Control And Modeling Of Viscosity For Coating Quality In A Single Screw Extruder

Bekir Cirak[1]
[1]Siirt University, Engineering Faculty, Department of Mechanical Engineering
Siirt, Turkey
E mail: bekircirak@mynet.com

***Abstract*—The quality of wire coating is emphasis the coating material viscosity as first indicator parameters in polymer extrusion. Also parameter which primarily determines of the viscosity is shear rate.The other parameters are extruder temperature, and screw rotation speed. ANN model to evaluate the viscosities of thermoplastic polymers in the extrusion process for quality control proposed in this article. Polyvınyl chloride (PVC) was used in this study to test the effectiveness of the model. Comparing the predicted results, it was found that the viscosities obtained with the ANN model are in agreement with those obtained by using an in-line rheometer. The result shows that the predicted method can be applied to control the polymer extrusion process.The topic of this paper is the design and experimental testing of a PID control system for the desired of the barrel temperature, extruder pressure and shear rate in a polymer single screw extruder. A three layer back propogation artificial neutral network (ANN) model was used for description of wire coating thickness. On comparing the experimental data, the predictions the ANN model predictions, it is found that the ANN model is capable of predicting the coating viscosity. In this paper, the results of experimental investigation are presented by comparing the coating quality on galvanized mild steel wire using EP 58 PVC molten is used as the coating material in a wire coating extrusion unit at different extruder temperatures, extruder speeds and shear rate value.**

Keywords—Barrel temperature; Extruder; MPC and PID control; ANN; Shear rate; Viscosity

NOMENCLATURE ; SSE-Single screw Extruder, PVC-Polyvinyl chloride, ANN-Artificial Neural Network, MPC-Model

Predictive Control, SISO-Single Input Single Output, ARX-Auto Regressive with eXogenous

I. Material And Experimental Procedure

In this study, EP 58 PVC coating plastic material was used as test material. The material was supplied from EL-Kİ KABLO (Manisa/Turkey). The experimental value and data is given from this company. The die heating zones was maintained at the same temperature, which was also varied during the experiments. Some of temperatures for each heating zone (barrel) ,the different screw speeds, shear rates and viscosity values are shown in Table 1.Sixty combinations were tested for their effect on the parameters of the extruded parts. The process settings were varied randomly and continuously; i.e. without stopping the process. Each setting was allowed to run. Table 1 shows first 30 experimental values used in training and used in testing.Total values used 60 piece.

Table I. Range of experimental process parameters

Experimental data values	: Manuel from process
Experimental name	: Coating Quality
Wire diameter	: 1,40 mm (7 x 0,20 mm)
Wire material	: Galvanized mild steel
Coating material	: EP 58 PVC
Time interval	: 10 min.

	INPUT						OUTPUT	
	Screw Speed (rpm)	1.Barrel Temperature (°C)	2.Barrel Temperature (°C)	3.Barrel Temperature (°C)	Shear Rate (1/S)		Viscosity (Pa.s.)	ANN
Setting Values	485	103	150	160	20		825	
1	485	103	147	159	20		825	First 30 experimental value used in training and other 30 experimental value used in testing
2	486	102	147	160	26		822	
3	485	104	148	161	26		822	
4	487	103	150	160	24		823	
5	485	103	150	165	22		824	
6	484	105	149	161	26		822	
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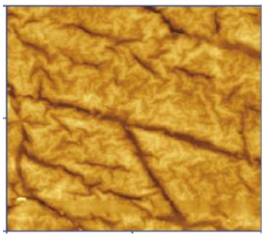
54	484	102	147	159	20		823	
55	485	104	150	160	24		824	
56	486	103	149	159	24		825	
57	485	105	149	161	22		826	
58	484	106	148	159	22		826	
59	483	102	147	159	20		825	
60	484	103	149	159	20		824	

To measure the viscosity and shear rate, each sample was measured at five different positions along its length by a in line rheometer and sample of the coated wire is noted. A small portion of the wire sample is cold mounted and is polished.

