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Set Point Tracking and Load Disturbance Rejection with PID and I-PD Controllers in Different Zones of Barrel Heating System

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Abstract : Most of the processes in process industries are non-linear and injection molding system is an example of such non-linear process. Maintaining proper barrel temperature is the key control action required for accurate shape and structure of the products. The mathematical model of each zone of the barrel can be used to analyze the characteristics of the plastic injection. Traditional Proportional Integral and Derivative (PID) and I-PD controllers are selected for analyzing performance of different zones of barrel heating system. The simulation results show that I-PD controllers outperform the conventional PID controller with improved set point tracking and load disturbance rejection.
Keywords : Barrel temperature, injection molding system, I-PD controller, mathematical model, PID controller, servo and regulatory control.

1. Introduction

Plastic products with accurate shape and structure are produced by plastic injection molding system. The temperature control of barrel heating system results in desired shape and structure. The quality of products gets affected by overheating or under heating[1]. The characteristics and performance of a system is identified with mathematical modeling. The model is developed to predict the dynamical behavior of barrel temperature in the Plastic Injection Molding system. Chattering, power consumption and poor product quality are the drawbacks of ON/OFF controllers. So continuous mode controller PID controller and I-PD controller are selected for controlling the barrel temperature in the plastic injection molding system

The design of controller for unstable, resonance and integrating processes using I-PD a modified structure of PID controller was proposed by[2] and discussed about the limitation of classical PID controllers.

2. Mathematical Model

The dynamic behavior of the system is analyzed by Mathematical models. The energy balance equation is used to develop the mathematical model[3].

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Heat in = Heat out + Heat stored (1)

Figure 1: Barrel Temperature Zone

In Fig 1 T is the temperature of barrel zone, Ta-Temperature of ambient zone, V is the supply voltage, R is Thermal resistance and C is thermal capacitance. In industrial heating system, the heat stored is directly proportional to temperature rise with respective time,

$$K.V = C\left(\frac{dT}{dt}\right) + \left(\frac{(T - Ta)}{R}\right) \quad (2)$$

The transfer function of the zone is given as,

$$\frac{T(s)}{V(s)} = \frac{K}{Cs + \frac{1}{R}} \quad (3)$$

where, R is Thermal resistance, C is Thermal Capacitance and K is Thermal Conductivity.
The Transfer functions of the selected zone is given below,
The Transfer functions of the three different zones are shown below,

$$ZONE1 = \frac{17.3e^{-3s}}{452s + 555.5} \quad (4)$$

$$ZONE2 = \frac{17.3e^{-3s}}{486s + 555.5} \quad (5)$$

$$ZONE3 = \frac{19.1e^{-3s}}{528s + 588.2} \quad (6)$$

3. Controller Design:

I-PD Controller:

I-PD controller reduces peak overshoot and it is best suited than PID controller[4,5]. The block diagram of the I-PD controller is shown in Figure

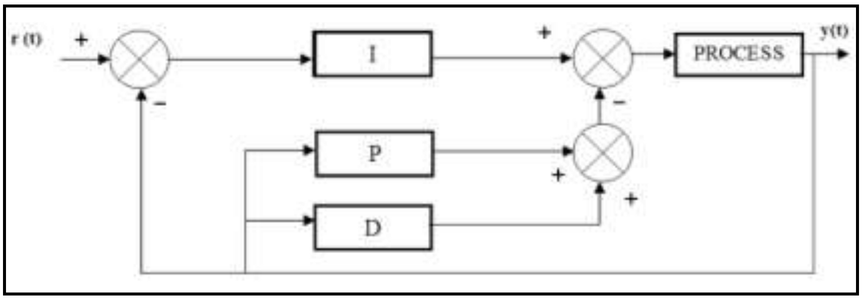

Figure 2: I-PD controller

From the above figure it is observed that the proportional and derivative actions are taking place only on controlled variable rather than error. With the I-PD controller, the improved set point tracking and load disturbance rejection can be achieved.

ZN Tuning

Ziegler Nichols (ZN) method PID controller parameters are obtained using. Controller parameters of Zone1, Zone1 and Zone3 obtained using ZN method are shown in Table 1[6,7].

