer controller. So, there are two thickness gauges in the AGC hydraulic computer control system, and one is used for the strip thickness before stand, while the other is for the strip thickness after stand.

As we know, the traditional PI control took a useful role for the gauge control in the hydraulic cold rolling industries, but this control approach is challenged by the increasing requirement on error. It is recently discovered that the electromagnetic disturbance can decrease the effectiveness of the AGC system, so a new control system that can adjust the parameters by itself is necessary against the disturbance. Due to the wrong experience and

random disturbance, the ineffective control may cause the damage of the control object and the operators. For example, a control algorithm is proposed with neural network (NN) is investigated [1]. In this paper, a secure gauge control system is designed on the Advanced RISC Machines (ARM) and intelligent PI control strategy [2, 3].

## 2. Problem Analysis

Figure 1 shows the traditional PI control strategy, which was used in the cylinder position feedback loop. Above all, the core of the AGC system is the position loop. Corresponding to AGC, the position loop mentioned ahead is called APC, namely, automatic position control system. In the hydraulic AGC system, the thickness deviation is eliminated by the screw-down servo system, which is made up with cylinder position control system (APC) and the rolling force control system.

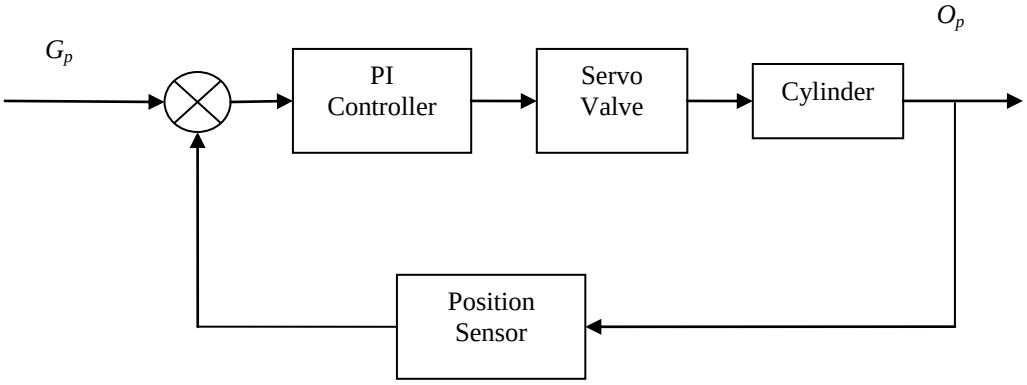


**Figure 1. Position Loop**

The hydraulic screw-down servo system of the cold rolling mill is made up by controller i.e. PI, electric-hydraulic servo valve, hydraulic cylinder, load of the mill, position sensors and pressure sensors. Executive mechanisms of the hydraulic screw-down system are the hydraulic cylinder and the electro-hydraulic servo valve. The servo valve is used to control the liquid flow entering the cylinder. Then the motion of the upper backup roll and the upper work roll is controlled by the hydraulic cylinder and the relevant mechanism to control the rolling force and the screw-down position. It is worthy of being mentioned that GP represents the given value of cylinder position and OP is the actual position of the hydraulic cylinder.

As mentioned ahead, two thickness gauges set on the hydraulic cold rolling mill just measure the actual gauge of the sheet strips before and after stand. Figure 2 shows the structure of AGC system with thickness gauge.

Here, Gg is the given value of Gauge of sheet strips, Gp is the given position value of hydraulic cylinder, Go is the actual gauge of sheet strips, and Op is the actual position of hydraulic cylinder.

From Figure 2, Gc1 and Gc2 cascade each other and the inner loop controls the position of the hydraulic cylinder, the outer loop controlling the thickness of sheet strips. So, Gc1 is thickness controller, and Gc2 is position controller.