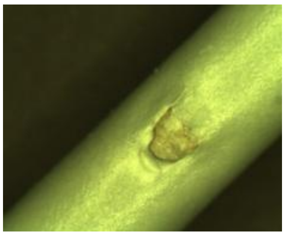
Fig.1. shows coating damages for coating quality and this views to obtained of an optical microscope in coating test laboratuary. Wire coating resulted in a wavelike structure on PVC surfaces containing 20 % plasticizer.The structure was similar regardless of whether the coating was thin or thick. With the thicker coatings the wavelike structure was

larger in area and its height differences were more notable than with the thinner coatings.

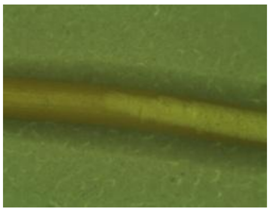
The structures of wire coatings on some sample surfaces are shown in Fig. 1a, 1b and c. Respectively, wavelike structures, plastical acne, matt and smoothless on coated surfaces The roughness of the surface increased when the thickness of the coating increased.The PVC coatings on surfaces containing 30% plasticizer had a structure similar to those with 20 % plasticizer, but the increase in the amount of plasticizer caused the coating to break. The cracks in wire coating surfaces as shown in Fig. 1- a



a- cracks and wavelike



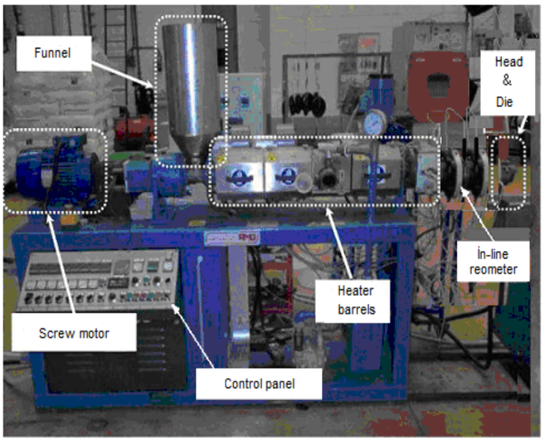
b- plastical acne



c- matt and smoothless

Fig. 1. The Surface Structures Of Coating Quality

The views gives damage of coating surface in wire coating section. In this paper, the wire coating quality of an industry example. The polymer material used for coating the cover is PVC. The other words, the coating material (PVC) shear rate via viscosity and coating surfaces of the wire coating states of an industry example, shown in Fig.1 was studied.



The SSE OMP T35 L / D 24 at the EL-Kİ Cable Co. Manisa / TURKEY

Fig.3. Polymer extruder and parts

Polymer extruder is a general concept and a sample plant which changes product name with construction of die in it. Besides pass to through of funnel and enter of extruder which the changes of polimer as for important as this design [9]. Reometer with to investigate fluid characteristics of coating material in Figure 3.

II. Artificial neural networks

The ANN model for the coating thickness variation of the part built by the above methods is shown in Fig. 4. The node number of the hidden layer was determined by train trials and the final value obtained was 9, that made the configuration of ANN as 3–9–1.A neural network system is presented for use in wire coating process. The tan-sigmoid transfer function was used as the activation function for the hidden layers, and linear transfer function was used for the output layers. Network architecture for viscosity and the contrast of prediction results and numerical experiment results of relationship between viscosity variation and process parameters are shown in Fig.4.

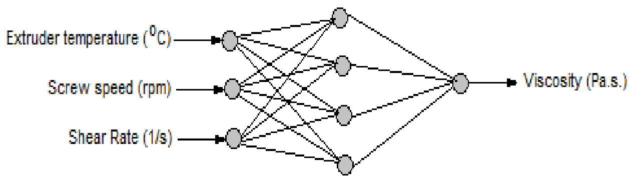


Fig. 4. Wire coating quality configüration of the ANN Model

Fig. 5 shows iteration number versus mean square error for training nonlinear coating viscosity.

