All about plastizicing screws
Part 2 of the series

In the previous issue of "innovations", the basic design of a plasticizing unit and the correct choice of the injection unit were discussed in the first part of this series. The way to determine the required screw diameter on the basis of the shot volume was also explained. By applying the formula for the mean residence time, the utilization rate and the thermal material load can be estimated; the latter needs to be kept low to achieve high end product quality. The maximum injection pressure and the available screw torque are additional key variables for successful injection molding production. These considerations form the basis for the choice of the barrel-and-screw combination and also the starting point for further optimizations. In the second part of this series of articles, the basic methods for simulative assessment of the geometry of a given screw are presented – using the example of a 3-zone screw.

Filipp Pühringer

Developing a screw geometry

The first question to be answered is what objectives should be pursued in developing a screw geometry. Often the goal can be clearly defined, such as increasing the flow rate, reducing the melt temperature, improving the quality of the blend, etc. The requirements become more complex as soon as the desired results are only indirectly linked to the screw geometry, or when they can be attributed to several causes, for example, when it is desired to reduce the formation of plaques, or when the wear behavior and conveying stability need to be improved. Such multiple demands on screw aggregates often conflict with each other.

Careful balancing of the layout is necessary to resolve such conflicts between several different objectives. It has become common practice to optimize the geometry of a screw by way of simulation before the first tests are carried out with real experimental screws. With PSI/REX, WITTMANN BATTENFELD has a special software at its disposal for calculating the screw design. This software is ultra-modern and subject to continuous updates by targeted research carried out at Paderborn University.

While using the computer to calculate the screw geometry, the geometry can be varied extremely flexibly, and the resulting change can be immediately visualized on the screen. By running systematically through a pre-defined series of tests, it is possible to analyze the emerging trends. Finally, the results of all calculations are combined and compared. From the sum of this information, the corresponding screw geometry is developed and further optimized down to the last detail – until the desired result comes into view.

Only then are experimental screws produced and used in practical tests. Depending on the complexity of the task, several different experimental screws may be used to approach the objective from various angles. If these tests prove successful, the optimization process is completed. Where there is still room for improvement, the development loop is re-run.

Screw geometry parameters

Next, the parameters of a standard 3-zone geometry shall be discussed, and their influence on the manufacturing process shall be illustrated by an example. In order to give a full description of such a geometry in terms of process technology, the following parameters must be known:

- D_{SC} = External screw diameter
- L/D and/or screw length
- l_E = Length of feed zone
- l_K = Length of compression zone
- l_M = Length of metering zone
- h_E = Flight depth of feed zone
- h_M = Flight depth of metering zone
- b = Flight width

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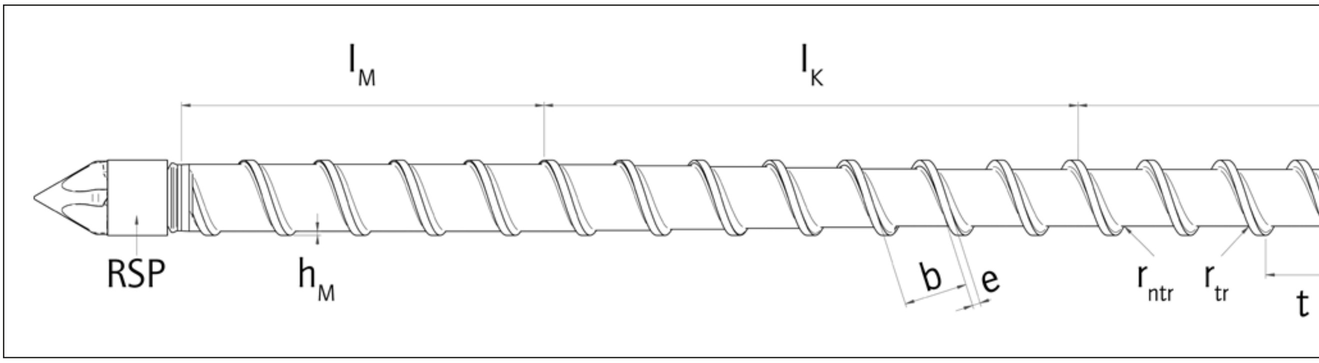


3-zone screw with number of screw flights i = 1.

- i = Number of screw flights
- t = Flight pitch
- e = Width of screw thread
- Flank angle, driving
- Flank angle, passive
- r_{tr} = Radius of driving flank base
- r_{ntr} = Radius of passive flank base

From the number of geometry parameters for only a relatively simple standard 3-zone screw, it is already apparent that there is basically a multitude of possible variants even for this type of screw. In the case of more complex geometries, such as those found in barrier screws, screws with shearing and mixing sections or shearing/mixing screws, the number of geometry parameters is many times higher.

Exemplary calculations

Starting basically from the recommendations available in the relevant professional literature, the optimization of the geometry for a 50 mm screw is calculated below as an example.

It is assumed that the length of the feed zone is 50% of the total length of the screw and the lengths of the compression zone and metering zone should each be 25% of its total length. We set the feed zone depth at 0.1 D, i.e. 5 mm. The flight depth ratio between the feed zone and the metering zone should be 2. The L/D ratio is assumed to be 22.

