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Experimental Results for Concentricity in Wire Coating Processes

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Author's contribution

This whole work was carried out by the author BC.

Original Research Article

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ABSTRACT

The wire coating thickness and quality depend on the wire speed, polymer viscosity, polymer melt temperature and the gap between the wire and exit end of the die. In this paper, 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 extrusıon unit at different extruder temperatures and extruder speeds. The coating thickness and quality are also discussed for different wire speeds of up to 15 m/s.

Keywords: Wire coating extruder; coating thickness; PVC; extrusion.

NOMENCLATURES

w_V : Wire velocity
p_t : Polimer temperature

1. INTRODUCTION

Polymer coating is often applied to wires, strips, tubes or ropes for insulation or protection against corrosion. There are three different methods which are mostly used for this coating process. These methods are coaxial extrusion, dipping and electro-statical deposition

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process. The first two processes can be reasonably fast but bonding between the continuum and the coating material is not so strong. The third process offers much stronger bonding but is relatively slow. If the coating material can be forced onto the continuum uniformly the bonding can be improved significantly.

A continuously increasing number of commercial products are produced by polymer extrusion using plasticating extruders, which are among the most widely used equipments in polymer process industry.The extrusion process has a standard setup includinga feeding section, a barrel and a head with a die for shaping. In the feeding section, the solid polymer is fed into the extruder through a hopper in the form of pellets or irregular small bits. Then, the polymer is transported along the barrel by means of a rotating screw.

The plasticating extruder is one of the main pieces of equipment used in the polymer processing industries. As plastics is found more uses, with more stringent quality specifications, the methods of increasing polymer production while improving product quality are needed. Extrusıon molding is the most widely used process in manufacturing plastic products. Since the quality of extrusıon coated plastic parts are mostly influenced by process conditions, how to determine the optimum process conditions becomes the key to improving the part quality.

Hydrodynamic wire coating was first carried out by Parvinmehr et al. who used a die-less pressure unit whose smallest bore was slightly greater than the diameter of the undeformed wire. For their work the tests were carried out with wire of 1.6 mm diameter.

S. Akter and M.S.J. Hashmi, studied hydrodynamic wire coating with Nylon 6 using a combined geometry pressure unit. They experimented carried out within the speed range of 2 and 12 m s^{-1}. They achieved the bonding quality of the coating with wire very good. [1-4]

Symmons et al. [5] reported the results of their works on coating of fine wire (diameter 0.45 mm) in relation to plasto-hydrodynamic drawing and coating. The drawing spee range was from 0.05 to 0.8 m s^{-1}. Also Lamb and Hashmi [6] and Yu and Hashmi [7] carried out their research on polymer coating using fine wires of diameter between 0.1 and 0.4 mm. They achieved a fairly constant polymer coating for wire speeds of up to a maximum of 0.6 m s^{-1}. Dormeier reported that the viscosity characterises the flow behaviour of the plastified polymer [8]. G.R. Symmons, M.S.J. Hashmi, H. Parvimehr For plasto-hydrodynamic die-less wire coating using aconical geometry pressure unit, theoretical models for pressure distribution have been developed in Cartesian coordinates in for polymer melt rheology based on Rabinowitch equation [9].

In the literature, many efforts have been made to establish the relationship between viscosity, temperature and shear rate. In other the study, it was assumed that the relationship between viscosity and shear rate is described by the power-law equation [10-12]. In all these works, the wire coating speed was rather low with little prospect of industrial scale production.The main objective of this paper is to present the results of research carried out on the quality of coating at wire velocities between 2 and 12 m s^{-1}. The effects of the polymer melt temperature and wire velocity on the coating process have also been investigated.

2. EXPERIMENTAL EQUIPMENT AND PROCEDURE

The experimental set up consists of the drawing bench, the wire bobbine, the cooling pool, the drive system (electrical motor), the polymer feeding and melting unit (extruder) and the drawer and winder unit. A schematic diagram of the process is shown in Fig. 1. The polymer granules are filled in the hopper and the hopper is connected to the body of extruder. The PVC compound was prepared using a proprietary formula which includes PVC resin, foaming (blowing) agent, heat stabilizer, lubricant, process aid, pigment and filler.

