Foam Injection Molding. Used by few processors in the past, the special process of injection molding for foamed components has grown to be widespread in recent years. The increased variety of applications leads to the question: Has thermoplastics foam injection molding been tapped to full potential yet? Or can the process be an alternative of standard injection molding enabling processors to step up their productivities?

Prototype of a blind for a Miele washing machine. The manufacturer claims the blind is 35 % lighter than a conventional compact part. Low weight thanks to its foam structure adds up to slim component design – keyword lightweight construction (figure: Trexel)

Better than Compact Injection Molding?

ERWIN BÜRKLE
HANS WOBBE

The term thermoplastic foam injection molding comprises several process variants, with their fields of application not restricted to specific industries. They comprise areas such as automotive manufacturing, the production of household appliance and entertainment electronics, and even the packaging sector with its demanding thin-walled articles. Foam injection molding can be carried out on the basis of either chemical or physical blowing agents [1]. It is a known fact that the process often yields poor surface qualities in components. However, this downside may be eliminated by variotherm mold tempering today **(Title figure).**

Translated from Kunststoffe 2/2014, pp. 44–46
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111592

Initially, foam injection molding used to be applied, mainly, in order to eliminate shrink marks from injection molding if packing pressure alone failed to generate satisfactory results. Talking about foamed components today, weight reduction is always named as their major benefit – certainly an aspect to be considered in the age of lightweight construction. After all, subject to the respective material and process conditions, weights are reduced by between 8 and 15 %.

This aspect has pushed to the background more than would be appropriate the many other benefits included in foam injection molding, e.g. low cavity pressure and the low demand of clamping force entailed, the favorable effect on shrinkage behavior, as well as cycle time reduction. These hidden characteristics are of crucial importance, though, frequently forming the basis for a clear decision made by the process engineer in favor of the foam injection molding process as an alternative of compact injection molding.

Separate Charging and Foaming

Examining the foam injection process more closely, many of the above-mentioned benefits are almost self-explanatory – provided the phases of charging and foaming are submitted to separate considerations. If the process is set correctly, foaming takes place in the mold only, whereas the phase of charging is carried out, in a well-aimed way, in the plasticizing unit. During charging, the blowing fluid, in a supercritical state, is introduced to react with the matrix polymer, thus forming a homogeneous single-phase mixture. The best known variant of this type of process is probably the MuCell technique (supplier: Trexel GmbH in Wiehl, Germany).

Injection pressure then makes the single-phase mixture of blowing agent and polymer expand into the empty cavity, and increase its volume, because the environmental pressure inside the partially filled cavity is below the partial pressure of the blowing agent. If the ratio between blowing fluid and matrix polymer is set to the optimum value, pressure builds up in the cavity – requiring no holding pressure, as is usually applied in compact injection molding. In terms of machine and process, this saves holding pressure time, thus reducing cycle time. Moreover, the necessary clamping force is significantly lower, due to the low injection pressure required for partial filling.

While the plastic expands as a result of bubble growth, this obviously eliminates problems such as shrink marks and warpage. In addition, the flow behavior of the polymer/blow agent mixture is improved. Not only does the process allow for thinner walls in components. Component geometries may also be optimized, and another aspect of weight reduction is obtained, and that is the foam structure, which in itself means weight reduction. Generally speaking, this potential is not utilized entirely, today, in lightweight construction.

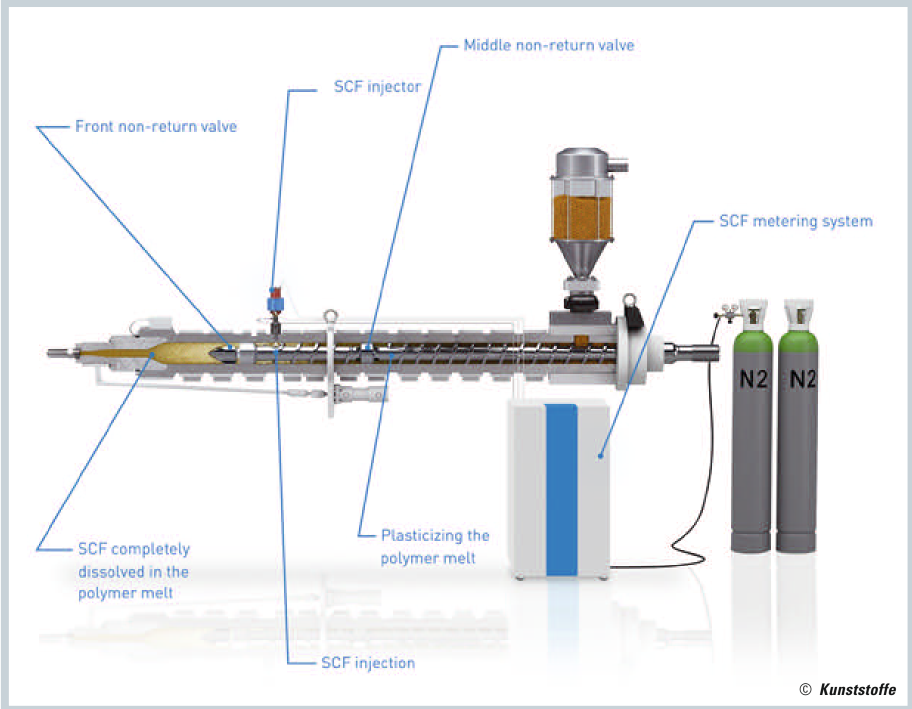

Fig. 1. Schematic presentation of a MuCell plant: The inert gas is dosed into the front third of the plasticizing unit, as a supercritical fluid (SCF) (figure: KraussMaffei)

