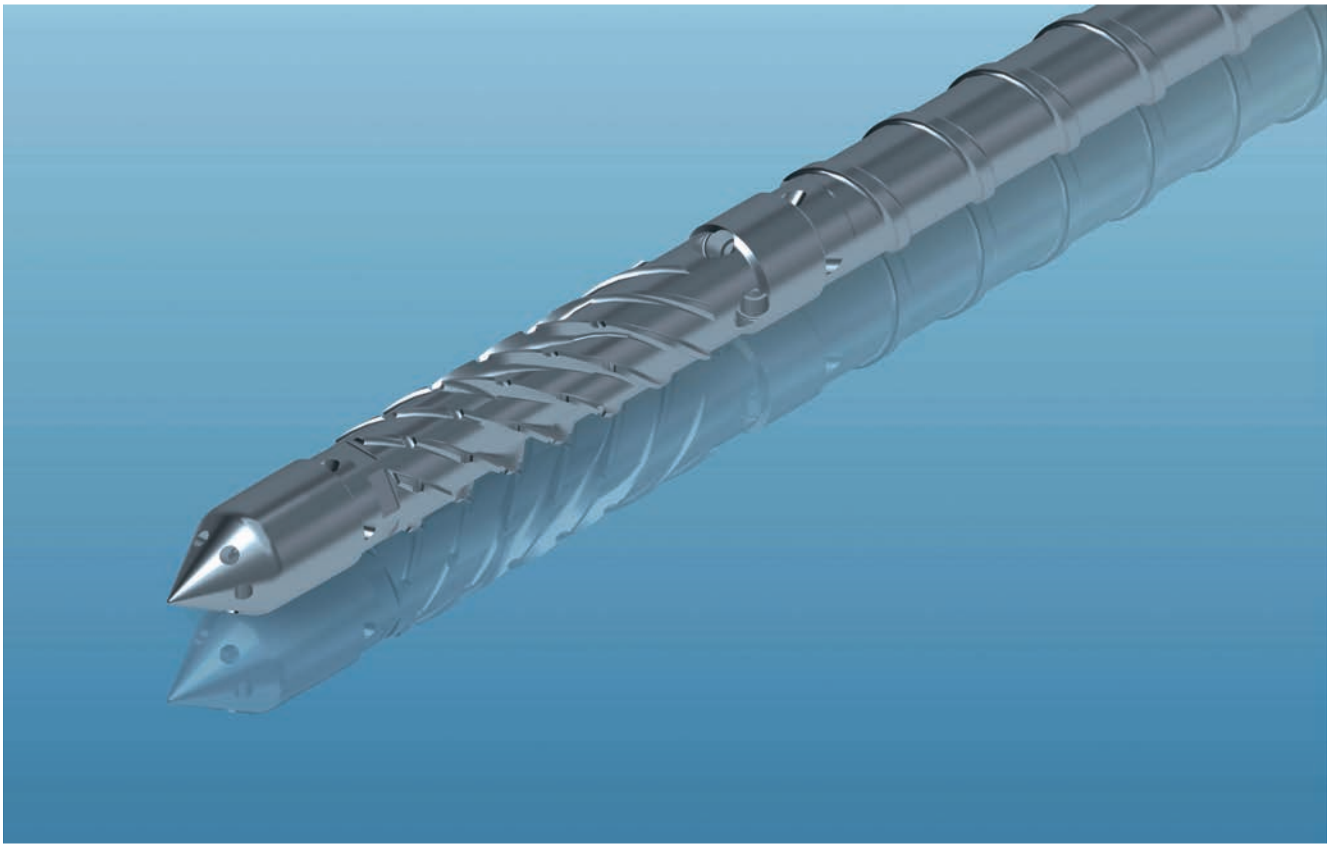
After Two Years of Lab Work, KraussMaffei Is Presenting a More Powerful Universal Foam Screw

30 Percent Higher Plasticizing Rate

KraussMaffei has offered physical foaming of plastics for over 20 years. Now, the team has examined all the screw types available on the market and, for almost two years, investigated their strengths and weaknesses regarding different materials. The result is a new universal foam screw with a 30 percent higher plasticizing rate plus a knowledge toolbox that allows custom production for special projects.



