# Research on laser cladding control system based on fuzzy PID

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**Abstract**. Laser cladding technology has a high demand for control system, and the domestic laser cladding control system mostly uses the traditional PID control algorithm. Therefore, the laser cladding control system has a lot of room for improvement. This feature is suitable for laser cladding technology, Based on fuzzy PID three closed-loop control system, and compared with the conventional PID; At the same time, the laser cladding experiment and friction and wear experiment were carried out under the premise of ensuring the reasonable control system. Experiments show that compared with the conventional PID algorithm in fuzzy the PID algorithm under the surface of the cladding layer is more smooth, the surface roughness increases, and the wear resistance of the cladding layer is also enhanced.

## 1. Introduction
In recent years, researchers at home and abroad to study the technology of laser cladding has been increased, meanwhile, the laser cladding has a series of advantages, in the chemical, petroleum, widely application field and machinery. But at present, its cladding process is complex, affected by many factors, and adopted the conventional PID algorithm; its control process is simple and convenient, but the control precision is low, so that the quality of the fused parts is reduced. Forming parts processing is required to put into production, it also increased the cost of production, and the production cycle is long these factors. The technology is difficult to develop well in industry, [1, 2].Therefore, the design, development and optimization of the laser cladding control system need to be solved urgently.

The laser cladding control system is studied in this paper [3], the core drive AC servo motor. This paper adopts three closed-loop speed control system, position loop adopts P control, PI control is adopted in the current loop, speed loop uses fuzzy PID control, integrated fuzzy control parameters self-tuning strategy has the advantages of strong adaptability and speed [4,5].

## 2. Establishment of Model
Three closed loop control system from the inside to the outside are position loop, speed loop and current loop [6]. The whole control system block diagram is shown in Table 1.
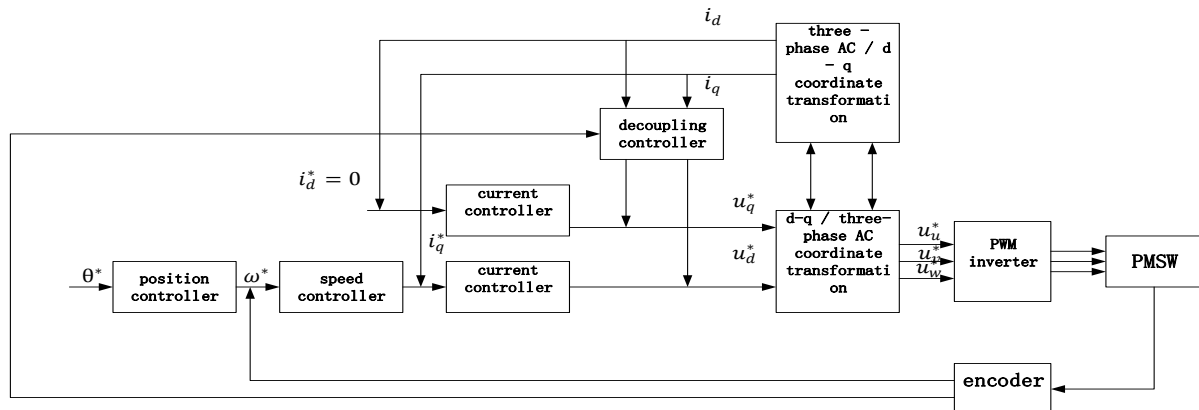
**Figure 1.** The whole control system

## 3. The design of fuzzy PID controller

### 3.1. Control scheme design

The speed of the motor varies nonlinearly with time due to the control process；  the load will change, so the motor speed change is not stable. To meet the process of laser cladding of motor speed control system is not very good for the conventional PID control, often control precision of motor speed, slow response speed etc. the problem. So the three closed-loop speed control system in the design, the speed loop uses fuzzy PID control as shown in Figure 2.
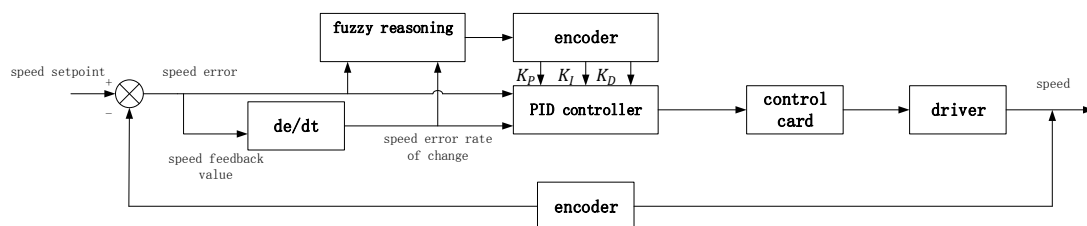


**Figure 2.** The speed loop

The fuzzy controller input to the deviation of the PID controller and the differential value of the motor speed error rate fuzzy processing, then through fuzzy reasoning, fuzzy solution obtained after correction parameter, then correction parameters to the controller, using the modified parameters on laser cladding in the control system. The whole system is in operation, in accordance with the set the sampling period, continuous detection of motor speed deviation, and through differential from the motor speed deviation change rate, motor speed control by fuzzy PID.