The extrusion process parameters; i.e. barrel heater zones' temperatures and screw speed were varied systematically and in random order to vary of the extruded parts. The available extruder incorporated five heating zones along the barrel and two independent heater zones at the die sections. In order to maintain a constant heat profile in the barrel, the ratio between the five heater zones was fixed during all experiments while varying the temperatures of all five heater zones accordingly. The die heater zones were maintained at the same temperature, which was also varied during the experiments.

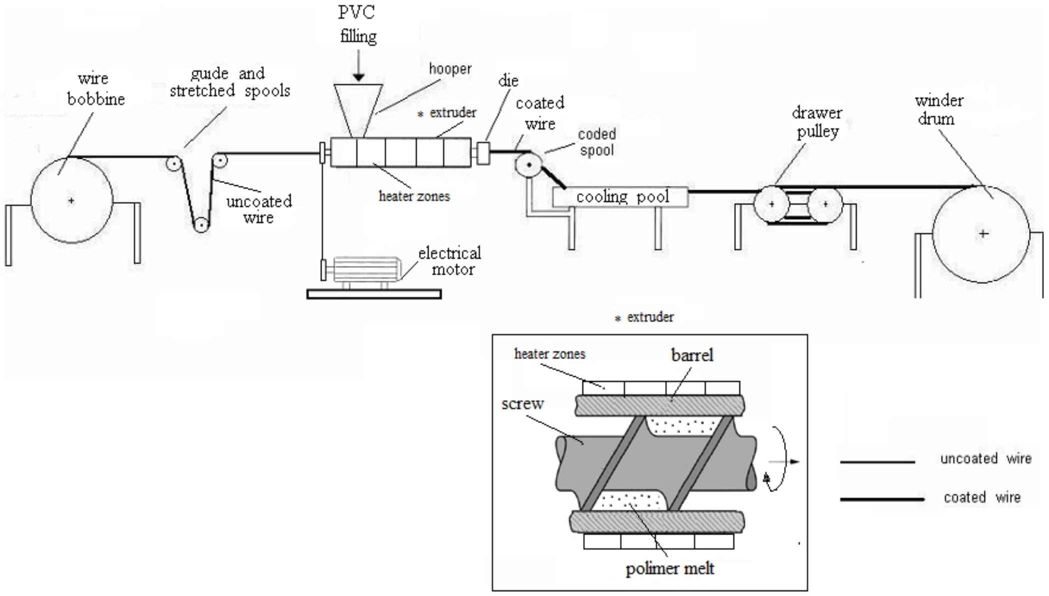

Fig. 1. Wire coating extrusion process scheme

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Coating Material and Wire Parameters

Coating material is PVC polimer. State the nature of PVC used plasticized. Polymer characteristics; Polymer type is EP 58 PVC , Polymer melt temperature is 150 – 200ºC and Wire characteristics; Wire diameter is 1.40 mm (0.20 x 7 mm) , Wire material is copper . Experimental work was carried out at polymer melt temperatures of 150, 175 and 200ºC. Polymer melt properties; Viscosity at polymer melt temperature 200ºC at different wire velocities and shear rates: at 2 m s^{-1} the shear rate is 2865 s^{-1} and the polymer melt viscosity is 53 Poise; at 4 m s^{-1} the shear rate is 5630 s^{-1} and the polymer melt viscosity is

34 Poise; at 6 m s^{-1} the shear rate is 8545 s^{-1} and the polymer melt viscosity is 24 Poise.This values measured by extruder and viscositer in a processes.

3.2 Die Parameters

The schematic diagram of the conical die is shown in Fig. 2. The total length of the die is 25 mm. Other geometric parameters are presented radial gap between the wire and the die in the inner of the first space, $h_1 = 0.85$ mm; radial gap between the wire and the die in the exit of the second space, $h_2 = 0.50$ mm.

