NOVEL SINGLE SCREW FOR RPVC DRY BLEND WITH HIGH OUTPUT CHARACTER

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Abstract

Currently, the single screw extruder (SSE) is not a primary processor of RPVC dry blend because they have required a complex vacuum hopper and a crammer feeder. Conical twin screw extruders (TSE), being capable of processing RPVC dry blend without the use of a crammer feeder or vacuum hopper has therefore dominated RPVC dry blend processing. A new SSE is introduced that overcomes the need for a vacuum hopper and a crammer feeder with a simple screw design. This paper presents data on an SSE showing simple processing of RPVC dry blend with a surprising increase in screw speed to 180 rpm and output at only 174 °C, vented, starved or flood fed.

Introduction

Typically, SSE's are not used primarily to process dry blend[1]. Although processing of RPVC dry blends on SSE's had been possible, it was very difficult and required a variety of special equipment. In order to produce constant feeding a vacuum crammer hopper was necessary. The vacuum crammer hopper consisted of an upper hopper which pulled the vacuum to remove air and densify the material, and also metered the RPVC powder into the lower hopper. The lower hopper was the crammer feeder portion which had a vertical screw perpendicular to the extruder screw and placed very close to the extruder screw for additional densification, Fig. 1, [2]. The vacuum hopper also provided for a single stage screw with a vacuum seal at the screw shank end which aided in the prevention of air and moisture entrapment in the melt [3].

The startup procedure for use with RPVC dry blends and the vacuum hopper was unique as stated by R. C. Neuman:

> "Extruder Start-up is done open-head. The screw is started slowly - about 5 rpm – until melt appears at the gate. The vacuum is turned on, and rpm increased to operating speed, typically 35-40 for 114.3mm (4 1/2") or 90mm (3 1/2") extruders. After the melt becomes soft and uniform in appearance, the machine is stopped and the die installed. The screw is again started slowly until melt appears at the lips, then increased to operating speed as the web is fed through the polishing stack and succeeding equipment" [4].

The screws were also bored for cooling, especially at the tip [5, 6].

Today, conical counter-rotating twin screw extruders (TSE) dominate RPVC dry blend extrusion. They are excellent at feeding powders [7, 8], have high outputs at low screw speeds [8], and provide low temperatures [9]. Conical TSE's are also used for processing RPVC dry blends because of their low shear characteristics Fig. 2, [10, 11, 12].

The goal of this paper is to test a new SSE mixer called the Elongator, hereafter the mixer, in two modes, starve fed and flood fed. It is a further objective to determine the maximum output in both modes at temperatures not exceeding 199 °C.

Mixer Description

The mixer is a spiral, fluted mixing element, as shown in Figure 3 and Fig. 4.

It is well known that elongational forces are more effective for dispersive mixing than shear mixing [13] and it is important to understand how this mixing element used in the SSE generates elongational flow. The mixer is placed within a few L/D of the water cooled feed section of the barrel. In this version, the flow is split into two channels and each channel feeds an elongating screw mixer. The elongating screw mixer is composed of three channels (C1, C2, C3 and two intermediate pumps P1, P2). Material is pushed into C1 by upstream flights. P1, by means of drag flow, pumps material from C1. The combination of pressure flow up the channel and drag flow perpendicular to pump inlet flow, produces an elongating flow in the approach to P1. This can act to mix and/or melt depending on the state of the material in C1.

Experimental

Materials

The polymer that was used in this study was a natural, extrusion grade, RPVC dry blend E3106N-000DB provided by Colorite Polymers, Ridgefield, NJ.

Equipment

A 1" extruder at 36:1 L/D was selected with a 5 horsepower AC motor with a maximum screw speed of 180 rpm. The screw was equipped with three mixers, the first with an atmospheric vent over the first mixer. There was a pressure transducer in the die and another pressure transducer just after the first mixer. A starve feeder was available to feed the RPVC dry blend into the extruder during starve feeding mode. The extruder was equipped with a 4 hole strand die.

Testing Procedures

First tests were performed at 60 rpm with process temperatures at 174 °C on all temperature zones and an open vent over the first mixer. We achieved 2.9 kg/hr without apparent degradation, the die pressure was 230 to 550 PSI. We increased the rpm's in 30 rpm increments until we reached 180 rpm, maximum for this machine, still with an open vent. Pressure was stable at 510 to 530 psi. We increased the output of the feeder slightly and at 50 PSI on the pressure transducer just after the vent, the vent began to fill. We closed the vent and flood fed.

