

THE VENTED BARRIER SCREW

Stephen J. Derezinski, Extruder Tech, Inc., Penfield, NY 14526

Abstract

The typical barrier screw (high efficiency screw) concept has been modified to provide for venting (devolatilizing) of polymer through a bore in the drive-end of the screw. The bore is connected to the melt channel by a vent hole in the melt-channel screw-root. The melt channel is deep so that a free surface of polymer melt and path exists to release gasses to the vent. The screw design was tested and shown to process and devolatilize PET powder, PET pellets, and PEN pellets at greater rates and with less power than a conventionally vented two-stage screw in the same extruder with the very same polymers.

Introduction

Venting in single screw extrusion is most typically done through the barrel, but it is also done through a bore in the screw [1]. In either case, a two-stage screw is used which has several diameters of deepened channel for release of vapors to escape to the vent (see Figure 1.) However, significant screw length is sacrificed to provide for the venting channel (normally about 4 diameters of screw length.) This diminishes the rate capability of the given extruder.

The barrier screw or high efficiency screw design [2,3] has been modified to provide for venting through a bore from the drive end [4]. The bore is connected to the melt channel by a vent hole in the screw root. A vacuum, if necessary, may be connected to the bore at the drive end of the screw by a rotary union.

Barrier screws, or high efficiency screws, produce much greater rate at lower power than do two-stage screws. It will be shown that the efficiency of the barrier screw is maintained in that flow rate and power requirements of the vented barrier screw are much better than for venting with a typical two-stage screw.

Standard Two-Stage Screw Design

Figure 1 shows the typical two-stage screw configuration. It has 5 basic sections: 1) solids conveying, 2)compression and melting, 3) metering, 4) venting, and 5) pumping. The figure shows that about 4 diameters of screw length are used to accomplish the venting. This uses extruder length that would otherwise be used to accomplish melting and develop melt temperature. Therefore, the addition of the venting section limits the rate capacity of the extruder.

Vented Barrier Screw Design

Figure 2 shows the vented barrier design. The design is basically the same as a standard barrier design with three sections: 1) solids conveying, 2)melting with barrier flight which separates unmelted and melted polymer, and 3) pumping section. Some distinct changes to this arrangement have been made to accomplish venting with the barrier screw design.

The standard barrier design is modified by making the melt channel to be deep along its entire length, providing a bore in the screw from the drive end, and making a vent hole to the screw bore at the beginning of the melt channel. The vent hole is in the screw root base, and it is made as large as possible to minimize the accumulation of polymer there. The vent-hole entrance is also "rounded over" to minimize the accumulation, and it is shown in Figure 3.

The flight heights in the vicinity of the vent hole are also specifically designed. Figure 4 shows that the barrier flight upstream of the vent hole is slightly higher than the main flight on the downstream side. This is opposite to the standard barrier configuration where the barrier flight is made low to allow melt to pass over into the melt channel. For the vented barrier design, the higher upstream barrier flight in the vicinity of the vent hole will scrape the polymer from the barrel wall such that polymer will not contact the lower downstream main flight and be brought into the melt channel. Fouling and clogging of the vent hole are minimized.

Figure 4 also shows that at about a diameter downstream of the vent hole the flight heights are made to function as a typical barrier screw. This means that the barrier flight is now lower than the main flight to permit melted polymer from the main channel to enter the melt channel. However, for the vented barrier design the melt channel is made to be deep enough so that the melted polymer cannot fill it. This provides an ample free surface of polymer melt for gas to escape and a path for it to travel to the vent hole. The typical standard barrier design has a shallow initial melt channel depth that increases towards the exit of the extruder.

Performance

In order to judge the performance of the vented barrier screw, a test was done with three polymers; 1)PET powder, 2)PET pellets, and 3)PEN pellets. The powdered resin was of special interest because it cannot be processed with a standard barrier screw where venting of pelletized

polymer often can be done by backflow of vapors and gases through the solids conveying section. In the case of powdered polymer, the compaction of the powder does not provide enough porosity of the solid feed plug to permit the backflow of vapors and gases. Therefore, the vented barrier screw can provide the advantages of a barrier design for powdered resins as well as any other resins that are particularly difficult to vent. This can be especially helpful if the same extruder is used for powder and pellets in that the screw will not need to be changed when changing polymer forms.

One extruder and two screws were used for the testing. The extruder was a Davis-Standard 25/1 L/D 63.5 mm machine. A standard two-stage screw and a vented barrier design were operated with the three polymers. The polymers came from the same lots for the all the testing. The same product temperature (280 °C – 285 °C) was maintained. The polymer melt was delivered through a die to a casting wheel where the occurrence of bubbles could be observed in the clear cast sheet.

A “bubbler” was also attached to the vent bore in the tail of the screw to observe and verify the release of gases by the venting system. The bubbler consisted of a clear piece of tubing in the shape of a “U.” One end was connected with flexible tubing to the extruder screw bore by a rotary union. The “U” shaped bubbler was half full of water such that any gases that were escaping from the extruder screw through the venting system would need to pass through the water, where they would form observable bubbles. The fact that gasses were being extracted was readily verified by the observance of bubbles in the “bubbler.”