### 3.2. Control system simulation

In this paper, Simulink is used as the simulation tool of the system, and two closed-loop control systems are used to simulate the laser cladding control system. The first is that the current loop and the speed loop are used anti-integral saturation PI control, as shown in Fig. (a) . The second is the current loop using PI control and the speed loop using fuzzy PID control, as shown in Fig. (b) . The difference between the two models is that the second simulation model encapsulates the fuzzy control module.
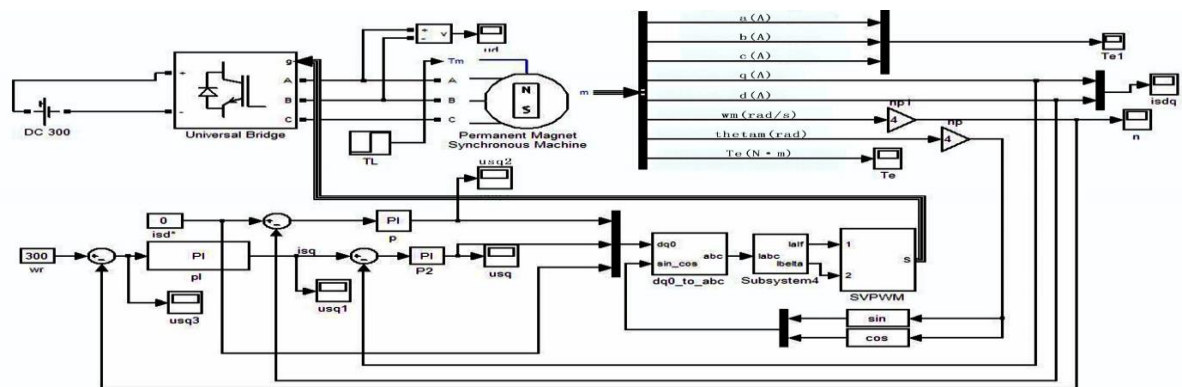
(a) PMSM closed loop PI vector control system simulation model
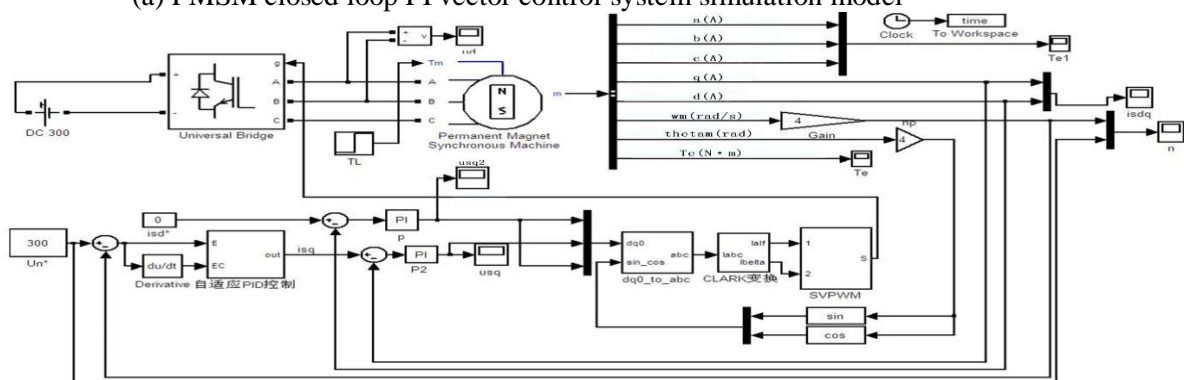


(b) PMSM closed loop adaptive fuzzy PID vector control system simulation model

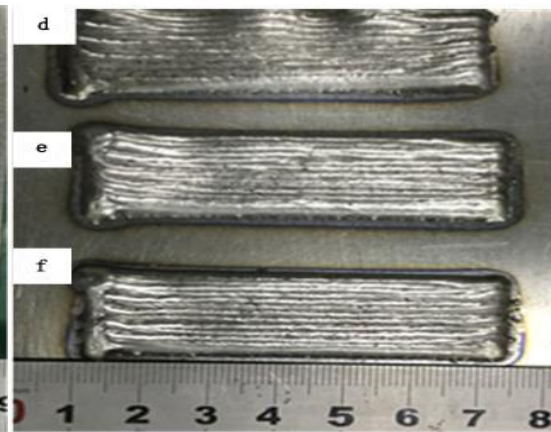**Figure 3.** Two kinds of double closed-loop control system

## 4.  Experiment

It is proved that the control system proposed by this paper is effective by simulation analysis. Compared with the conventional PID control system, the fuzzy PID control system has obvious advantages. On the basis of this, the laser cladding experiments and the frictional wear experiments were carried out on the three closed-loop control systems based on fuzzy PID and the traditional control system. The effects of different control systems were compared. Finally it is reasonable to verify the fuzzy PID-based laser cladding control system.