The new "HPS-Physical Foaming" screw is universally applicable and offers improved plasticizing performance. © KraussMaffei

Physical foam injection molding is a wide field – applications of the MuCell process (supplier: Trexel), in particular, are a growing market. In the course of the generally sought-after conservation of resources and the reduction of the carbon footprint required by politicians and customers, it is being used ever more frequently, since it allows lightweight construction applications to be easily implemented. In thermoplastic foam injection molding (TFIM), a physical blowing agent (often nitrogen) is added to the melt, which forms a cellular structure in the cavity. Compared to non-foamed parts, this can make significant material savings and reduce the part weight [1]. Since the gas reduces the viscosity of the melt, longer flow paths are possible for thin-walled parts. Due to foaming, the holding pressure can be eliminated and low-warpage parts are produced. If the part design is tailored for plastics, the cycle time can also be shortened by eliminating the holding pressure. Because of the lower pressure demand, the clamping force can also be reduced – the energy consumption of the injection molding machine is decreased [2, 3].

To understand the central role of the screw in this, and why there was a need to improve KraussMaffei's plasticizing unit development, it is appropriate to consider the process in detail.

Before the blowing agent can be injected, the material must be completely melted and homogenized. For this purpose, the MuCell screw has the familiar three-zone geometry. Nitrogen is an inert gas that can only be dissolved in the plastic melt in extremely small

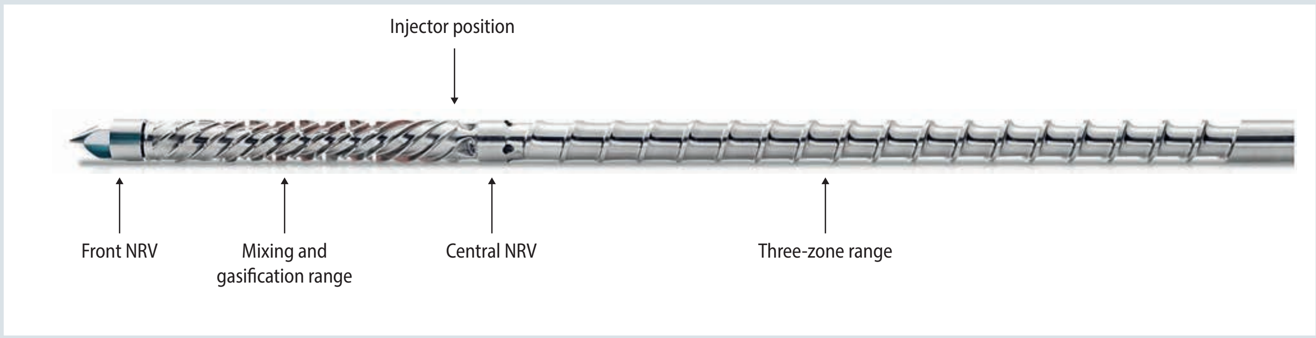


Fig. 1. The former screw geometry for physical thermoplastic foam injection molding. © KraussMaffei

amounts. To obtain precise metering and good solubility, it must be in the form of a supercritical fluid. This is achieved under conditions above both the critical pressure and the critical temperature. In the case of nitrogen, these values are 33.9 bar and –147 °C. Since the thermoplastic injection molding process always takes place in the range above the aforementioned temperature, it is only necessary to keep the pressure value above 33.9 bar for as long as the melt is in the plasticizing chamber. It is only due to the pressure drop occurring in the cavity during the injection phase that the melt is supersaturated with blowing agent and the foaming process starts [4, 5].

The melt-gas mixture is very low-viscosity, so that the critical pressure can only be maintained with the aid of a shut-off unit (e.g. a non-return valve). This shut-off element has the function of preventing excessive pressure drop. It is located directly in front of the gas injector position on the screw and separates the three-zone region from the mixing and gassing range (**Fig. 1**).

At the end of the metering process, this shut-off element, for example a central non-return valve (C-NRV) closes, and ensures a reproducible pressure level, which is the prerequisite for a stable and reproducible process with the same degree of foaming and the lowest possible shot-weight tolerance.