Further evidence of the effectiveness of the screw venting system was obtained by blocking the venting bore of the screw. When this was done, the clear cast sheet was filled with bubbles, usually less than a mm in diameter. Reopening the venting system then soon eliminated the bubbles in the cast sheet.

However, for processing PET powder a vacuum (about 700 mm Hg.) was needed and attached to the vent bore of the screw by a rotary union in place of the “bubbler.” This was necessary to eliminate all bubbles in the cast sheet. Without a vacuum, the edges of the cast sheet showed minute bubbles less than about 0.5 mm in diameter. However, the center of the cast sheet remained optically clear and perfect. It must be noted that a vacuum system is needed to process this powdered PET with the traditional two-stage screw, also. The “bubbler” was not used with the vacuum connected by the rotary union.

Flow Rate

Figure 5 shows the flow rate comparison between the barrier screw and the standard two-stage screw. The extruder is a 63.5 mm, 25/1 L/D machine and the polymers were all from the same lots. The flow for the vented barrier screw is about double for that of the standard two-stage screw design. This is a result of the use of about 4 L/D for the extraction section in the two-stage screw as shown in Figure 1. Length is needed to accomplish melting and to build the melt temperature. Therefore, building melt temperature in a short length requires low rate. This limits the design rate of the two-stage screw because of the loss of 4 L/D length just for extraction. Extraction for the barrier is done in the same channel that is normally used to pump the melt so there is no loss in length for the purposes of venting.

Power

Figure 6. shows the power comparison between the standard two-stage screw and the barrier screw. The power is given in terms of flow rate. The product temperature for all data were held to be between 280 °C and 290 °C The barrel zone temperatures for the standard two-stage screw were providing significant cooling, while those for the barrier screw were not. This indicates that the barrier screw had a much smaller temperature gradient in the last melt pumping section (last part) of the screw. Greater thermal uniformity of the melt would be expected from the minimized temperature gradients. A high degree of conductive cooling or heating in any part of the extruder always creates undesirable high thermal gradients which lead to non-uniform product temperature distributions.

Another Application

It may be possible to also use this barrier design concept in a gas infusion process. If the pumping section is designed to hold back pressure of gas being supplied to the polymer melt (instead of designed to build delivery pressure,) then the system could be used to infuse a gaseous component into the polymer at high pressure. A rotary union connected to the screw bore would be used to supply the gas under pressure. A foamed product would be one application of this process. Further development work is needed for this application.

Conclusions

1. A barrier screw design has been successfully modified to include a vent in the screw root.
2. The vented barrier screw was built and tested to show that effective venting was obtained.

3. The vented barrier screw was tested and shown to provide higher rate and require less power when compared to a two-stage vented screw.

References

1. Ernest C. Bernhardt, *Processing of Thermoplastic Materials*, Reinhold Publishing Corporation, 1959, pp. 163-164.
2. Chris Rauwendaal, *Polymer Extrusion*, Hanser Publishers, 1990, pp. 403-415.
3. Chan I. Chung, *Extrusion of Polymers, Theory and Practice*, Hanser Publishers, 2000, pp. 298-300.
4. Stephen J. Derezinski, *Vented Single Stage Barrier Screw with a Gas Vent Hole and Axial Bore in the Screw for Venting Gases*, US Patent 6,293,690, September 25, 2001.

Key Words

Venting, Extrusion, Barrier, Devolatilization, degassing

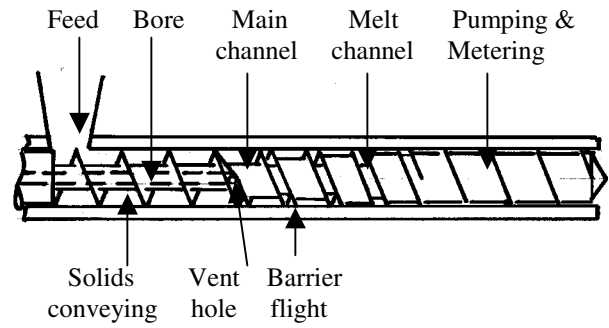


Figure 2. The vented barrier screw general set-up.

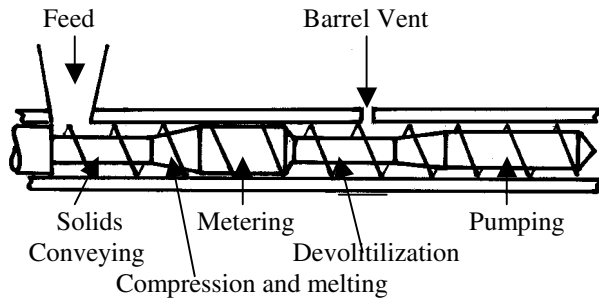


Figure 1. A typical two-stage vented extruder set-up.