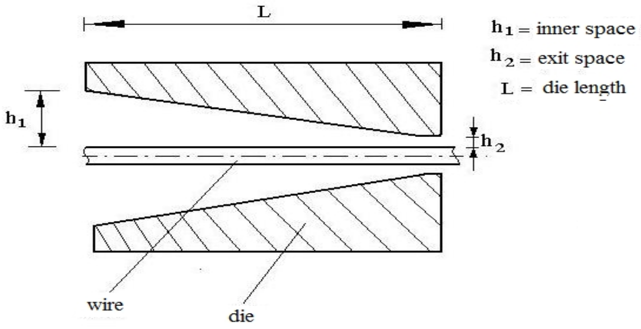

Fig. 2. Schematic diagram of a conical die

4. EXPERIMENTAL AND THEORETICAL WORK

Experimental work was carried out at polymer melt temperatures of 150ºC, 175ºC and 200ºC. For different combinations of polymer melt temperature, experiments were carried out for wire velocities of 2, 4, 6, 8, and 10 m s^{-1}. The results of these tests are presented in the following figures in terms of the coating thickness and drawing load.

4.1 Coating Model and Measure

To measure the coating thickness, each sample is measured at five different positions along its length by a micrometer and the average diameter of the coated wire is noted. A small portion of the wire sample is cold mounted and polished. An optical microscope is then used to assess the actual coating thickness and the concentricity of the coating on the wire. Fig.3. shows coating model and this model to consist of an optical microscope.

The thickness was almost equal to the exit gap between the wire and the unit (0.051 mm). In these experiments it was observed that there was no deformation of the wire. If there is no deformation in the wire then theoretically the coating thickness should be equal to the gap between the wire and the exit end of the conical die. The experimental results confirm this. Upon visual inspection the coating on the polymer appeared to be concentric. To confirm this a number of samples were prepared and polished for examination using an optical microscope.

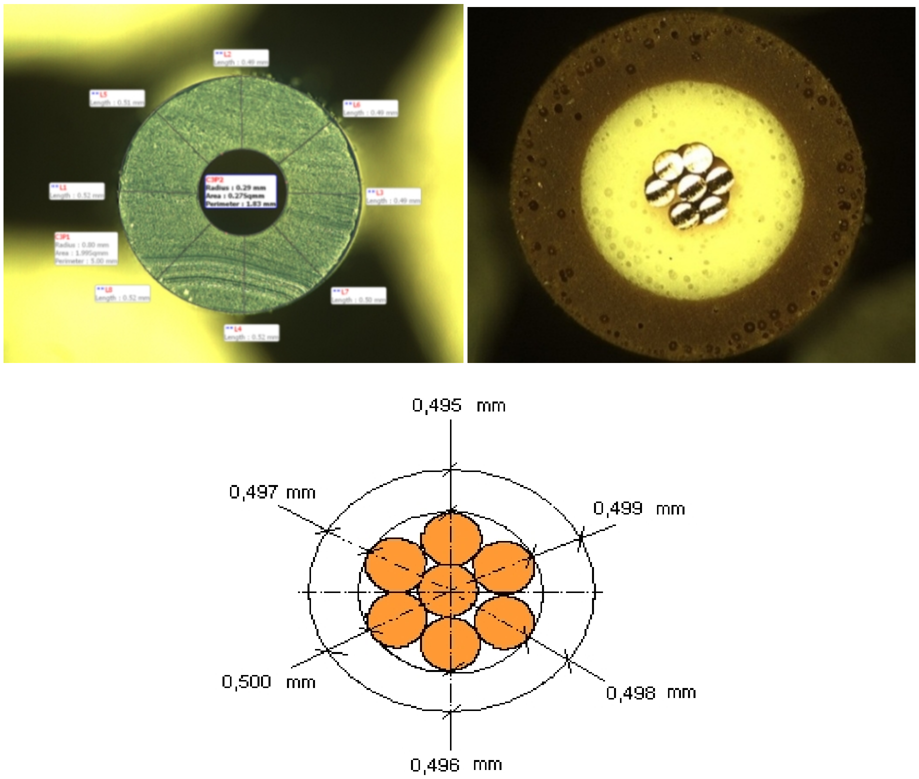

Fig. 3. Coating model

The geometry gives distance of coating centre between wire centre of wire coating section. In this paper, the wire coating states of an industry example, shown in Fig. 4, was studied. The polymer material used for coating the cover is PVC.

