ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization    Volume 5, Special Issue 1, March 2016

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st & 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

# A Novel Model Based Controller for Polymer Extrusion Process

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**ABSTRACT:** In this paper we are designing controllers to maintain the average melt temperature of polymer extrusion process. The basic technique of processing polymeric materials for controlling the melt temperature for obtaining high quality extruded products is known as extrusion. Therefore maintaining the melt temperature is an important concern for high quality products. It is known that melt temperature varies based on the radial position of the die, hence point based measurement is not used since it has limited performance. A novel model based control has been proposed then for the control of melt temperature with the help of profile prediction sensor and fuzzy logic controller. The result shows that it gives the average melt temperature in the case of temperature variance. Therefore, this would be an alternative to point based measurements for present industry.

**KEYWORDS:** Fuzzy logic controller, melt temperature, model based controller, polymer extrusion process, PID controller.

## I. INTRODUCTION

Extrusion is one of the main methods of processing polymeric materials and this process is involved in final production of polymeric materials such as pipes, films, tubes, rods etc. The screw is said to be the major component of an extrusion machine and it has been divided into three functional zones based on the operations of the machine which is shown (1).

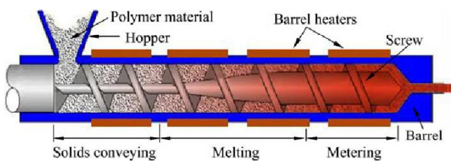


**Fig.1:Functional/geometrical zones of a single screw extruder.**

The transition points between the extruder are said to be dependent to screw speed, pressure, temperature and also the polymer type. There are two type of polymer extruders used in present industry, that is, continuous and batch extruders. Continuous extruders are the one that is mostly used in present industries but they give poor performance. Hence, this study is focused on the continuous extruders' development. Among continuous extruders, we have single screw continuous extruder, which is widely used because of their simple operation, low costs, reliability and their ability to generate pressure. The other is the Twin-screw extruders are generally used in industries, where the applications such as mixing, compounding or in the reaction of polymeric materials. In future, multi-extruders would be researched for the extension of controller's operation.

## II. CONTROL OF MELT TEMPERATURE

The melt temperature is predicted with the help of sensor and it is combined with the control of decision making mechanism for novel model based controller design which is shown (1)

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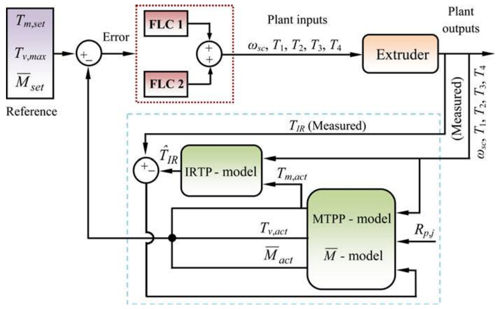


**Fig.2:Structure of the proposed soft sensor to predict the melt temperatureprofile across the extruder output melt flow in real-time.**

Both the fuzzy logic controllers' output adjusts the manipulated variable for maintaining the thermal stability at their limits while the required mass flow rate is achieved at each screw speed.As figure-2 shows the soft sensor provides two models. One is for measuring the melt temperature and hence said to be as melt temperature profile prediction (MTPP) model which takes six inputs. The inputs are said to be screw speed ($\omega$sc), the radial position across the melt flow (Rp,j) and temperature of 1-4 extruder barrel zones (T1-T4). The predicted and measured IR temperature is also taken as the input to this model.The other model is said to be the IR temperature prediction (IRTP) model which takes all the six inputs and it also predicts the melt temperature at 15 different radial positions by the IR temperature sensor.

## III. TEMPERATURE CONTROL MODEL

Step response method is obtained based on the transient response tests. Step input is generally given as input to the transfer function of the system.This represents the unit step response of the system (2).

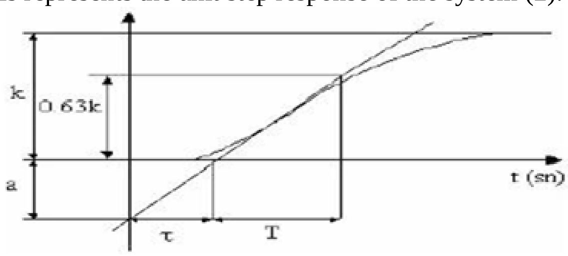


**Fig3:Unit step response of a typical industrial process**

Here K is said to be as static gain, □ is apparent time delay and T is said to be the apparent time constant and the transfer function of the system is named as G(s).The polymer extrusion process generally uses the first order transfer function. The parameters of the equations are K=0.92, T=144S and τ =10seconds.

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

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

## IV. DESIGN OF PI CONTROLLER

PI controller is designed to ensure that the desired temperature gets maintained by regulating it, so that it maintains the operating points in the case of disturbances, set points and noise. The PI controller has a set of gain values such as Proportional gain (Kp) and Integral gain (Ki) whose values are obtained by the method of Zeigler-Nicholas method and Cohen-coon method.

