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# Temperature Controller For Extrusion Process With Dynamic Compensator

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**ABSTRACT**

The process stability and product quality of the extrusion process is mainly determined by the temperature involved in the process. This paper aimed to provide a better temperature control by using conventional controllers with addition to anti-windup compensator. The performance of the compensated conventional controllers was better than the uncompensated controllers. The proposed controllers were simulated using MATLAB software and the results were provided.



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## INTRODUCTION

The extrusion is a process in which the material is passed through series of stages to get the deformation by melting it first and later into a die to get the desired form. The different stages require different temperatures for operation and the operator find its challenging as even a slight change in temperature might change the quality of the product. Among all the extruders available, the single screw extruder is most preferred due to the reliability, operation simplicity, etc. shown in Fig.1

In this paper due to the availability in industry and the availability of process mechanism, we have chosen the single screw extruder as the process equipment and the temperature as the controlling parameter of importance.

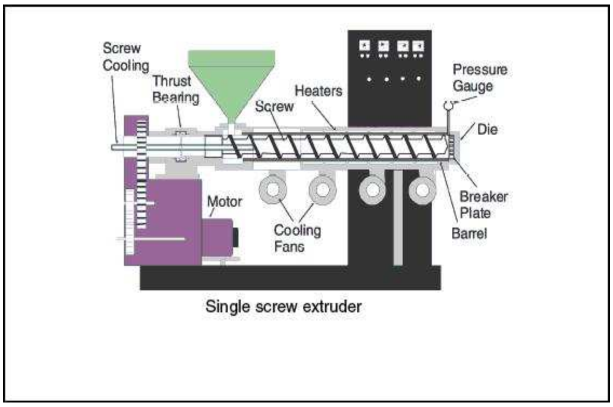


**Fig. 1:** Single screw Extruder

The temperature process of a single screw extruder is a kind of a common controlled objective in temperature control system. It can be described by the given model shown in equation (1).

$$G(S) = \frac{K}{TS+1}e^{-\tau s} \quad (1)$$

And hence for the given system the transfer function (Manikiran, P., G. Ramesh, 2013) obtained

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as

$$G(S) = \frac{0.92}{144S+1}e^{-10s} \quad (2)$$

Where,
Static gain (K) 0.92
Time constant (T) = 144sec
Lag delay time (τ) = 10 sec

***II. Previous studies on Temperature control:***

The initial work on this control of temperature started with Fontaine (1975) in his research he developed the transfer function model and proposed a control strategy to remove certain instabilities in the process but compromised on the quality of the product. LaterFingerle (1978) suggested a modification in the design of the extruder with the PID controller though his work showed an improvement in temperature control, the change in design of the extruder was considered as the limitation.Dormeier (1979) designed a PID control algorithm to control the melt temperature with three heating zones. It showed better performance than other analog controllers but failed to regulate high frequency disturbances.

Hassan and parnaby (1981) improved their system with adaptive control and developed a model reference steady state computer controller. The authors proved that the controller was able to sustain the temperature with small variations to the essential limits.C. Muhrer, C. Guerrero, and W. I. Patterson (1983) introduced a cascade (PI) control scheme to regulate the temperature by manipulating the barrel zone temperature. The controller has to be tuned for various operating condition to attain the proportional and integral gains of the controller.

D. D. Germuska, P. A. Taylor, and J. D. Wright (1984) used the screw speed, die heater power and the mass flow rate thereby they developed an adaptive and multivariable control approach to control the melt pressure, temperature and extrudate thickness. The controller for controlling the temperature and pressure showed good performance but the extrudate thickness controller failed to perform well due to the noisy thickness measurements.Chi-Huang Lu &Ching-Chih Tsai (2001) combined the adaptive and predictive control and proposed the adaptive decoupling predictive temperature process for extrusion process. They used the TMS320C31 digital signal processor for recursive least square estimation algorithm.

