

# RESEARCH OF CONVEYING CHARACTERISTICS OF POLYMER VANE EXTRUDER

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## Abstract

The working principles of vane extruder are entirely different from screw extruder. Materials were conveyed and plasticized by a group of vanes and the materials suffered mainly normal stress during processing. The heat history and mechanical history that the materials suffered were greatly decreased contrast to screw extruder. In this paper working principles of the vane extruder were introduced in detail. Experiments were carried out on the vane extruder to study the conveying characteristics and the experimental results were presented. Experimental results showed that the specific energy consumption is low and the change of material's properties has little effect on throughput.

## Introduction

The screw machinery, such as screw extruder, screw injection molding machine and so on are widely used for polymer processing. Screws are essential for conveying and plasticizing polymer materials in polymer processing. The screws usually are long so that the equipments are bulky. To convey and plasticizing materials, screw machinery relies heavily on the friction between the materials and the internal surface of the barrel and also the internal friction of the materials which change with the processing conditions such as temperature, die pressure, materials' properties and so on. It is often extremely difficult to obtain reliable friction factor data for a given polymer resin [1, 2]. The melt throughput usually fluctuations in screw extruders caused by inadequacies in wall temperature control [3]. The increased throughput

obtained in single-screw extruders with grooved feed zones raises their productivity it also frequently leads to higher wear and lower energy efficiency [4]. Consequently, the materials suffer long thermal- mechanical history. Many investigations [5~8] in polymer processing have shown clearly that the introduction of vibration force reduced the viscosity and hence improved flowability of the melt. And also the thermo-mechanical history can be shortened. Consequently it can decrease the specific energy consumption and improve the plasticizing capacity. However, during the conveying and plasticizing process the materials still suffers vibrating shear stress. It can't overcome the shortcomings that exist in common screw machinery thoroughly.

In this work, we designed a novel vane extruder to study its conveying characteristics. The vane extruder is entirely different from screw extruder for the reasons as follows: (1) no screw needed; (2) the materials mainly suffer normal stress during conveying and plasticizing process; (3) the change of material's properties has little effect on the throughput. Experiments were carried out on the vane extruder and experimental results were presented in detail as follows:

## Experimental Producer

### Vane Conveying and Plasticizing Unit

Vane conveying and plasticizing unit is the most important element for a vane extruder. The schematic diagram of the Vane conveying and plasticizing unit used

in vane extruder is shown in figure 1. As shown in figure 1, a vane conveying and plasticizing unit comprises six parts, that's to say one rotor; one stator, two baffles, two male vane and two female vane. The internal surface of the stator is eccentric to the outer surface,  $e$  is the eccentric distance. The columned rotor has two perpendicular slots along the radial direction. Two male vanes and two female vanes are installed in the slots which can move freely along the radial direction. Each end of the stator installed one baffle; the baffles are used to control the flow direction of the materials.

As illustrated in figure 1, the volume enclosed by the baffles, vanes, the internal surface of the stator and the surface of the rotor changes from small to big ( or big to small) periodically as the rotor rotate. When the volume changes from small to big (A in figure 1), the materials can flow into it from the hopper or from the upriver vane conveying and plasticizing unit. Accordingly when the volume changes from big to small (B in figure 1), the materials were forced out to another vane conveying and plasticizing unit. When the volume decreases to zero, the materials were completely forced out. The materials were squeezed, grinded and heated by electric heat and the heat generated by internal friction. The materials suffer mainly normal stress during conveying and plasticizing processing. Three or more vane conveying and plasticizing units connected in series can form one vane extruder.

### **Vane Extruder**

The schematic diagram of the vane extruder used in the experiment is shown in figure 2. The vane extruder comprises three vane conveying and plasticizing units. The rotors of the three vane conveying and plasticizing units were drove by the transmission shaft. As showed in figure 2, the space's volume under the hopper always changes from small to big as the transmission shaft rotation. The materials in the hopper flow into the vane conveying and plasticizing unit I and were forced out from unit I into unit II and then flow into unit III for further plasticizing. The

material can only flow from unit I into unit II but can't from unit II into unit I and also the material can only flow from unit II into unit III but can't from unit III into unit II.