A variety of different calculations can be performed for a plastizicing screw with these pre-defined parameters. The present discussion focuses on the melt throughput, the pressure curve or pressure build-up capacity and the melting process.

Further assumptions also include the metering stroke (85 mm) and the cycle time (35 s). The back pressure is set at 80 bar. To simulate moderate and realistic metering con-ditions, a circumferential screw speed of 300 mm/s is assumed.

The barrel temperature profile follows the pattern illustrated below for all calculations: The calculation of the profiles (pressure curve, melting process) is carried out for the 50 mm screw position.

Throughput behavior

For the previously selected cycle parameters, the average metering performance is calculated at about 12.49 g/s for the present pastizicing screw geometry. The total output is 44.92 kg/h. This means that the injection molding machine transports 12.49 g/s in the metering phase and thus takes about 12.7 s to plasticize 158 g of the respective material.

With a residual cooling time of more than 12.7 s, the molding machine can start a new metering stroke on time. But if plasticizing takes longer than the residual cooling time, the timing of metering impacts the total cycle time and thus reduces productivity.

The total output determines the amount of material consumption in the course of production. Since the screw does not dose during most of the cycle time, this output falls below the figure suggested by the average metering performance. The total output is the decisive parameterin dimensioning auxiliary equipment (dryers, material loaders, etc.).

Pressure build-up capacity

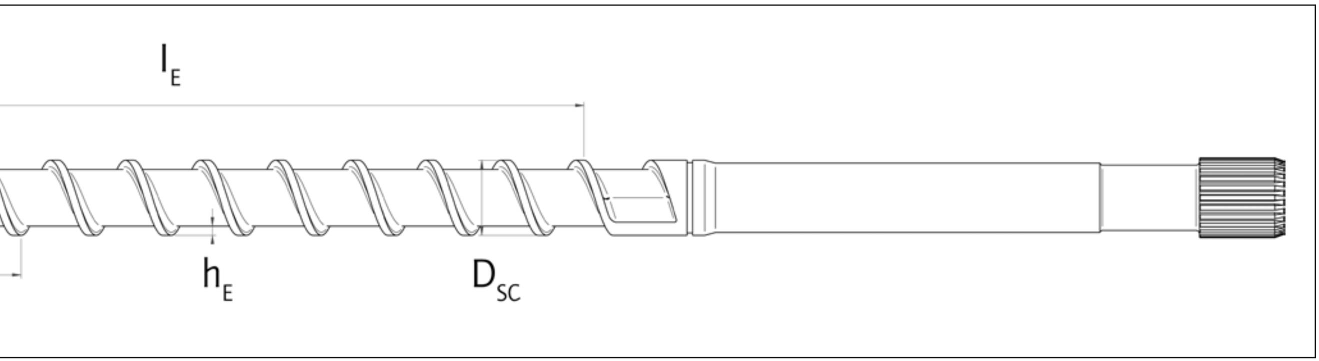
During the metering phase, the pressure inside the screw channel increases from the feed opening to the back pressure in the antechamber. Depending on the screw geometry, there may be one or more pressure peaks in between.

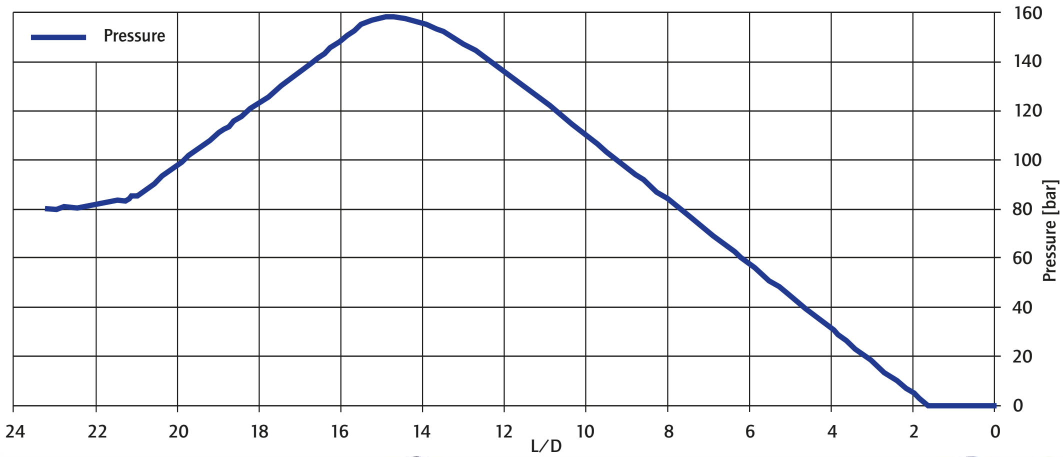
The graph on the next page shows the pressure curve over the length of the plastizicing screw. In this particular case, the pressure curve begins to rise at about L/D 2 and reaches the peak pressure of about 160 bar at about L/D 14.25. In the last zone of the screw, the metering zone, the pressure drops continuously up to the check valve.