## 3. Design of Controller based on ARM

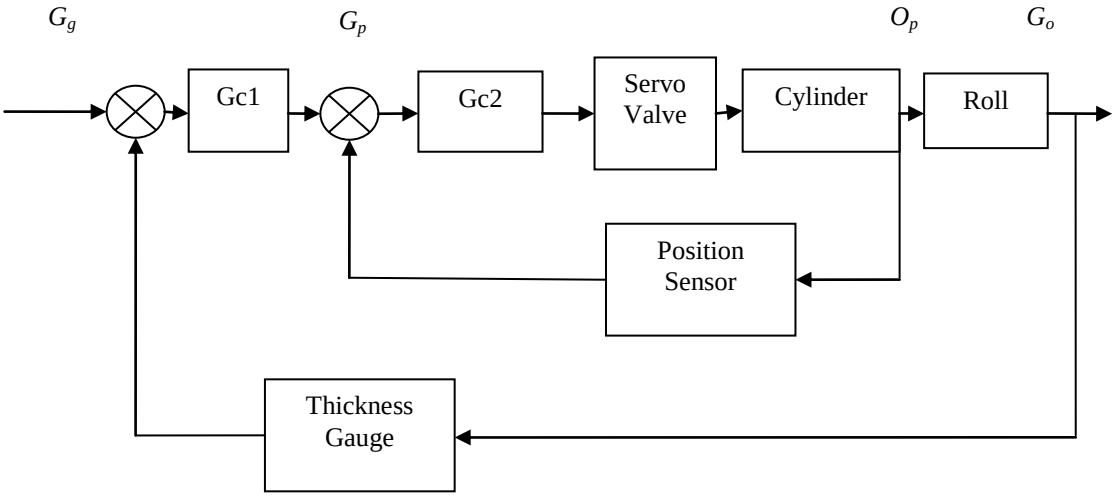


**Figure 2. AGC System with Thickness Gauge**

With the requirement of the quality of sheet strips, specially the thickness deviation between 2~3 micrometer, the traditional AGC control strategy meets great challenges. Through the analysis of the dynamic model of the hydraulic cold rolling mill, we find that nonlinearities exist and it is terribly difficult to cope with slowly time-varying factors. It is more and more clear that classic control theory is not use for nonlinearities, time-varying and strong coupling factors, etc. Therefore, modern control theory and intelligent theory like fuzzy logic and fuzzy inference should be studied deeply and it is necessary to transplant these intelligent algorithms to modern process control industries. What is more important, traditional AGC system is realized by PLC or Industrial Computer, and gauge controller based on ARM is illustrated as follows. With the development of embedded technology, more and more embedded systems based on functional processors surge into the computer market. As for the nonlinear and time-varying characteristics of hydraulic screw-down servo system, it's important to design a intelligent gauge controller based not on accurate mathematic models of objects with great stability and control precision. Figure 3 gives the improvement of AGC based on ARM and fuzzy controller. The root of the problem is that, the conventional PID does not have parameter self-setting function, and not address complex environment to make the adaptive parameter adjustment. Compared to traditional AGC system, the control scheme above takes some advantages. First, with the fuzzy controller, it's no need to build the accurate mathematical models of hydraulic cold rolling mills. Second, experience from experts and even from operators becomes several basic principles and it leads to extent of satisfactory of system control.

Figure 4 shows the modules of the AGC fuzzy PID controller based on ARM. According to modular strategy, the fuzzy PID controller is made up of technological setting module, position signal sampling module, gauge signal sampling module, executing unit, signal processing unit and pressure signal sampling module, and so on.

In order to prompt the anti-interference ability of the ARM-based fuzzy PID controller, several measures have been taken. First, in the power supply of ARM chip, the join of decoupling capacitor improves the circuit of electromagnetic compatibility

(EMC) ability. Second, photoelectric isolations assure that the electrical current cannot feedback to the fragile ARM chip.