## **Materials and Materials Processing**

Low density polyethylene (LDPE, 951-050) resin was used for the experimental work, and it was manufactured by MaoMin Branch of China Petroleum and Chemical Corporation. The resin had a solid density of  $0.92 \text{ g/cm}^3$ . The melt index (MI) for the resin was  $2.17(\text{g}/10\text{min})$  ( $190^\circ\text{C}$ ,  $2.16\text{kg}$ ).

### **Experiment**

A self-made vane extruder as illustrated in Figure 2 was operated according to the parameters listed in Table 1. The temperatures were measured and controlled by thermocouple, the die pressure were measured by pressure transducer installed on the flange.

## **Results and Discussion**

Figure 3 showed the Influence of die pressure on throughput at different rotation speed. As illustrated in figure 3, the throughput decrease with the increase of die pressure. There is a platform on the curve. With the increase of rotation speed the platform region is wider. In the platform the throughput decrease little while after the turning point the throughput decrease fast. This mainly because when the die pressure is high enough the leakage flow will increase rapidly which leading to the fast decrease of throughput. The leakage flow of vane extruder is caused by the gaps between vanes, rotor and stator. If the gaps can be strictly controlled, the leakage flow will be very little.

Figure 4 showed the Influence of rotation speed on throughput at different die pressure. As illustrated in figure 4, the throughput increase almost linearly with the increase of rotation speed at different die pressure. The throughput

is insensitive to die pressure. This is because that vane extruder is completely positive displacement volumetric transport. The amount of the material transport is independent of the friction between materials with barrel or the internal friction of materials. During conveying and plasticizing the materials suffers mainly normal stress thus the shear dissipation energy is very small.

Figure 5 and figure 6 showed the influence of die pressure and rotation speed on extrusion power (no heaters power included). As seen in figure 5, the extrusion power increase almost linearly with the increase of rotation speed at constant die pressure. As illustrated in figure 6, the extrusion power first increase and then decrease a little with the increase of die pressure at constant rotation speed. This mainly because the increase of die pressure leading to high flow resistance and also more leakage flow which cause the throughput decrease.

As the vane extruder is much shorter than conventional screw extruder so the energy consumption should be low. Figure 7 is the change of specific energy consumption with die pressure at different rotation speed. When the die pressure increased, the flow resistance will increase accordingly. As can be seen form figure 7, the specific energy consumption increase with the increase of die pressure. Figure 8 showed the relation of specific energy consumption with rotation speed at different die pressure. As can be seen form figure 8, the maximum specific energy consumption doesn't exceed 0.18 KW/(Kg/h). The specific energy consumption decrease fast with the increase of rotation speed at first and then increase a little when the rotation speed of is over 60rpm.

## Conclusions

On the basis of experimental results, the important conclusions are:

- (1)The conveying process of a vane extruder is completely positive displacement volumetric convey;
- (2)During the conveying and plasticizing the materials

suffers mainly normal stress. The change of material's properties has little effect on throughput and the throughput is insensitive to die pressure.

- (3) The specific energy consumption is low. The vane extruder is much shorter than conventional screw machinery that the thermal-mechanical history the material experience can be greatly shortened.

## Acknowledgements

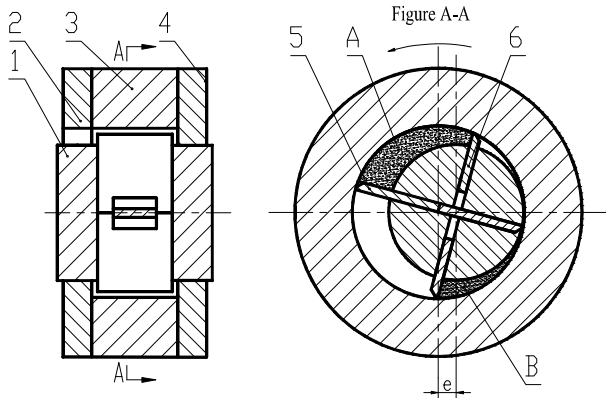
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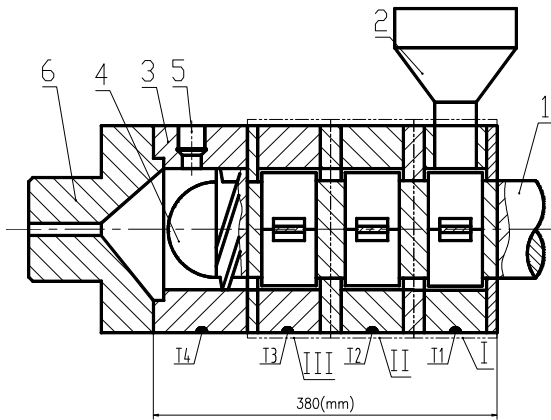
Table 1: Temperatures at different position (°C)