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## V. DESIGN OF PID CONTROLLER

Designing of PID controller is similar to that of the PI controllers except that the PID controller has an extra gain value, that is, the derivative gain (Kd). The gain values of PID such as Kp (Proportional Gain), Ki (Integral Gain) and Kd (Derivative Gain) are obtained using the Zeigler-Nicholas method and Cohen-coon method.

| Type of controller | Kp | Ki | Kd |
|---|---|---|---|
| **PI** | 12.6 | 0.378 | - |
| **PID** | 16.8 | 0.84 | 84 |

**Table 1:Zeigler-Nicholas method**

| Type of controller | Kp | Ki | Kd |
|---|---|---|---|
| **PI** | 14.08 | 0.48 | - |
| **PID** | 20.95 | 0.87 | 75.23 |

**Table 2:Cohen and Coon method**

## VI. DESIGN OF FLC

The Fuzzy-Logic controller is widely used for process control applications. The fuzzy logic controller is designed with the help of framed rules. This controller mainly improves the behavior of the response and also the efficiency of the process.The inputs of the fuzzy logic controller are given by means of membership functions which are known to be as fuzzy sets. The process which converts the crisp quantity into fuzzy values is known as fuzzification and its vice versa is the defuzzification.

| e/ce | NB | NS | Z | PS | PB |
|---|---|---|---|---|---|
| NB | NB | NB | NB | NS | Z |
| NS | NB | NS | NS | Z | PS |
| Z | NB | NS | Z | PS | PB |
| PS | NS | Z | PS | PS | PB |
| PB | Z | PS | PB | PB | PB |

**Table 3**

The above tabular column shows the fuzzy rules used in designing the fuzzy logic controller.

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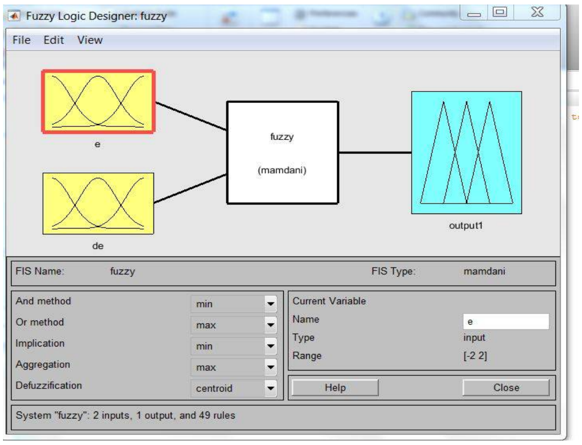


**Fig.3: Membership function of fuzzy logic controller**

This shows the member function used in fuzzy logic controller.

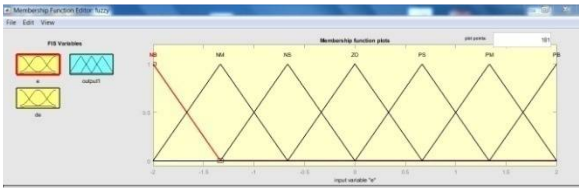

**Fig.4: Error range of FLC**

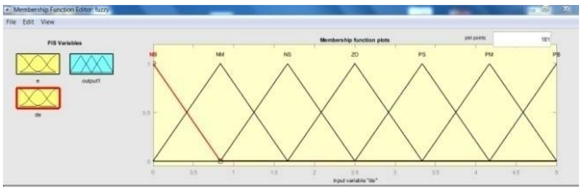

**Fig.5: Range of change in error**

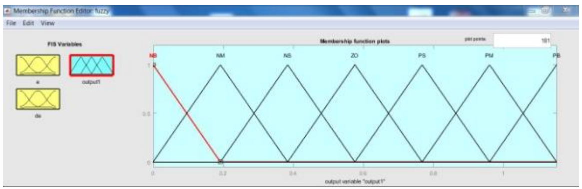

**Fig.6: Output range**

These figures show the error, change in error and output ranges of fuzzy logic controller.

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## VII. RESULT

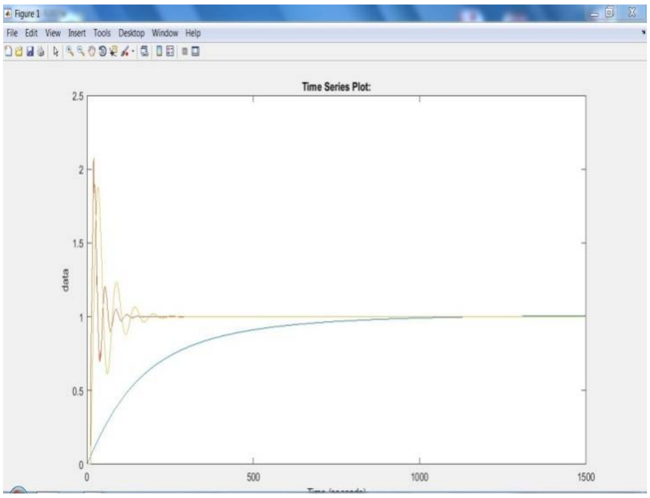


**Fig.7: Response of PI, PID and FLC**

The above is the response of PI, PID and fuzzy logic controllers designed in MATLAB simulink. And the results are compared with the help of their response.

## VIII. CONCLUSION

This paper has demonstrated that the design, analysis and suitability of temperature response control model for plastic extrusion of PI, PID and Fuzzy logic control. A comparative study of performance of PI PID and Fuzzy logic controller is studied. It uses Matlab/Simulink for simulation. From the observations above, it shows that PID gives much better response.

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