Relevant Process Parameters for Twin Screw Compounding

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Introduction

Screw conveyors have a long history. The first screw conveyor was in invented by Archimedes († 212 BC) and is still in use for irrigation. Industrial use of screw conveyors started in middle of the 19th century. Significant Industrial utilisation polymer processing began in the 1st half of the 20th century. The single extruders are used to melt and shape the polymers but they are limited in their performance. They operate with a complete filled barrel under pressure so no venting or split feeding is possible. Also the mixing capabilities are limited.
To satisfy the growing demands in the polymer industry for continuous mixing R. Erdmenger developed a co-rotating twin screw compounder with intermeshing, self wiping screws and got it patented in 1944. Various compounding tasks and the process dependent and independent parameters will be discussed in this paper. An overview how to optimize the compounding process and the screw configuration is also introduced. An automated measurement of the retention time and how to scale up the test of a small laboratory compounder to bigger pilot plant or smaller scale production extruder is presented.

The compounder

The main compounding steps in a parallel twin screw compounder are: feeding, melting, conveying, mixing, venting and extrusion of the homogenized product – Fig. 1. In the feed zone solid material is fed by volumetric or gravimetric feeder. Air is removed and material with low density is compacted. In the next step the material is move forward and heated up in a partial filled and not pressurised conveying section. In the following first mixing zone the material is molten and plastified. The mixing zones are complete filled with material. Now a conveying zone is added and can be used for venting, split feeding of fillers or liquid feeding. Than alternating mixing and conveying sections follow to achieve a homogeneous product. As next to last section consist of conveying screw elements and are used for venting volatiles and air either at ambient pressure or by vacuum. The role of the extrusion section is building up pressure and shape the material, in most of the applications a strand is extruded which is cooled in water bath and cut to pellets.

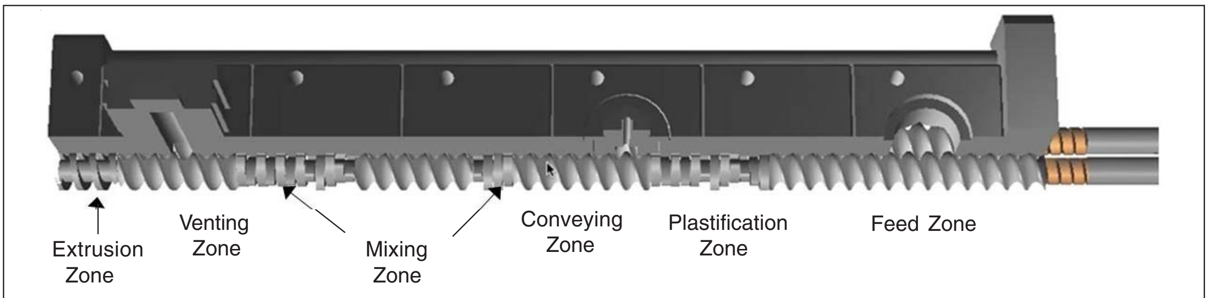

Fig. 1: Barrel and screw layout

The screw elements

Due to the segmented screw design the assembly of the screw is variable. The most common used screw elements are self cleaning and intermeshing conveying elements with a shape according to Erdmenger. The other screw elements are mixing, extrusion and special distributive mixing elements – Fig. 2.

Processing parameters and dependencies

The throughput has significant influence on the residence time. A higher throughput decreases the mean residence time and the width of residence time distribution – Fig. 3. The influence of the screw speed on the residence time is rather low and depends only on the screw speed in conveying zones. Backward mixing elements have a high impact on the residence time and distribution increases. The main effect on the melt temperature has the screw speed and feed rate. A higher melt temperature is measured due to mechanical energy input in mixing zones at higher screw speed – Fig. 4.

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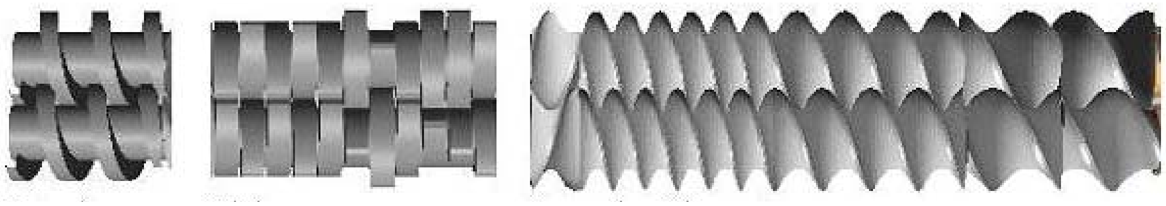

Fig. 2: Screw elements

The main effect on the melt temperature has the screw speed and feed rate. A higher melt temperature is measured due to mechanical energy input in mixing zones at higher screw speed – Fig. 4.