T1	T2	T3	T4
190	210	210	210



1 rotor; 2 baffle ; 3 stator; 4 baffle ; 5 male vane;  
6 female vane;

Figure 1 Schematic Diagram of the Vane Conveying and Plasticizing Unit



1Transmission shaft; 2 Hopper; 3 Flange ; 4spreader;  
5 Pressure Transducer; 6 Die

Figure 2 Schematic Map of the vane extruder

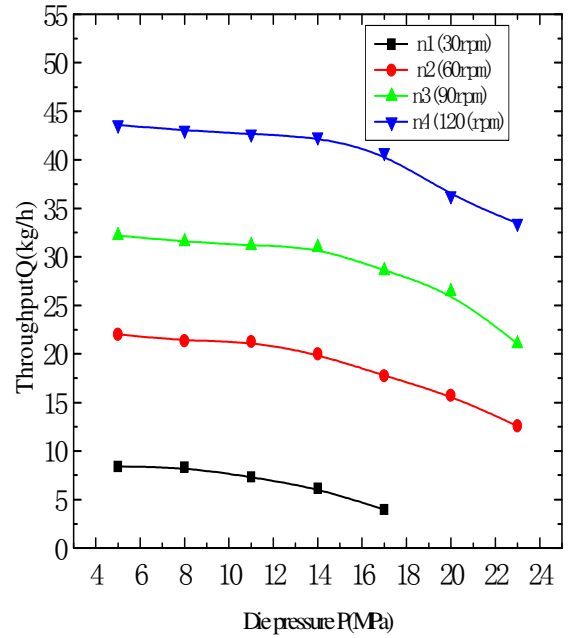


Figure 3 Influence of Die Pressure on Throughput at Different Rotation Speed

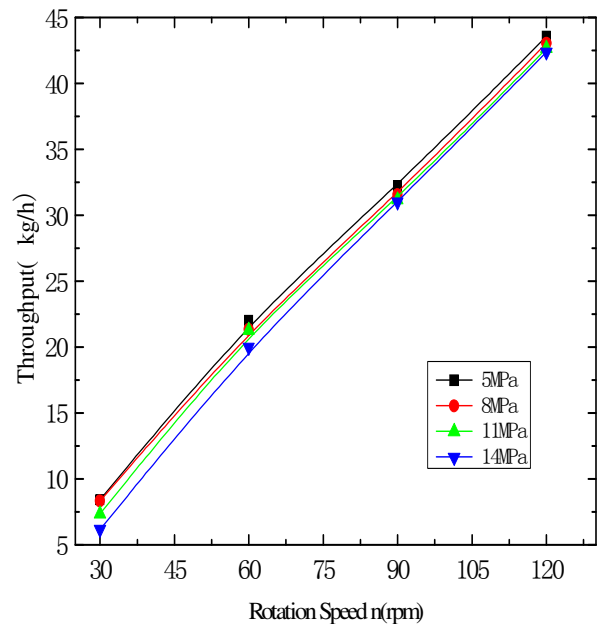


Figure 4 Influence of Rotation Speed on Throughput at Different Die Pressure