***II. System Design with Uncompensated ConventionalControllers:***

A simple controllers widely used in industrial control is PI and PID controller. But the parameter selection for the $K_P$, $K_I$, $K_D$ gains is always a challenging work. Many tuning algorithms were developed, but still it is a most important twinge to select exact algorithm for designing PID gain values for the exact system for an exact process control. The system block diagram with PID controller is shown in Fig.2

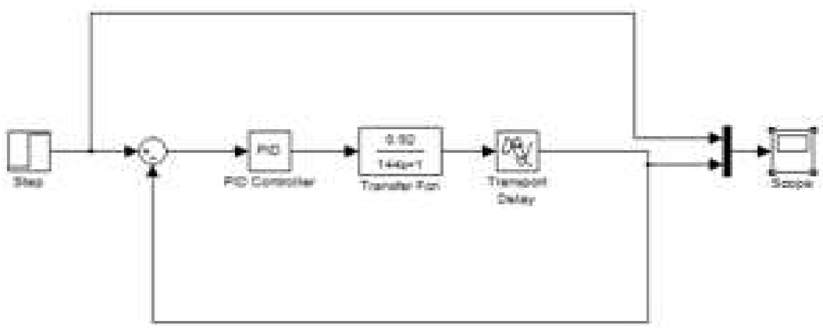


**Fig. 2:** Uncompensated PID controller

The Ziegler Nichols Tuning method is used to tune the PID controller by setting up the values of $K_P$ = 7, $K_I$ = 0.35, and $K_D$ = 33.

The system block diagram with PI controller is shown in Fig.3

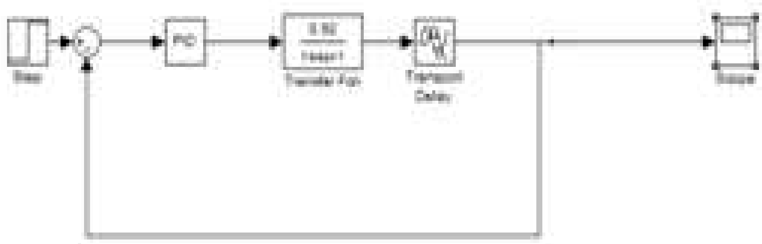

**Fig. 3:** Uncompensated PI controller

The Ziegler Nichols Tuning method is used to tune the PI controller by setting up the values of

$K_P = 3.0375$, $K_I = 0.049430431$, and $K_D = 0$.

***III. System Design with Compensated Conventional Controllers:***

The addition of anti-windup compensators will reduce the overshoots caused by the integral part of the controller section. An anti-windup (Jonas Ohr, 2003) compensator consists of a nominal controller appended with anti-windup compensation. An important property of anti-windup compensation is that it leaves the loop unaffected as long as saturation does not occur. Consequently, the control action provided by the anti-windup compensator is identical to that of the nominal controller, as long as the control signals operate within the saturation limits. Anti-windup was originally used for preventing the integrator state in PID controllers from growing large and cause overshoots and limit cycles. Anti-windup compensation is the simplest and most commonly used modification of a linear controller, aiming at retaining stability and most of the performance in such a system.The system block diagram with Compensated PID controller is shown in Fig.4

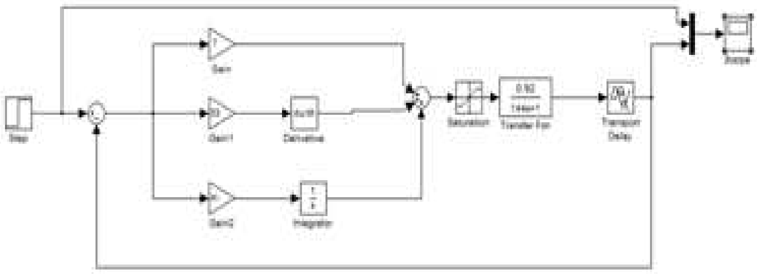


**Fig. 4:** Compensated PID controller

The system block diagram with Compensated PI controller is shown in Fig.5

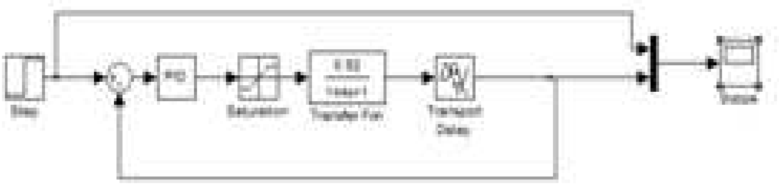


**Fig. 5:** Compensated PI controller

## RESULTS AND DISCUSSIONS

The various simulation results for the above controller block diagrams are provided here. These results show that the addition of anti-windup compensator to the system gives better performance by reducing the overshoots caused by the conventional controllers.