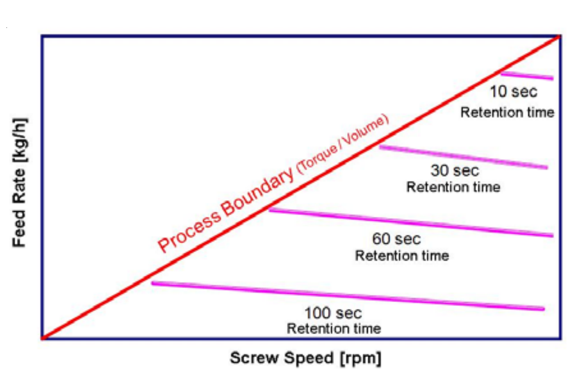

Fig. 3: Residence time and feed rate

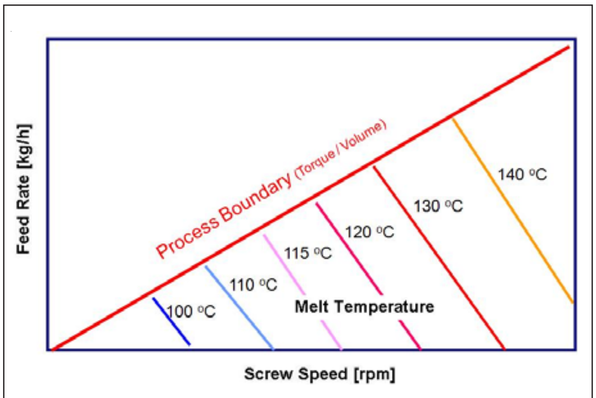

Fig. 4: Residence time and screw speed

Scale up

After successfully trials with small scale laboratory compounder – Fig. 5 – there is always a challenge to transfer the process to a bigger pilot plant of production compounder. The basic requirements are to use the same or at least similar barrel geometry and the same screw configuration in both compounders. The residence times and melt temperatures should be similar as in the laboratory test also the compounder should operate adiabatic. In a first approach the screw speed and temperature profile is the same as in the laboratory trials. The start feed rate is calculated according to the rule of Schuler [1]. In a next step the specific energy is adjusted by changing the throughput. The main energy is generated by the shear energy of the screws. The scale up is limited because of the available surface of the barrel, the heating and cooling decreases with increasing barrel diameter. The volume increases to the power of three but the surface area increases only to the power of two.

A test was conducted on the Thermo Scientific Process11 an 11 mm laboratory twin screw extruder with throughput of 1 kg/h and a screw speed of 200 rpm. Those settings result in a specific energy of 559 kJ/kg and a residence time of about 55 s. For an upscale on Thermo Scientific Eurolab 16 mm compounder the throughput according to the rule of Schuler should be 3 kg/h. The measured residence time and specific energy is significant lower. A correction of the feed rate to 2.5 kg/h gives a similar result of the residence time and the specific energy (566 kJ/kg) – see Fig.6.

Fig. 5: Thermo Scientific Process11 - 11 mm lab scale screw compounder

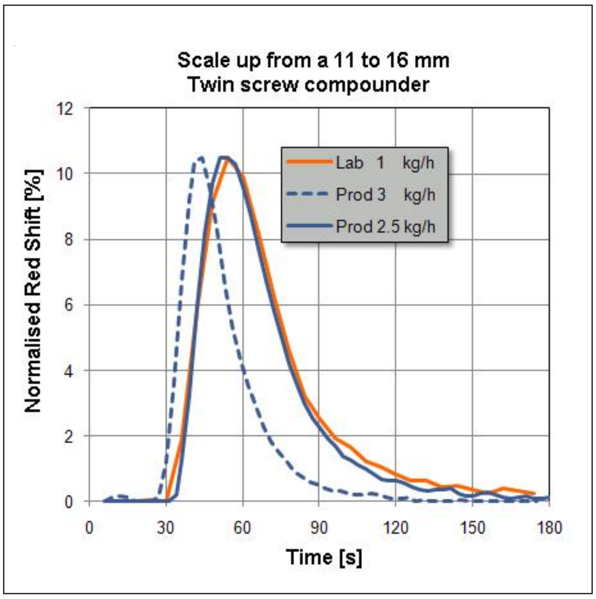

Fig. 6: Residencwe time for scale up tests

Conclusion

With the knowledge of the processing parameters of the laboratory scale compounder a scale up to an identical bigger unit is possible but the theoretical factor for the throughput has to be adjusted. The retention time is an important process parameter for the scale up. Instead of the measuring the residence time with tracer and stop watch it is better to replace the stop watch by a camera system and analyse the change of colour intensity of the tracer. The result is a retention time distribution with the average retention time as the maximum.

Reference

[1] W. Schuler (1996). Process Engineering Design of Co-Rotating Twin Screw Extruder, Dissertation, University of Wales Swansea, 1996.

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