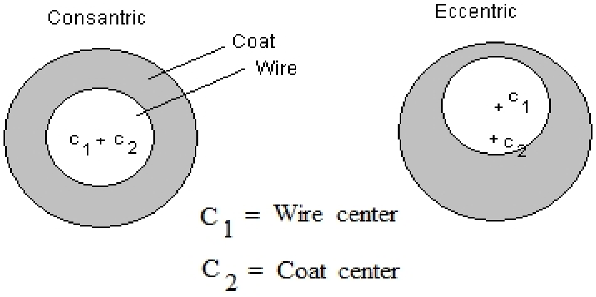

Fig. 4. The eccentricity and concentricity status between centres of wire and coating

The barrel wall is equipped with a number of electric heaters which melt the polymer. The material is melted and pushed towards the die where the extruded final product is shaped and expelled. During the process, the polymer coating is often applied to wires, strips, tubes or ropes for insulation or protection against corrosion. Also the geometry gives distance of coating centre between wire centre of wire coating section.The other words , the eccentricity (üniformess coating) and concentricity (üniform coating) of the wire coating states of an industry example, shown in Fig. 4 was studied.

4.2 Experimental Figures

Figs. 5-7 present the coating thickness on wire deposited using a conical die. The variables were drawing speed (up to 10 m s^{-1}) and polymer melt temperature (150ºC, 175ºC and 200ºC). In all these cases the coating was found to be continuous.

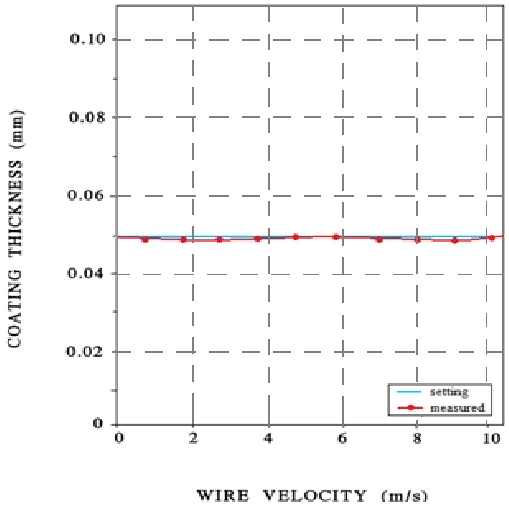

Fig. 5. Coating thickness on wire in the extruder for p_{t} = 150ºC

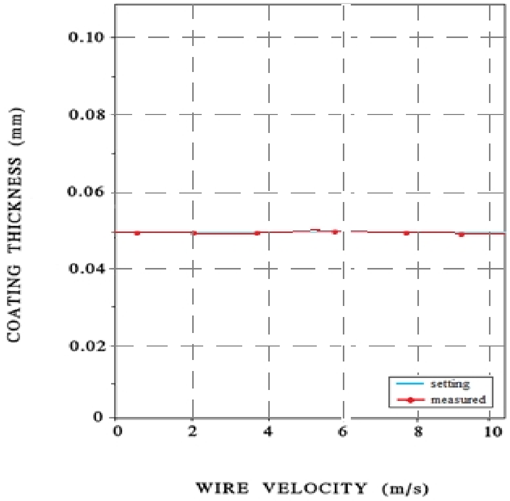

Fig. 6. Coating thickness on wire in the extruder for p_{t} = 175ºC.