### 4.1.  Laser melting coating

The matrix material is mine hydraulic support column base material 27SiMn steel, and the size is 300mm * 200mm * 25mm. the cladding material is Fe based alloy powder. Before the experiment with sand on the surface of the processing, the purpose is to avoid other problems affecting the experimental results in the processing; In addition, before the experiment, the metal powder should be dried in vacuum to remove moisture. In the experimental program, experiments were repeated three times in each experiment, and the two groups of experiments are laser power, the same overlap rate, scanning speed, scanning path. Cladding samples as shown in Fig. 3,4. The specimens a, b, and c in Fig. 3 are samples that are clad under the ordinary PID control algorithm, and the specimens d, e, and f in Fig. 4 are samples that are clad under the fuzzy PID control algorithm.
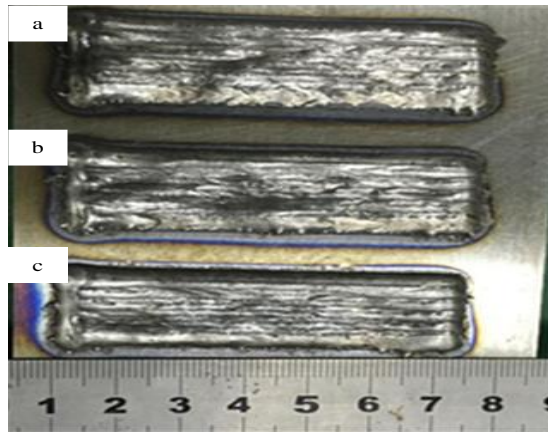
**Figure 4.** the conventional PID control      **Figure 5.** fuzzy PID control system

system of cladding specimens                cladding test specimen

*4.2. Frictional wear*

In order to reduce the chance of the experiment, samples in fig. 3 and fig. 4 respectively in the two groups of samples were selected. The selected specimens were subjected to wire cutting to make friction and wear samples, as is shown in figure 5. Abrasive hardness is 60 HRC. A and b are the cladding samples under conventional PID, and c and d are the cladding samples under fuzzy PID. Then four groups of specimens for surface were treated and cleaned , and the experimental conditions of the four sets of specimens are the same. The quality of the sample before and after wear was measured before and after the experiment, and then calculated the weight loss. The experimental results are averaged.
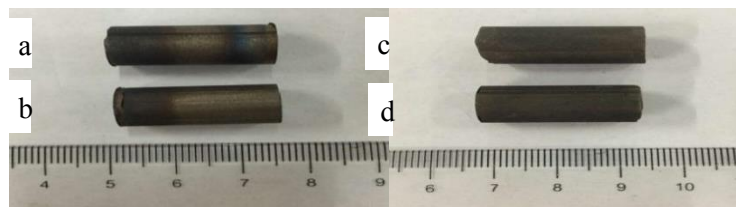


**Figure 6.** friction wear

*4.3. Interpretation*

In Fig. 3, a, b, c is a common PID algorithm under the cladding samples ; In Figure 4, d, e, and f are clad in a fuzzy PID algorithm . From Fig. 5, it can be observed that the two sets of specimens are different in appearance . Sample a, b, c can be seen that the coating surface is uneven and the surface roughness is low ; The specimens d, e, f can be seen that the surface of the coating is relatively smooth and surface smoothness improved .

The results of friction and wear experiments are as follows:

**Table 1.**  Friction and wear state of different samples under the experimental value

| Pin sample | Quality before wear /g | Quality after wear /g | Wear loss/g | friction factor |
|---|---|---|---|---|
| Conventional PID sample | 13.7313 | 13.4485 | 0.28280 | 0.177 |
| Fuzzy PID sample | 13.3427 | 13.1068 | 0.2359 | 0.159 |

Table 1 shows: under conventional PID algorithm, the friction coefficient and wear rate of the sample were larger than those under fuzzy PID algorithm. The wear resistance of cladding specimens increased in the fuzzy PID algorithm. To a certain extent, the friction coefficient is an important index reflecting material wear resistance, and there was positive correlation between wear resistance [7].

## 5.  Conclusion

The experimental results show: in the conventional PID algorithm, laser cladding experiment platform trajectory is not steady. The motor control precision is relatively low. There is the phenomenon of vibration control system. Uneven surface cladding of the surface has large ripple. Surface roughness is low. In the fuzzy PID algorithm, the operation of the motor is more stable. The control precision is increased. The surface of the cladding layer is smoother and the surface smoothness is improved. According to the friction and wear experiments, the wear resistance of the cladding layer is enhanced by the fuzzy PID algorithm. These results indicate that the fuzzy control system for laser cladding PID control has good dynamic characteristics, steady performance, and the cladding quality obviously improves.

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