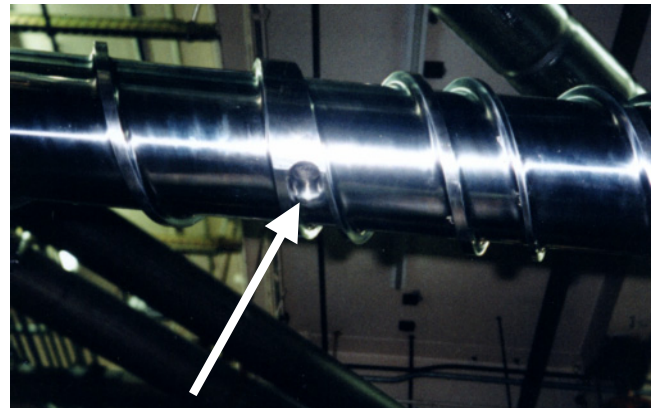


Figure 3. Vent hole in the melt channel of a vented barrier screw.

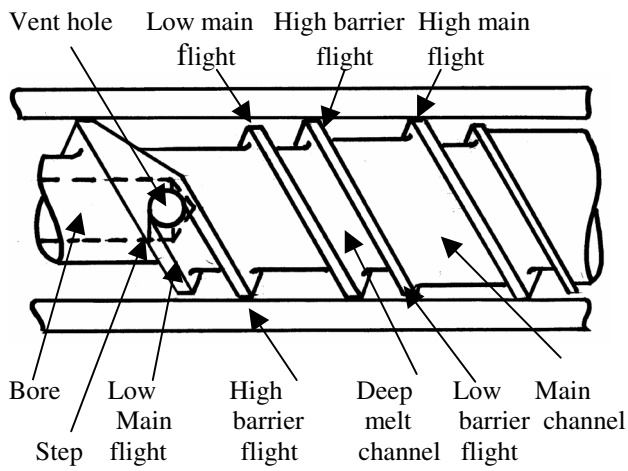


Figure 4. Details of the vent hole and surrounding flights.

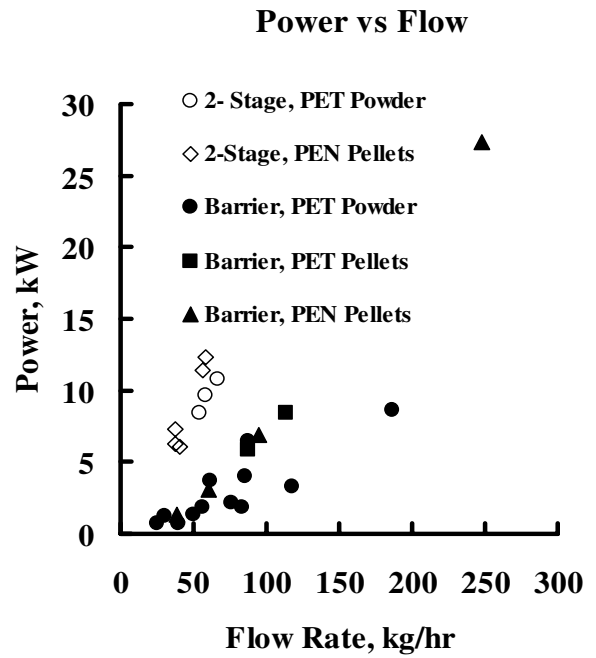


Figure 6. Power versus Flow Rate. The efficiency of the barrier type of screw is obvious from the lower power required for the same materials.

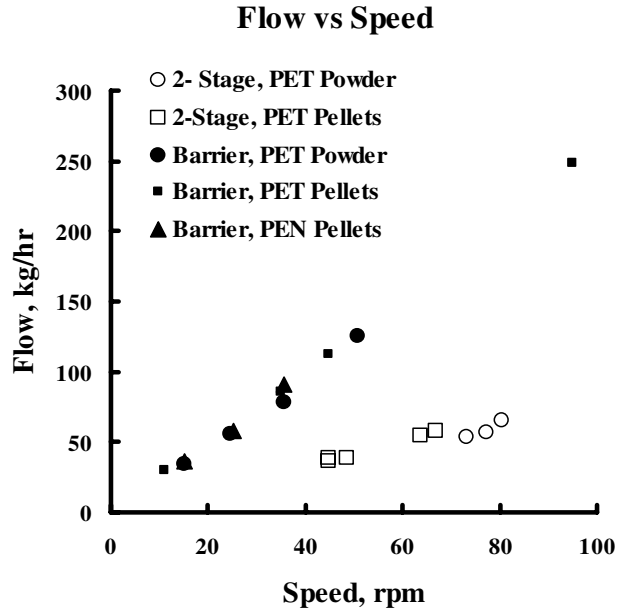


Figure 5. Flow Rate versus Screw Speed. About double the flow rate is possible with the vented barrier over that for a typical two-stage screw.