New Universal Foam Screw Required

Since the KraussMaffei's MuCell customers implement very different applications with different materials, the demand was clear: to create a new universal foam screw. At the beginning of the two-year analysis and test phase, there were two main questions:

- How can the plasticizing performance be improved?
- And can we perhaps do without the C-NRV?

Until now, it was necessary to use larger screw diameters for MuCell applications than for non-foamed injection molding, since, due to the gassing zone and C-NRV, the entire screw length was »

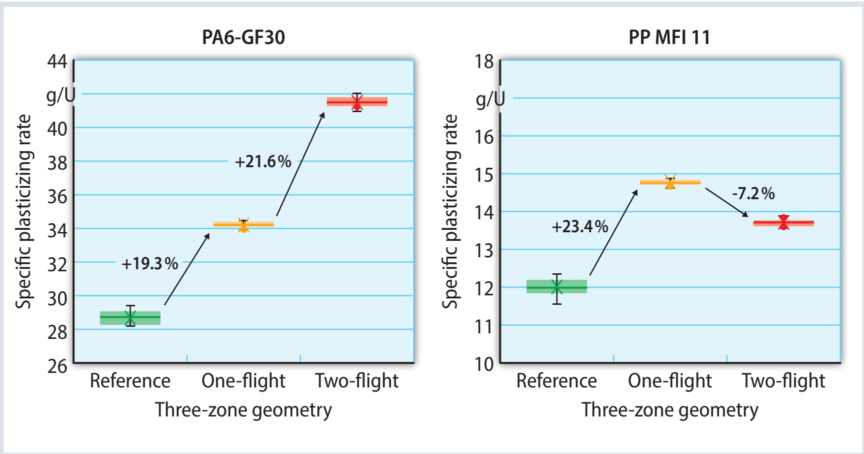


Fig. 2. Difference of the specific plasticizing rate between reference, one- and two-flight three-zone range; left PA6-GF30, right PP MFI 11. Source: KraussMaffei; graphic: © Hanser

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References

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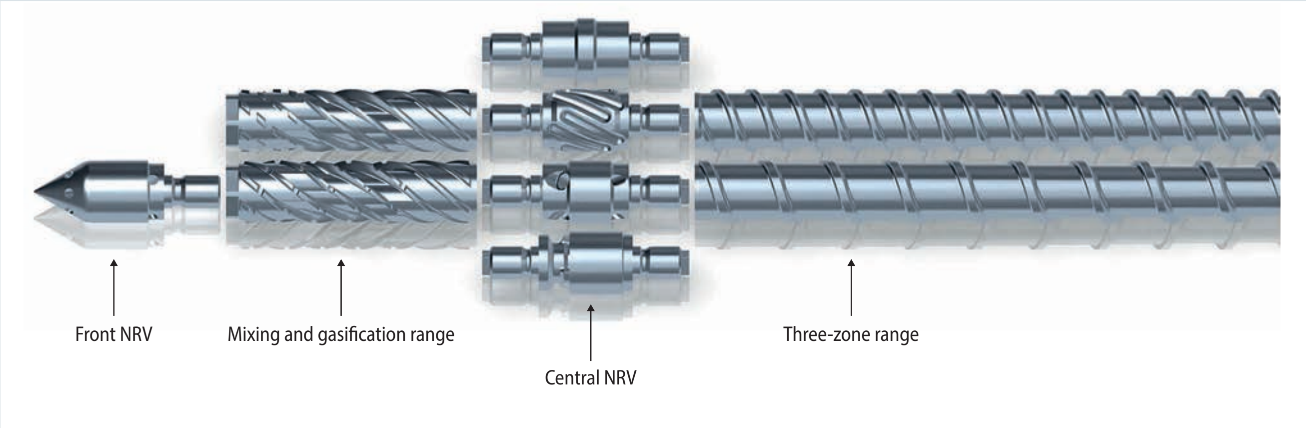

Fig. 3. Modular screw concept: The individual functional areas of the screw can be freely combined. The individual elements are screwed together.
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not available for melting and homogenization. Where otherwise an 80 mm screw was sufficient, 90 or 100 mm was required – resulting in higher costs. The C-NRV, in turn, was often called into question by users as a constriction (shearing and damage to the plastic) and as a wear point of the plasticizing system.