Melting process curves (MP)

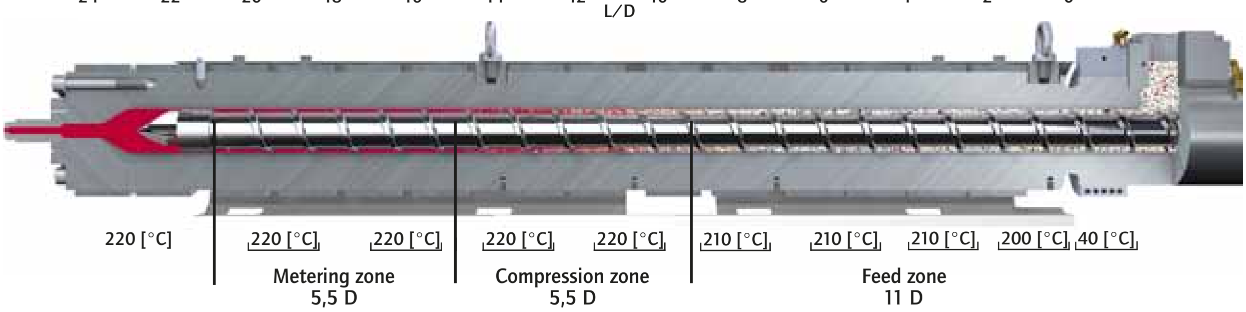
The melting process (see the respective graph on the next page) is visualized via two curves: the solid bed width (red) is shown for the corresponding screw channel section, and the proportion of molten material (blue) during the metering process. In addition, the development of these two parameters towards the end of the cycle is illustrated (in green and orange). From the results, it can be concluded that this melting process promises good melting of the material, since the proportion of melt has already reached 100% at about L/D 8 (proportion of melt MP = 1). In other words, the solid bed width has been reduced to 0. ◆

In the next issue of the "innovations" magazine, in the 3rd part of this series of articles, the calculation results will be analyzed, and first steps towards optimization of the geometry will be outlined.

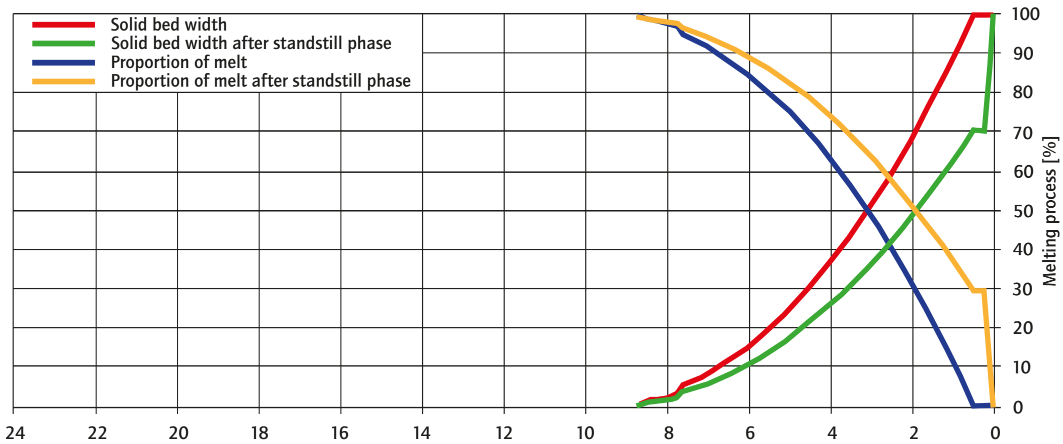




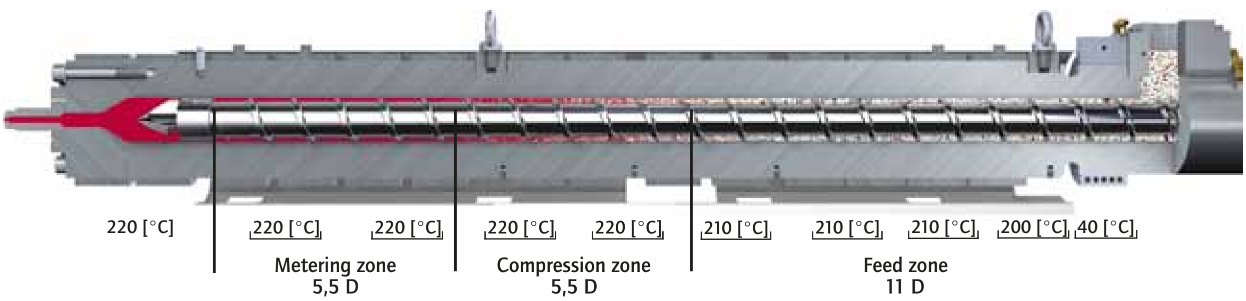
Pressure curve along the screw at 50 mm stroke position.



The calculations are based on the barrel zone temperatures.



Melting process curves for the screw at stroke position 50 mm towards the end of the cycle.



***Filipp Pühringer** is Head of the Process Engineering Development Department at WITTMANN BATTENFELD in Kottingbrunn, Lower Austria.*