Single-Phase Mixture vs. Decomposition Products

The choice of blowing agent, i.e. whether chemical or physical, is a basic feature distinguishing the plastic materials used for the desired molded part. Chemical blowing agents are supplied as masterbatches and are molten together with the polymer. They decompose in an endothermal or exothermal way, and sometimes, in addition to the blowing fluids desired, generate undesired side products [2].

For instance, a mixture of sodium bicarbonate and citric acid mainly dissociates water and carbon dioxide. Azodicarbonate yields 32 % of gas, i.e. N_2, CO, CO_2 and NH_3 – in addition to 68 % of solid residues [3]. These non-volatile decomposition products restrict the application of chemical blowing agents considerably, and are a major feature distinguishing them from inert physical blowing agents. These decomposition products may, for example, speed up mold corrosion and cause the basic polymer to degrade. Along with this, they sometimes cause bad smells.

By using typical physical blowing agents such as nitrogen (N_2) or carbon dioxide (CO_2) the user can eliminate such effects entirely, because these blowing agents are inert gases. The physical blowing agents, in a supercritical state, are introduced into the molten matrix material under pressure [1]. In terms of process engineering, this technique is more de- →

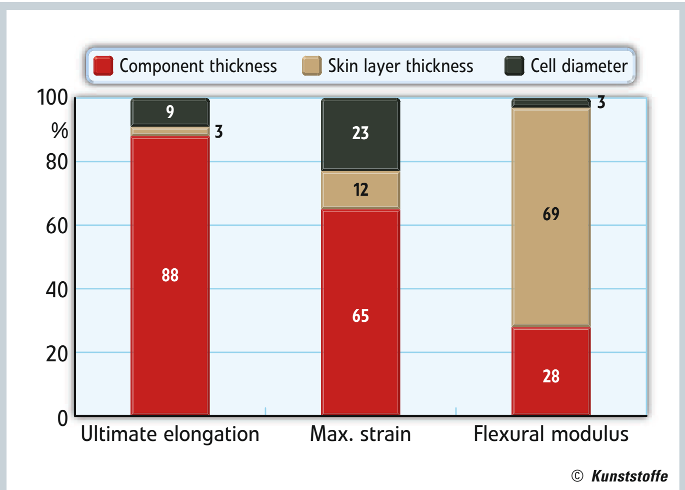

Fig. 2. Bending stress acting upon a component of polybutylene terephthalate (PBT): The graphic chart shows the skin layer thickness determining the flexural modulus, while component thickness is the crucial influencing factor to strain and ultimate elongation (source [4]: IKV Aachen)

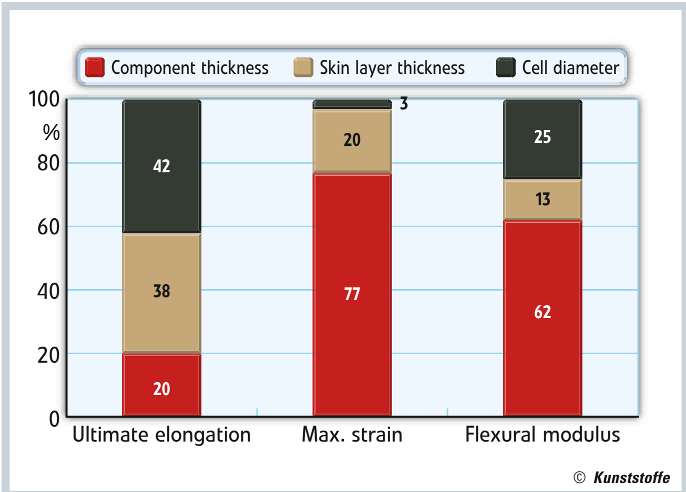

Fig. 3. Tensile stress for a component of polybutylene terephthalate (PBT): The graphic presentation shows that tensile properties are largely determined by the component thickness (strain and flexural modulus). Ultimate elongation mainly depends on the thickness of the skin layer and on the cell diameter. A coarse cell structure and low skin layer thickness reduce ultimate elongation (source [4]: IKV Aachen)

manding than foam injection molding with chemical blowing agents. From a blowing fluid dosing station, the physical blowing agent is injected directly into the plasticizing barrel, and, by a special screw, is taken to the plastic melt, mixed into it, and maintained in solution **(Fig. 1)**.