Results

Using a starve feeder, vented, extrusion at 180 rpm and 174 °C on all temperature zones, produced 11.3 kg/hr with no apparent degradation (no yellowing, browning, or burning) of the RPVC dry blend and stock temperature of 177 °C.

The vent was then capped and the extruder was flood fed. Again all extruder zones set and controlling at 174 °C. The output was 13.2 kg/hr, the melt at 177 °C, and at 180 rpm.

Residence time was measured by dropping 5 red pellets into the hopper and measuring the time it took for the color changed at the die, which was 45 seconds, and then how much time it took for material to change back to white, which was one minute.

Discussion

We have not found data for a 1 inch extruder processing RPVC dry blend, so we don't have a proper control for an output comparison. However, the output of a 25 mm (1 inch) extruder processing RPVC pellets is know—about 2.3 kg/hr at 30 rpm. [14]. It is well known that the SSE for pellets of RPVC is limited to slow screw speeds, typically about 30 rpm. Thereafter the temperature rises and degradation occurs. Unfortunately, the RPVC pellets cited [14] are not the same composition as the dry blend and this lessens the quality of the comparison. Nevertheless, the output achieved for the dry blend represent a significant increase in output at 11.3 kg/hr.

We were able to process the RPVC dry blend without the use of a vacuum hopper, without a crammer feeder and without a bored screw for cooling. We were able to maintain an atmospheric vent.

We believe that the reason for this surprising result is that the first mixer is further upstream than normal and with little compression zone upstream of the mixer. This allows the material to be brought directly into the mixer which then acts as a melting and mixing device. Once the material is melted in the mixer degassing takes place in a normal fashion through the hopper or the atmospheric vent.

Conclusions

The screw used in the study permitted RPVC dry blend processing at high screw speed and high output at reasonable processing temperatures. Venting was effective. Extruder pressure was stable. If these results scale to larger SSE's, then the SSE can become a primary processor of RPVC dry blend. Scale up work is ongoing.

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Keywords

RPVC dry blend, mixing, elongating, SSE.

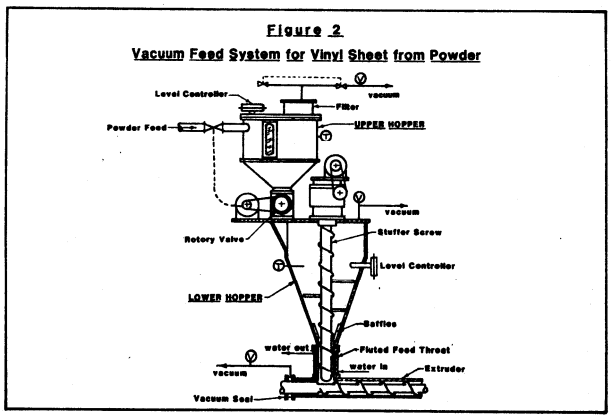

Figure 1.

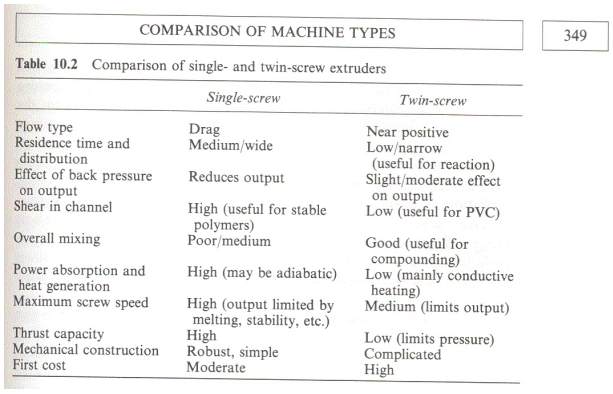

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Table 10.2 Comparison of single- and twin-screw extruders

	Single-screw	*Twin-screw*
Flow type	Drag	Near positive
Residence time and distribution	Medium/wide	Low/narrow (useful for reaction)
Effect of back pressure on output	Reduces output	Slight/moderate effect on output
Shear in channel	High (useful for stable polymers)	Low (useful for PVC)
Overall mixing	Poor/medium	Good (useful for compounding)
Power absorption and heat generation	High (may be adiabatic)	Low (mainly conductive heating)
Maximum screw speed	High (output limited by melting, stability, etc.)	Medium (limits output)
Thrust capacity	High	Low (limits pressure)
Mechanical construction	Robust, simple	Complicated
First cost	Moderate	High

Figure 2.

Fig. 3: Three Mixers On 36/1 Screw