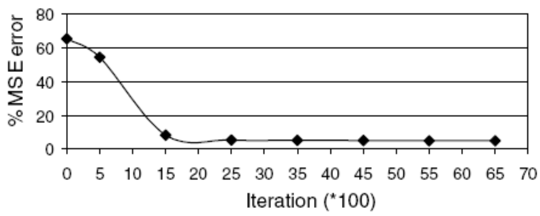


Fig. 5. Iteration number versus mean square error for training nonlinear coating viscosity

The simulation function based on the ANN was used as the objective function of the optimization problem, and the process window for each variable as given above was used as the boundary restrictions. The remaining 60 samples were then used to test and to train the performance of the ANN. As shown in Fig. 6,7

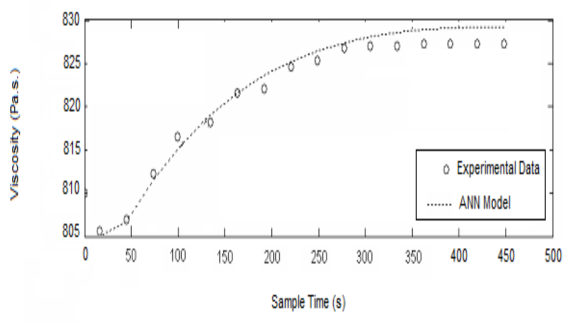


Figure 6. Plant and model responses to a unit step changes in test samples

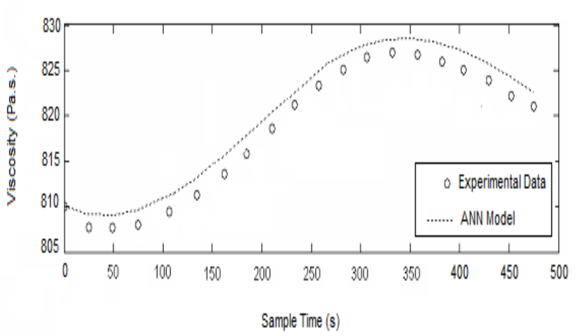


Figure 7. Plant and model responses to a unit step changes in train samples

III. Model Predictive Control

Identification of the system used Matlab 2009b-toolbox to creat a model program in MPC control, again by using Matlab 2010-a toolbox system for modelling. MPC occured by plant model enviroment. ARX and ARMAX models are used. For preparing of models, linear parametric models are satisfied by MATLAB System Identification Toolbox 7.9. System models are lineeralized by basic polinomal equations,

$$A(q) = 1 - 0,3055\, q^{-1} + 0,2457\, q^{-2} - 0,1536\, q^{-3} \qquad (4.8.)$$

$$B(q) = 0,2471\, q^{-4} - 0,09878\, q^{-5} \qquad (4.9.)$$

MPC control model inner system for ARX model, taken from system and non-linear data linearized by equations of (4.8.) and (4.9.) for viscosity model. Linear model output values, approximately equals to real results and benefit to curve at Figure 8. ARMAX and ARX models outputs and process real data are showed at Figure 8 by comparing each us. ARMAX and ARX models by using experimental results which is fitted at 89,10% ratio to ARX models. ARMAX model is fitted at 51.08% ratio.

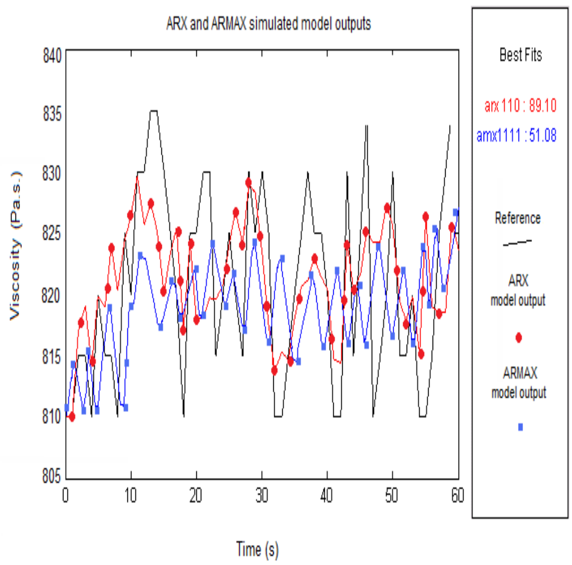


Fig.8. ARX and ARMAX model responses to unit step changes in viscosity

Feedback control loop for PID controllers and MPC controller designed in SIMULINK. PID control and MPC control loops designed using SIMULINK is given in Figure 9 and Figure 10.