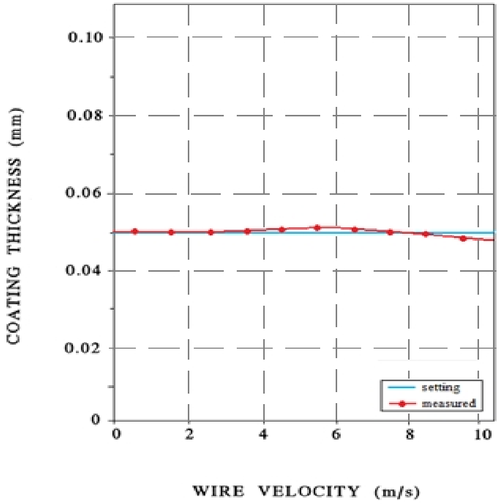

Fig. 7. Coating thickness on wire in the extruder for p_{t} = 200ºC

Fig. 8 shows the drawing force generated by the wire in the extruder for the polymer melt temperature of 150ºC. This figure illustrates that with the increase in wire velocity, the drawing force also increases. With the increase in the wire velocity, the viscosity of the polymer increases. Subsequently the drawing force due to the shear force on the wire also increases.

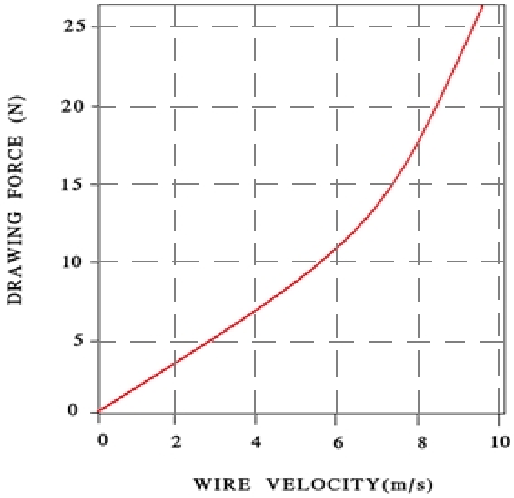

Fig. 8. Drawing force on wire in the extruder for p_{t} =150ºC

Figs. 9 and 10, respectively represent the generated drawing force for polymer melt temperatures of 175ºC and 200ºC.