Table 1: ZN tuned PID Controller Parameters

Zone	Controller Parameters		
	Kp	T_i (sec)	T_d (sec)
I	23.38	3.71	0.92
II	23.87	3.75	0.93
III	23.07	3.77	0.94

4. Results And Discussion:

The performance indices such as settling time, peak undershoot, IAE and ITAE of the each zone are analyzed with ZN tuned PID and I-PD controllers. Simulated response of zone 1, zone 2 and zone 3 shown in Figure 3, Figure 4 and Figure 5 respectively.

Zone1 Barrel Temperature Control

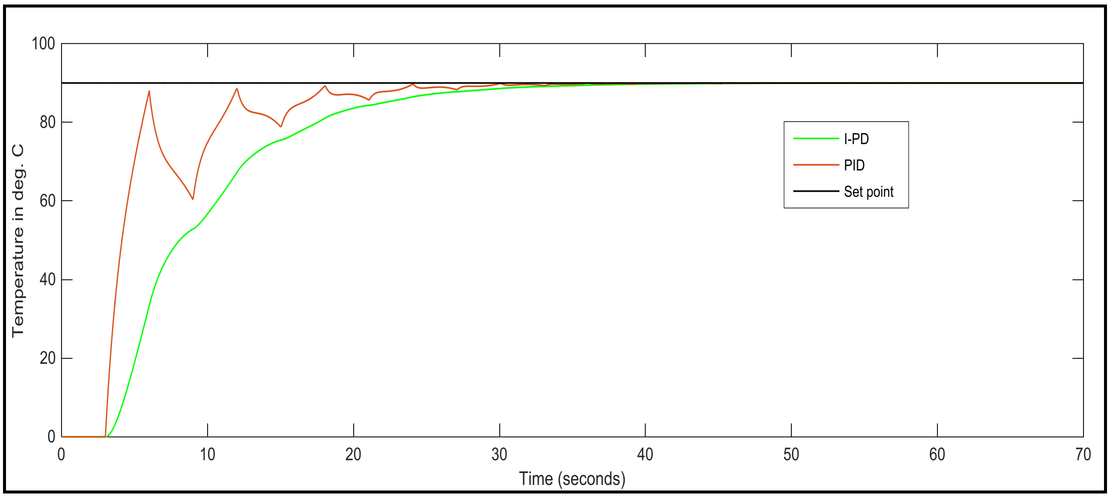

Figure 3: Zone1 Barrel Temperature Control

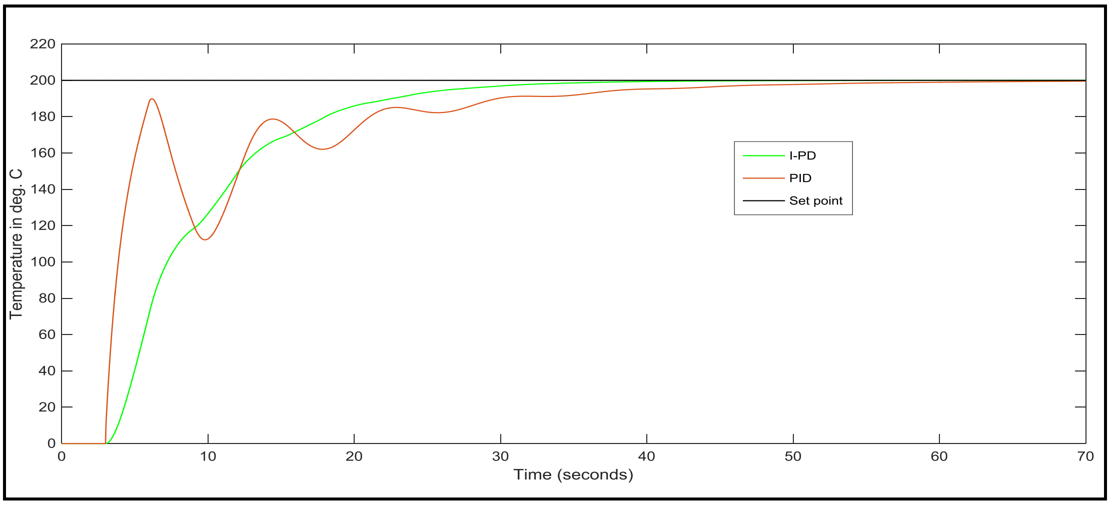

Figure 4: Zone2 Barrel Temperature Control

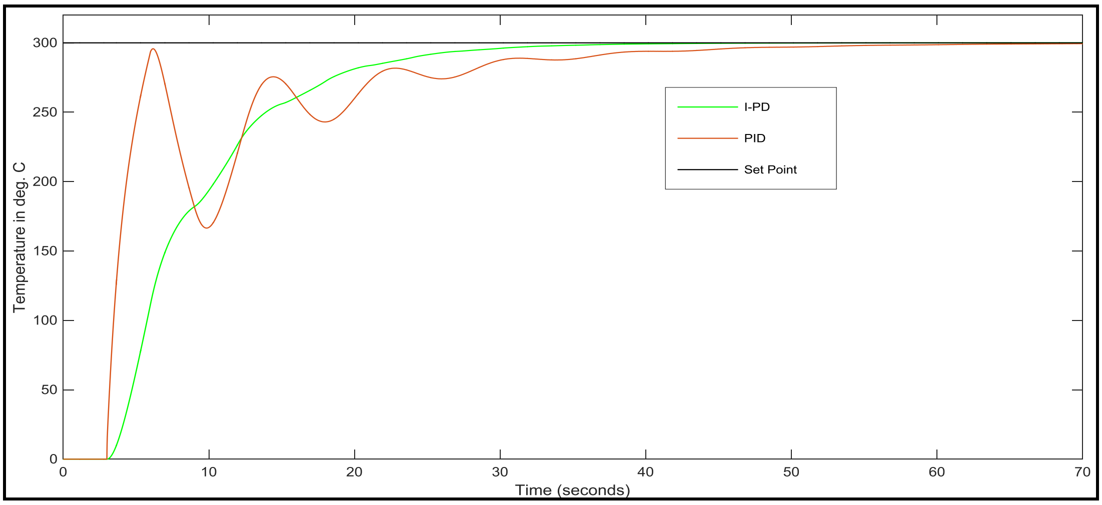

Figure 5: Zone3 Barrel Temperature Control

ZN tuned responses of all the three zones shows that the PID controller produces high oscillations. ZN tuned PID and I-PD responses are compared. For zone 1, response of ZN tuned PID settles at 45 seconds and I-PD settles at 32.3 seconds, for zone 2 response of ZN tuned PID settles at 43.9 seconds and I-PD settles at 33.4 seconds. For zone 3, response of ZN tuned PID settles at 43.5 seconds and I-PD settles at 30.4 seconds. ZN tuned PID of all three zones has large undershoots of 40% and over/under heating of the melt is possible to a great extent. I-PD controller produces less overshoot than PID controller.

4.1 Set point tracking and load disturbance rejection in zone-3 of barrel heating system:

The set point tracking of zone -3 of barrel heating system is selected for the analysis and the response is shown in Figure 6.