Physical Blowing Agents Yield Better Mechanical Properties

When working with chemical blowing agents, conventional plasticizing units are applied together with injection molding machines. The chemical blowing agents are usually added as concentrate to the pellets before or in the feed hopper. To control the pressure in the screw prechamber, it is necessary for the machine to feature a shut-off nozzle and active position control of the screw position.

Other than components produced by compact injection molding, foamed components have outstanding mechanical characteristics related to weight, as well as excellent acoustical and heat-insulating properties. The effect of foam structure on the mechanical properties of components has been subject to a number of investigations [4, 5], for instance concerning the foam structure's impact on characteristic values under various types of stress **(Figs. 2 to 4)**. The effects are classified according to component thickness, skin layer thickness and cell diameter.

Whenever designing a component, it is necessary to know the local material properties; the foam structure significantly determines these features. Referring to a component's impact resistance, for instance, the outer layer in its cross-section is most important, in this case of stress. The outer layer thickness itself largely depends on the process parameters – as melt temperature rises, the thickness of the compact skin layer increases, as does the cell density [5].

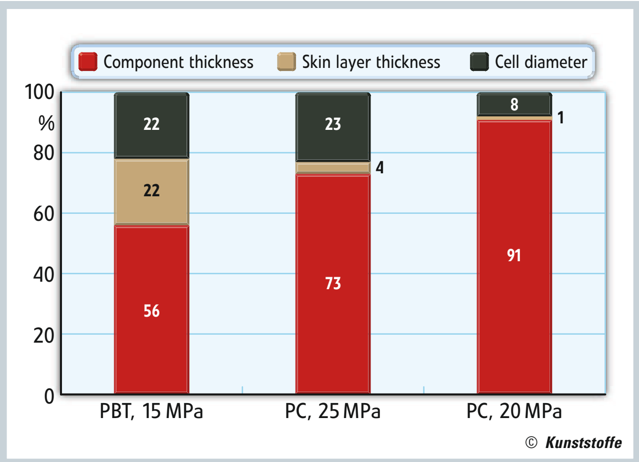

Fig. 4. The graphic chart shows the crucial impact of component thickness on the creep modulus, independent of the type of polymer investigated
(source [4]: IKV Aachen)

It is a known fact, that, comparing cell structures, foaming with physical blowing agents can lead to cell structures that are finer (microcellular) and more homogeneous (cell densities 10^9 to 10^{12} cells per cm^3) than can be achieved with chemical foaming. Due to the process applied, component-specific property profiles can be set in a more targeted way. Other features of differentiation between physical and chemical foams are cell diameter ($d_{phys.} < 100$ µm) and component density (foam density $\rho_{phys.} = 0.1–0.5$ g/cm^3). Process control is able to influence these characteristics, too.

In fact, no comparative investigations on this issue have been made available as yet. However, as a logical conclusion, it can be said that well-aimed application of physical blowing agents leads to better mechanical properties in components, than can be achieved with chemical blowing agents. In addition, chemical blowing agents cause decomposition products along with their downsides, as mentioned above. For most cases of application, users are therefore recommended to prefer inert physical blowing fluids.

Conclusion

With solutions available today to avoid poor surface qualities – the only real disadvantage involved in foam injection molding – this process has grown to be a real alternative to compact injection molding. The key for this lies in mold tempering (at present). The latest tempering techniques (dynamic variotherm processes) open up an even wider range of applications for foam injection molding. Moreover, future scientific investigations will need to look into the foaming phase inside the mold, in order to tap the process to full potential.

As was described above, various benefits are included in foam injection molding, making the process superior to compact injection molding. This is why processors should consider the process of physical foaming as an alternative technique of standard injection molding, in order to step up productivities. ■

REFERENCES

1 Altstädt, V.; Mantey, A.: Thermoplast-Schaumspritzgießen. Carl Hanser Verlag, Munich 2010
2 Habibi-Naini, S.: Neue Verfahren für das Thermoplastspritzgießen. Dissertation, RWTH Aachen University 2004
3 Throne, J. L.: Thermoplastic foams. Sherwood Publishers, Hinckley, Ohio/USA 1996
4 Research project: AiF-Vorh.-Nr. 15010 N Charakterisierung spritzgegossener thermoplastischer Schäume. IKV Aachen 2009
5 Jaeger, A.; Musialek, M.; Schulte, M.: Tailor-Made Polyamides for Physical Foaming. Kunststoffe International 100 (2010) 10, pp. 157–160

THE AUTHORS

After a long career in engineering, DR.-ING. ERWIN BÜRKLE, born in 1942, and DR.-ING. HANS WOBBE, born in 1951, agreed to establish a partnership designed to initiate and support innovations in plastics engineering. Their office is named Wobbe – Bürkle – Partner and is situated in Hitzacker/Elbe, Germany; www.wb-partner.com