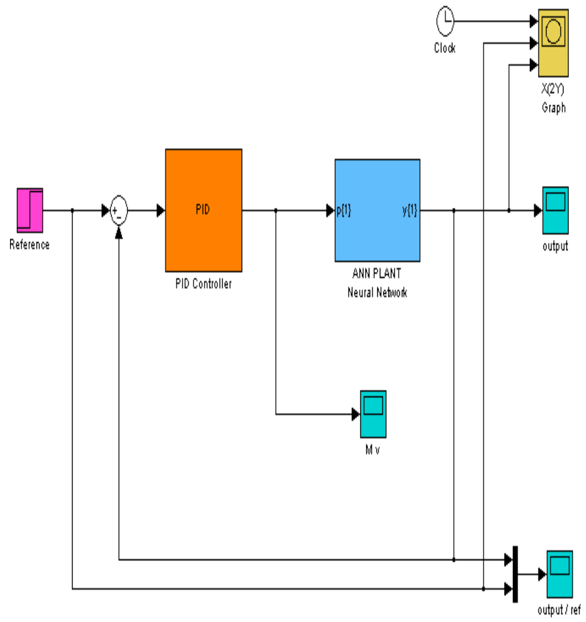


Fig. 9. PID Control Model by Simulink

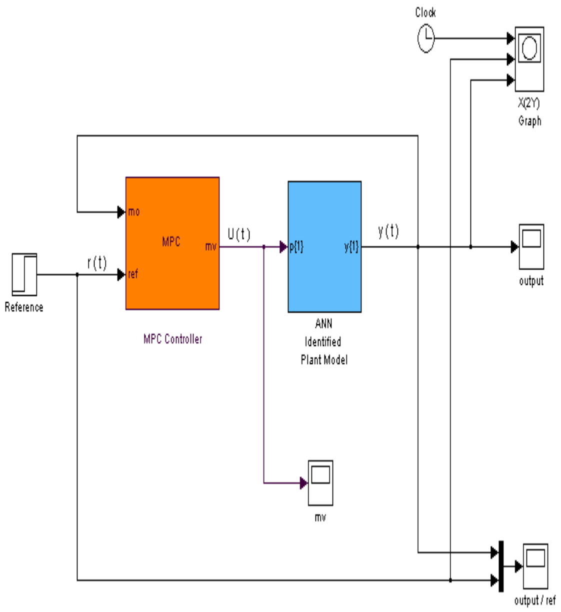


Fig. 10. MPC Control Model by Simulink

As can be seen at Figure 11 in references to the variable that is running under the process of MPC, and PID control with the MPC there is a distinct difference between the answers of a more rapid response than the PID controller are given. MPC-line method, the reference value of viscosity of less than 1% error with a permanent error with PID control method, permanently settled in around 1%. Describes the model predictive controller has a faster response than PID controller.

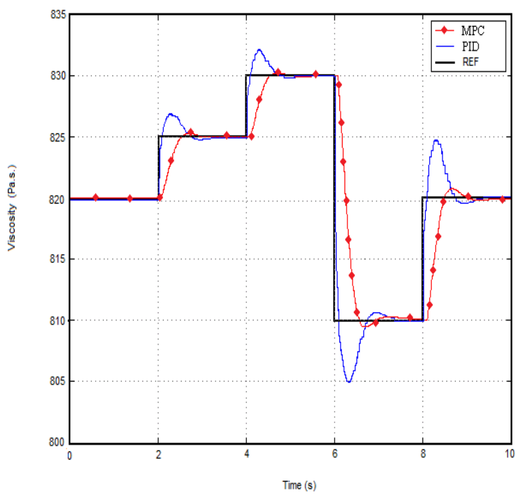


Fig.11. Comparison of MPC and PID results (Viscosity ref=820-825-830-810-820 Pa.s.)

IV. Conclusion

In this study, experimental and theoretical studies are done to design an nonlinear control scheme for the feedback control of wire coating quality during polimer extrusion process. Quality viscosity of 820 Pa.s.-830 pa.s. in the range selected for the simulation of the system if it is controlled by PID controller, while exceeding the 5.8% of the exceedance, when controlled by the model predictive controller was observed to be 2%. However, the value of viscosity of the PID controller, a 5% error with the reference model predictive controller 1.8% error with the reference placed settled.

As a result, the model predictive control (MPC), the desired wire coating system is controlled within acceptable limits. Compared with PID controllers, PID controller, MPC observed that the control system, such as variable references under the system successfully. However, given the restrictions on the model predictive controller based PID controller concluded that a more healthy work

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