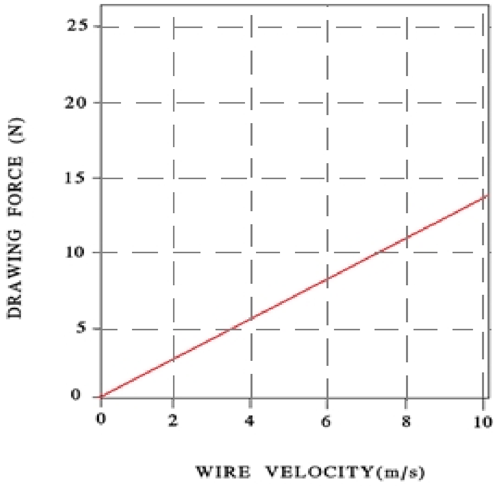

Fig. 9. Drawing force on wire in the extruder for p_{t} =175ºC

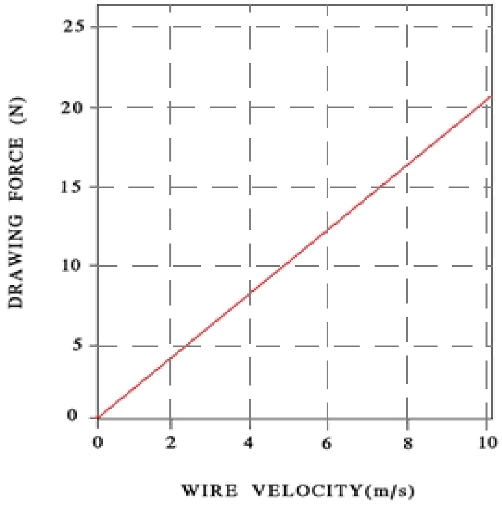

Fig. 10. Drawing force on wire in the extruder for p_{t} = 200ºC

They show similar trend as in Fig. 10 i.e., with the increase in wire velocity the drawing force increases. As the viscosity decreases with the increase in the polymer melt temperature, the drawing force also decreases which has been confirmed by these three figures. The extruder was too small to incorporate temperature transducers at different locations and thus, it was not possible to measure the experimental pressure distribution within the processes. According to von Mises theory of yielding, the deformation of the wire starts when axial stress equals or exceeds the elastic limit of wire material [13].

In this case the drawing force at polymer melt temperature of 200ºC, and wire velocity 2 m s^{-1}. So in this case the drawing load is not sufficient to cause any plastic deformation in the wire. Experimentally it was also observed that there was no plastic deformation of the wire at wire velocity of 2 m s^{-1} or even at 10 m s^{-1}. The coating thickness, mentioned in this paper therefore is accurate and represents the gap between the wire and the exit end of the extruder. The cross section of the wire was observed to be circular and the coating was reasonably concentric. Fig. 11 shows the concentricity of the coating on wire formed using an extruder. The wire velocity was 8 m s^{-1}, and the melt temperature was 175ºC.

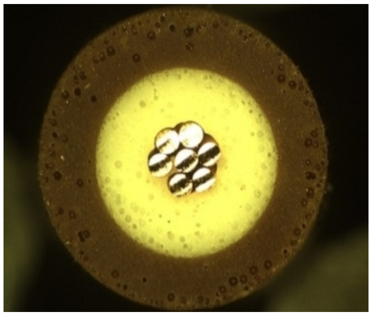

Fig. 11. Concentricity of coating on wire
($h_2 = 0.051$ mm, $w_V = 8$ m s^{-1}, $p_t = 175$ºC)

Fig. 12 represents the coating concentricity for wire velocity of 4 m s^{-1}, polymer melt temperature of 150ºC. Both plates show a concentric coating.

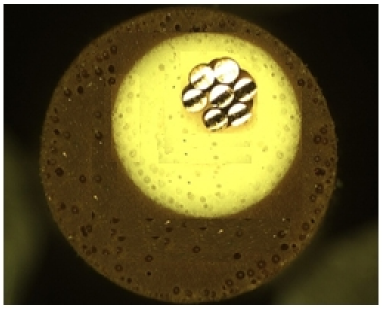

Fig. 12. Concentricity of coating on wire
($h_2 = 0.051$ mm, $w_V = 4$ m s^{-1}, $p_t = 150$ ºC)

It may be mentioned again that there was no discontinuity of the coating in any of these cases. For each of the test conditions the adhesion of the coating to the wire was assessed qualitatively by attempting to scratch off the coating using a sharp edged tool. It was quite difficult to debond the coating from the wire unless the tool edge sharpness is like that of a razor blade. As such, the coating applied should be good enough to withstand any subsequent processing steps involving contact with mechanical tools and dies.

5. CONCLUSIONS

Conventional wire coating with EP 58 PVC using a conical die has been presented. The experiments were carried out within the speed range between 2 and 10 m/s. The polymer coating on the wire is continuous and concentric for speeds of up to 10 m/s. The concentricity quality of the coating with wire was very good.

This paper has presented knowledge based and neural network approaches to wire coating for polymer extrusıon. Experimental results of wire coating extrusion with EP 58 PVC have been presented. Due to some limitation in the present experimental set up the drawer speed is limited to about 10 m/s. Therefore, experiments were carried out within the speed range of up to 10 m/s. The polymer coating on the wire is continuous for speeds of up to 10 m/s.

The bonding quality of the coating with wire was found to be very good. Concentricity is beter in the case of extruder with screw speed 485 rpm and wire velocity 2050 rpm (10 m/s.) Application of screw speed and wire velocity (drawer speed) generally improves the quality of the coating.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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