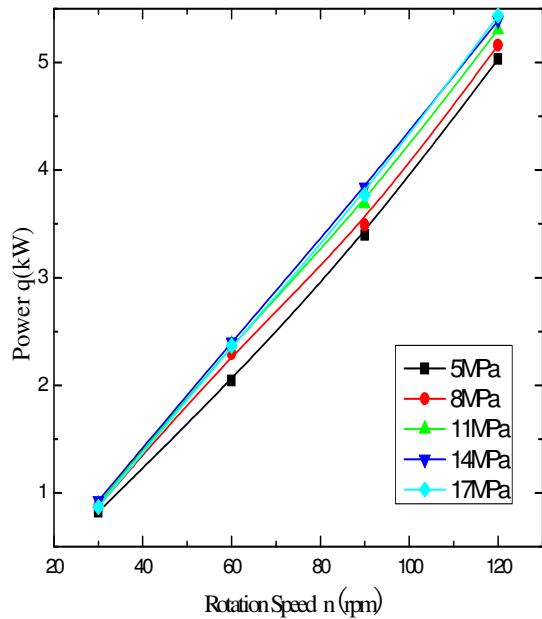


Figure 5 Influence of Rotation Speed on Power at Different Die Pressure

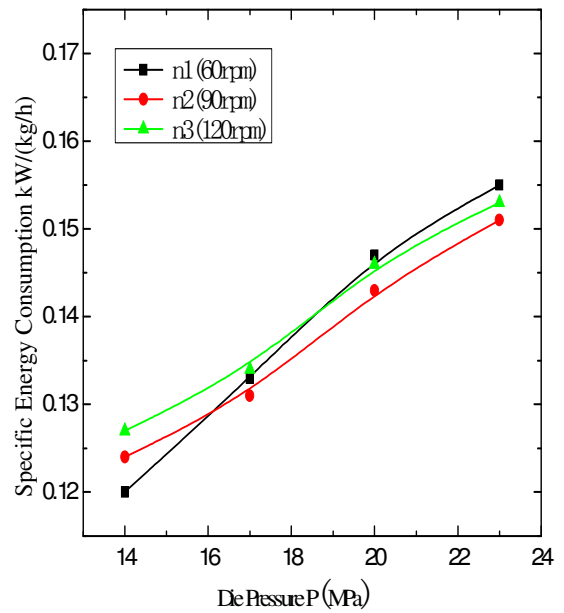


Figure 7 Influence of Die Pressure on Specific Energy Consumption at Different Rotation Speed

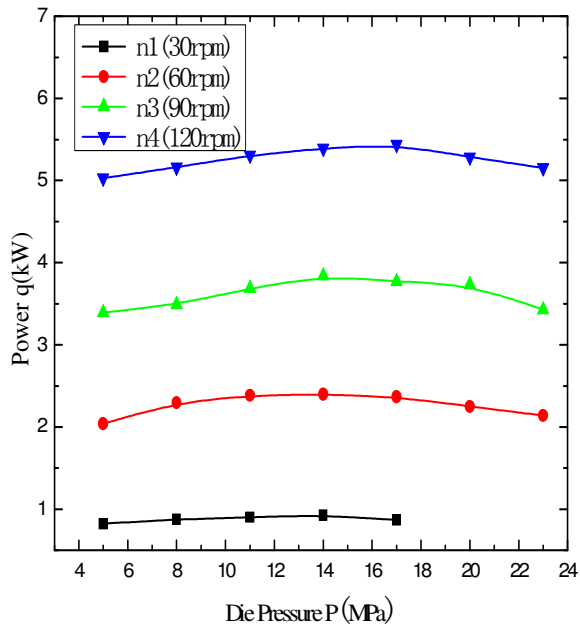


Figure 6 Influence of Die Pressure on Extrusion Power at Different Rotation Speed

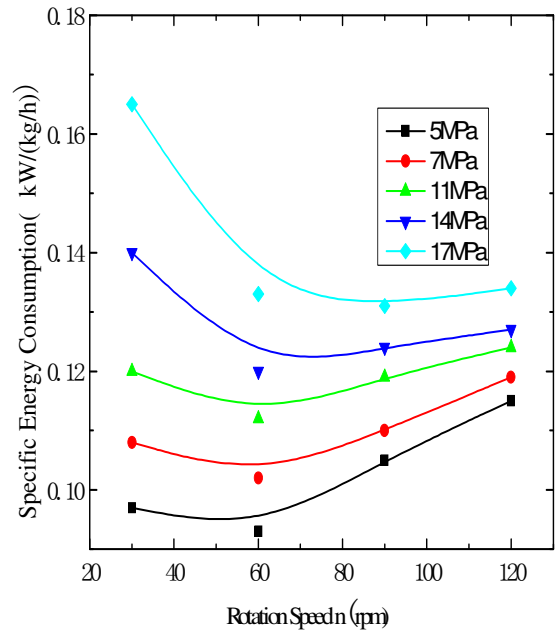


Figure 8 Influence of Rotation Speed on Specific Energy Consumption at Different Die Pressure

Key Words: Vane, Extruder, Conveying properties.