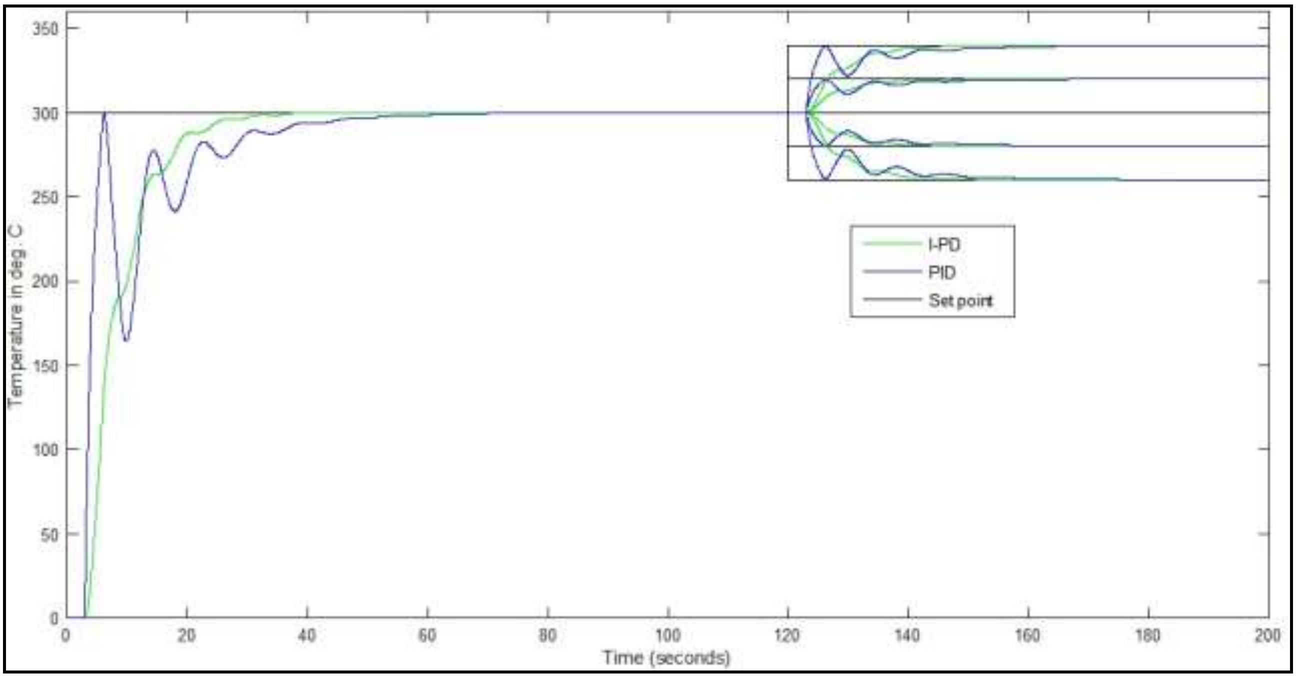

Figure 6: Servo Control in zone-3 of barrel heating system

From the above figure it is inferred that, set point changes of +20, +40,-20 and -40 deg. C is given at 120 sec. it is observed for all set point changes the I-PD controller outperforms the PID controller and tracts the set point with minimum setting time. The regulatory control operation of I-PD controller for the zone-3 is shown in Figure 7.

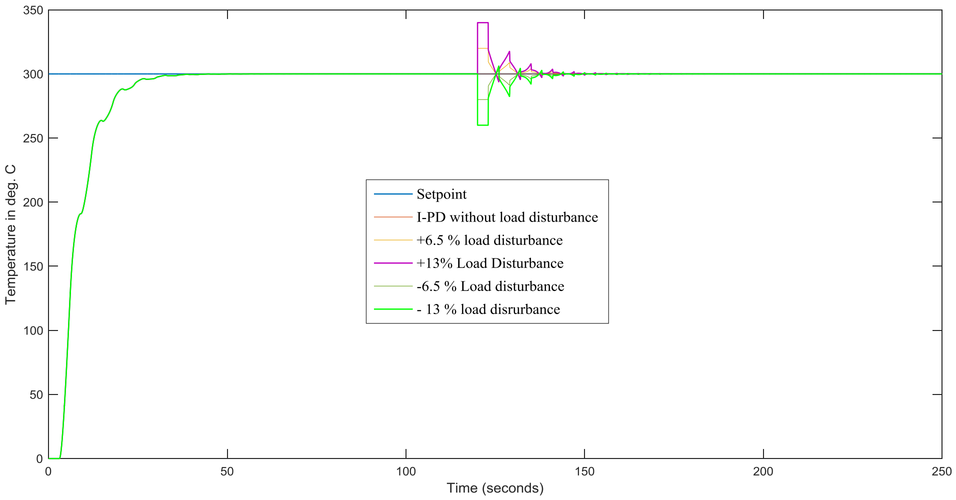

Figure 7: Regulatory Control in zone-3 of barrel heating system with I-PD controller

From the above figure it is observed that the load disturbances are give as +6.5%, +13%, -6.5% and -13% of set point and analysis is done. The I-PD controller rejects the load disturbances given as 120sec and reaches the set point with in 30sec.

5. Conclusion:

The characteristics of barrel temperature control of the plastic injection molding system are analyzed with the mathematical model. The I-PD controller reduces settling time and oscillations compared to conventional PID controller. Thus the I-PD controller avoids the drawbacks of the PID controller. Improved set point tracking and load disturbance rejection is achieved with I-PD controllers than the conventional PID controller

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