To be able to selectively investigate all regions of the screw, KraussMaffei developed a modular concept, in which various designs of the mixing and gassing range, C-NRV and three-zone range can be interchanged and combined by screwing. The analyses were performed on two three-zone regions, two mixing geometries and four central non-return valves (C-NRV), consisting of shearing elements of different gap widths, the standard ball check and an annular C-NRV. The existing foam screw served as a reference parameter for the results (**Fig. 1**). The tests were performed by the developers with seven different materials (**Table 1**).

Abbreviation	MFI / MVR
PP MFI 11	11 g/10 min (230 °C / 2.16 kg)
PP MFI 44	44 g/10 min (230 °C / 2.16 kg)
PP Mineral	21 g/10 min (230 °C / 2.16 kg)
PP-GF20	2 g/10 min (230 °C / 2.16 kg)
PP-LGF30	2 g/10 min (230 °C / 2.16 kg)
ABS	34 cm^3/10 min (220 °C / 10 kg)
PA6-GF30	(Not applicable)

Table 1. Plastics used to investigate modular screw designs. Source: KraussMaffei

Optimizing the Plasticizing Performance

At first, the aim was to optimize the plasticizing performance and the three-zone range for this. Its length was 15 times that of the screw diameter (15D). However, analyses showed that the mixing and gassing range (6D until now) could be reduced by 2D without loss of quality. Thus, the melting and homogenizing range could be increased to 17D, which also had a favorable effect on the wear behavior.

With the single-flight three-zone range, the plasticizing rate increased by about 20 % compared to the previous screw geometry. With a two-flight three-zone range, it even increased by a further 20 % for a glass-fiber-filled polyamide 6. However, an unfilled PP MFI 11 showed a decrease in the plasticizing rate, depending on the level of the backpressure (**Fig. 2**). With the use of low-viscosity plastics, the effect turned even more negative and led to a severe collapse of the plasticizing rate. For the sought-after new universal foaming screw HPS-Physical Foaming, it was therefore necessary to choose the single-flight option.

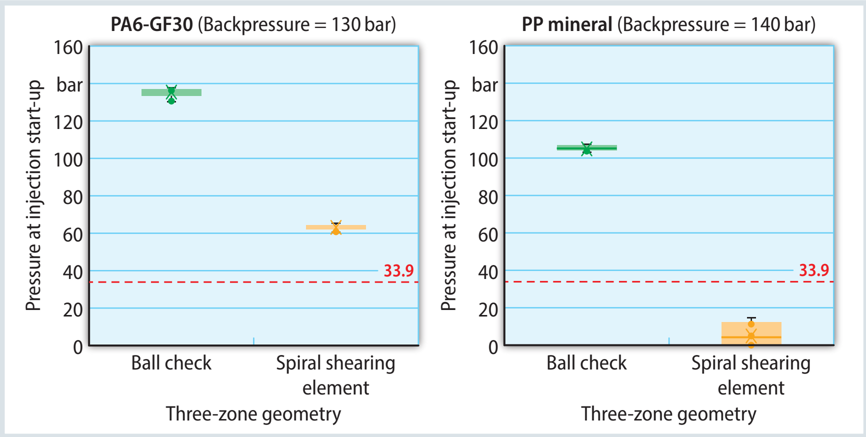

Fig. 4. Comparison of the pressure levels before injection. For PA6-GF30, the pressure for both elements is above the critical pressure of 33.9 bar. For PP mineral, it lies above in one case and below in the other. Source: KraussMaffei; graphic: © Hanser

Optimization of the Non-Return Valve

Another focus of the laboratory work was the C-NRV, since there are a large number of fundamentally different solutions on the market, four of which were taken into account here (**Fig. 3**). The main function of the C-NRV is to keep the pressure above the critical value (for nitrogen 33.9 bar) during the time between metering and injection, and so prevent backflow of the gas-charged melt towards the feed point. In principle, this function can be performed by a non-moving resistance element (such as a spiral shearing element) or a moving non-return valve (such as a ball check). In addition, the plastic melt should be able to pass easily through the C-NRV during metering to ensure high plasticizing rates and short metering times with as little shear as possible.