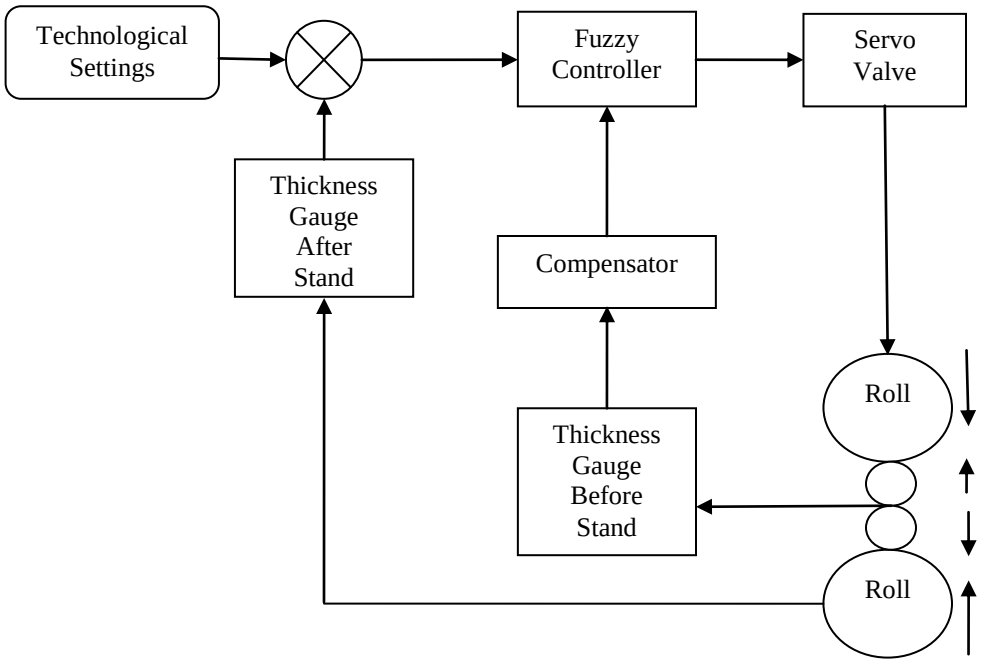


**Figure 3. Structure of Controller Based on Fuzzy Logic**

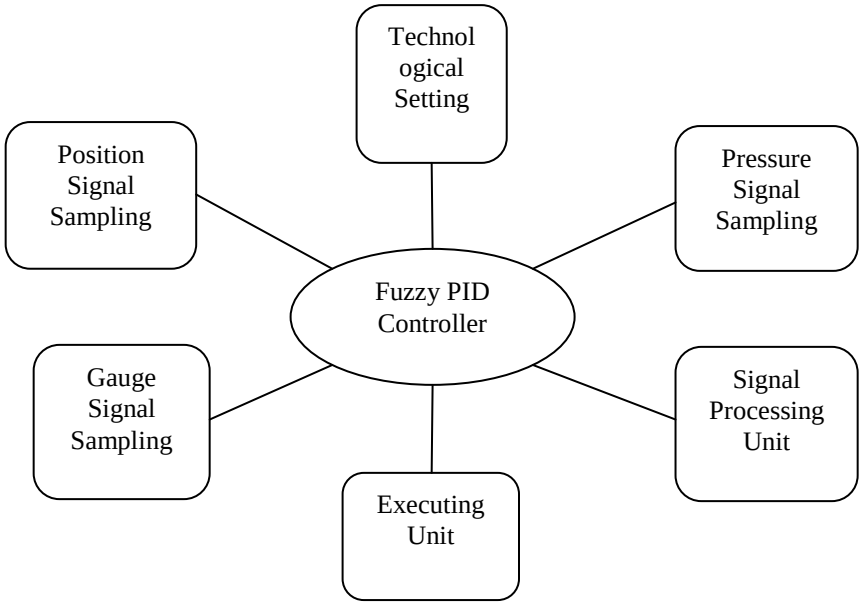


**Figure 4. Fuzzy PID Controller Based on ARM**

## 4. Experimental Simulations

First, build the transfer function of hydraulic screw-down servo system of the cold mill. The screw-down system consists of servo valve, amplifier and hydraulic cylinder. Figure 5 shows the components of the screw-down system. Here, Vg is the given value of roll gap, and Xp is the actual position of the hydraulic cylinder.

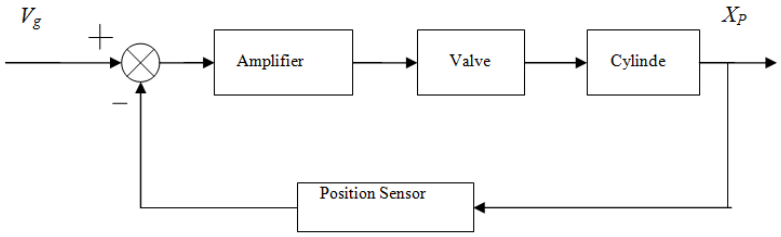


**Figure 5. Screw-down System**

With the control object of hydraulic screw-down servo system mentioned above, the AGC system with fuzzy PID controller is built with Simulink, as shown in Figure 6.

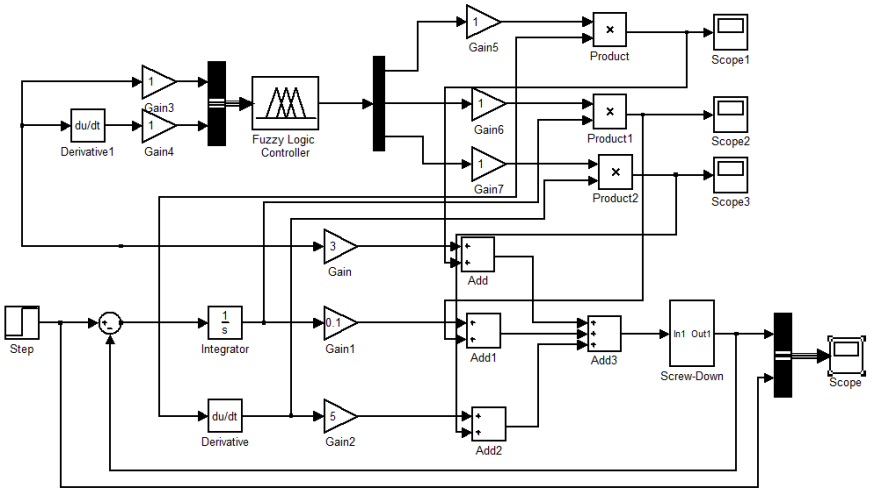


**Figure 6. Root-Level of the Screw-down System**

Compared to the traditional Screw-down System, the response is smoother and the system's anti-interference ability is improved. Besides, the over shoot is also smaller. And the methods of gauge control based on ARM and fuzzy PI algorithm get great effect in the AGC hydraulic computer control system.

## 5. Conclusion

Compared with the conventional PID using in traditional AGC control system, the gauge control system based on ARM and fuzzy PI is more helpful to improve the system stability and less dependent on the accurate mathematics model of object. Based on the inherent nonlinearities of fuzzy control strategy, our design of combining fuzzy logic with conventional PID plays an important role in the hydraulic rolling industries.

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