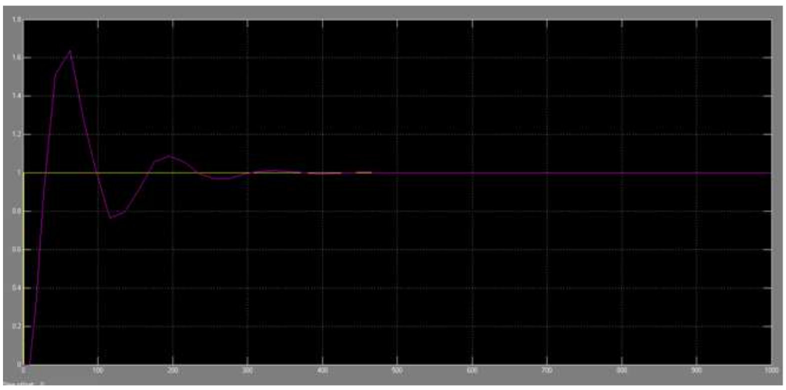

**Fig. 6:** Uncompensated PID controller response

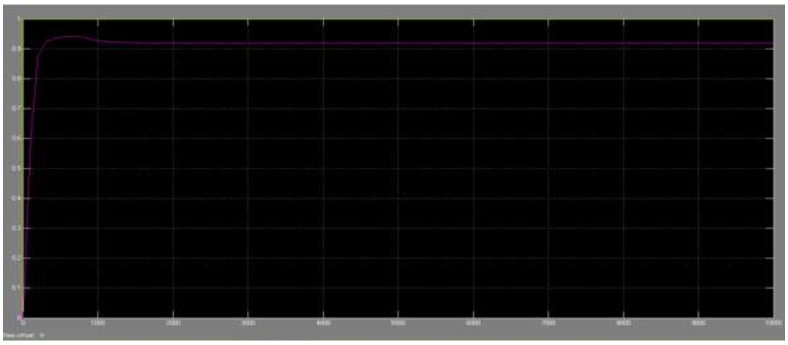

**Fig. 7:** Compensated PID controller response

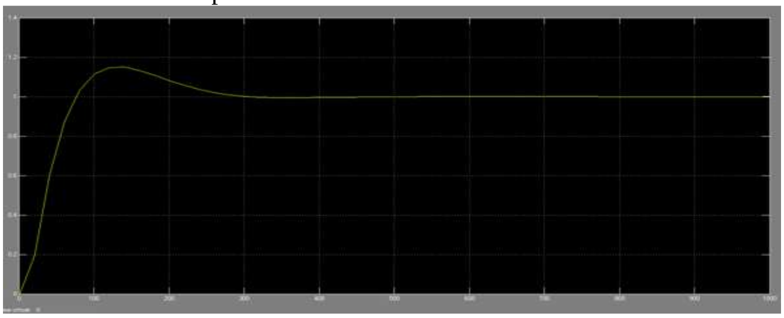

**Fig. 8:** Uncompensated PI controller response

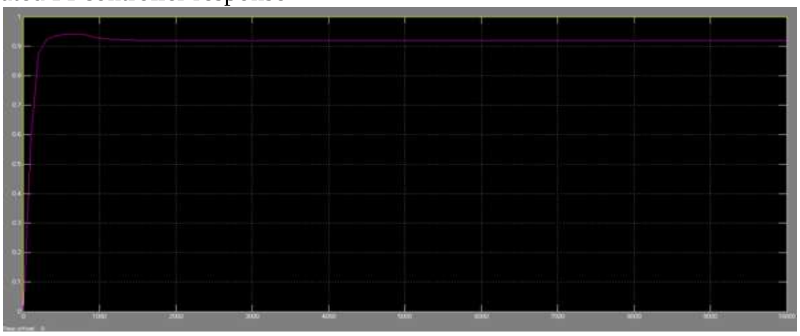

**Fig. 9:** Compensated PI controller response

***Conclusion:***

From this works it was observed that in addition to the conventional PI and PID controller, the addition of the Anti-windup compensator has reduced the overshoot to the maximum and moreover it improved the performance even with good setpoint tracking. Though the anti-windup compensator gives good performance thefurther improvements can be done by using artificial intelligence such asneurofuzzy may yieldbetter performance.

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