The results for the C-NRV show a differentiated picture: The fixed resistance elements in the form of the spiral shearing element and the cylindrical shearing gap offer an acceptable seal together with good plasticizing performance for high-viscosity polymers. In the case of PA6-GF30, the pressure in the phase between the end of plasticizing and the beginning of injection in the next cycle fell to about 60 bar (**Fig. 4**). The gap width did not have a significant influence on the pressure level reached.

However, with low-viscosity plastics, such as mineral-filled PP, the resistance elements reached their functional limits. Thus, until the beginning of injection in the next cycle, the pressure fell below the critical value (**Fig. 4**), which led to bubble growth in the plasticizing unit and made a stable process difficult to impossible to achieve. Strictly speaking, the gap between the resistance element and cylinder edge would thus have to be adapted to the viscosity of the particular plastic, or at least there would have to be several variants.

The ball check, on the other hand, showed good sealing behavior for both high-viscosity and low-viscosity polymers, and kept the pressure in the mixing section constant and reproducible above the critical value (**Fig. 4**). To ensure process reliability under a variety of background conditions and to reliably prevent the separation of gas and melt in the plasticizing unit, this option was chosen for the new foam screw (**Title figure**).

New Universal Foam Screw with 30 Percent More Plasticizing Rate

The result of the development work is the "HPS-Physical Foaming" model, which is suitable for a wide variety of materials and improves the plasticizing performance by up to 30 % compared to the previous screw geometry (**Fig. 5**). Due to the extended three-zone range, the residence time until C-NRV is increased, which has a favorable effect on the melt quality and wear behavior of the entire screw. The non-return valve at the screw tip was retained, which proved advantageous for high shot-weight constancy.

However, the new screw is not the only result of the two-year research work, since in the course of this, a large number of further analyses were performed, which are now available to the team in the manner of a toolbox. With the aid of these findings, plastics processors with MuCell applications, who process the same polymer over long periods of time, can develop the optimum screw, for example, with a two-flight three-zone range. The modular concept allows targeted material tests to be carried out without the need to produce a new screw.

Physical foam injection molding is and will remain a technology that is increasingly gaining in importance – driven by the desire for cost, energy and resource saving. With the new HPS-Physical Foaming, KraussMaffei provides the suitable solution for the TFIM process. ■

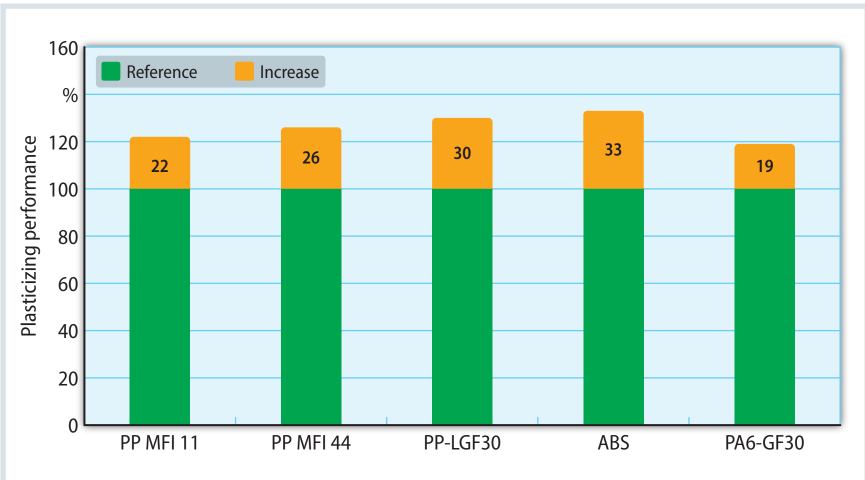

Fig. 5. The new HPS Physical Foaming increases the specific plasticizing rate, as can be seen here on selected plastics. Source: KraussMaffei; graphic: © Hanser