More than Just Foam Bubbles

Optimized Design Can Further Reduce the Weights of Physically Foamed Plastics Moldings

A large number of processors are employing the technique of injection molding today to generate physically foamed parts. However, when applying the foaming process, users need to consider, at a very early stage, the respective major aspects of component design. Only then can they benefit from the entire potential of this special process. In most cases, this technique is then superior to compact injection molding in terms of efficiency, enabling significantly enhanced productivities.

Application of physical foam injection molding techniques is increasingly gaining speed in the automotive industry, in particular. The process of thermoplastic foam injection molding (FIM) is not used in the vehicle sector alone, though. It has also become an established technique among the producers of white goods and electronic components and devices, as well as for packagings. However, for an insight into the latest developments in the area of physical foaming examples of automotive applications are excellently suited.

The MuCell process by Trexel, Inc., Wilmington, USA, supplier of technology solutions, is the best known and the most widely spread foaming process in industry. Considering this process as an example, a development curve summarizes the steps of development, market introduction, growth and state-of-the-art technology (**Fig. 1**). The components are additionally classified according to their visual surface qualities – i. e. class A surfaces, visible and non-visible parts.

The chart is impressive proof of the success story of the FIM process with its great potential. And it also shows the long and rocky path of elaborate research and development work that was necessary to make the former niche application the reliable large series production process of today. The MuCell process features a high number of beneficial properties affecting the component and process in a favorable way. They make the technique a good choice for applications requiring high dimensional stability and for weight-optimized components. The process also offers additional potentials concerning the design of foamed non-visible components, or for in-mold decorated parts. However, these potentials are hardly utilized as yet, even though, especially in these areas, the benefits are evident:

The center console of the Mercedes-Benz C-Class car (W 205) comprises six different foamed parts (figure: Trexel)

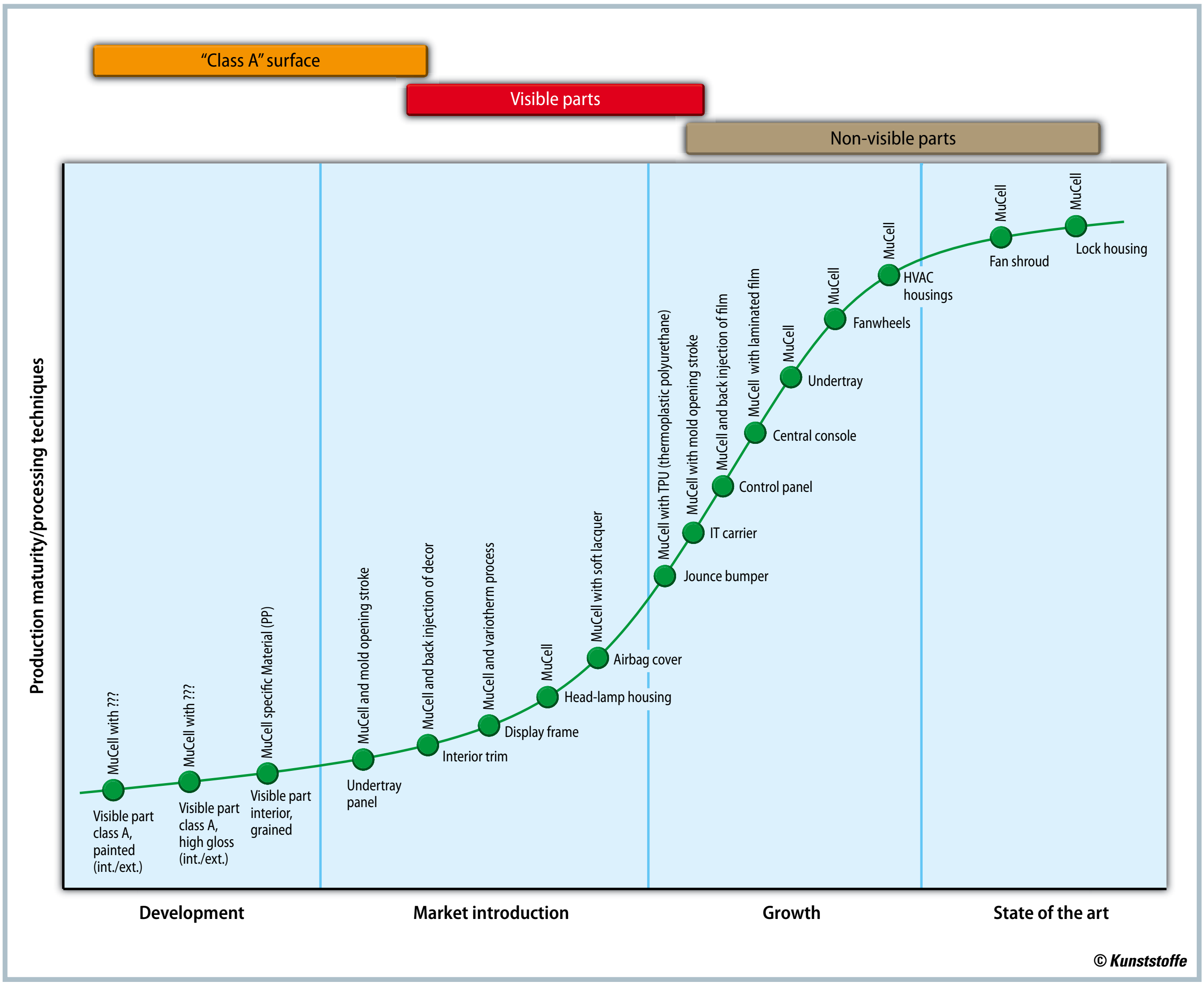

Fig. 1. As an example representing other foaming processes, too, this development chart summarizes automotive applications of the MuCell process (figure: Trexel)

- Low warpage,
- no sink marks in case of thin-walled design,
- high flowability of the melt and
- low pressures in the mold.

This effect, named lightweight design in the following, cannot be overstated (**Fig. 2**). For example, in the case of a washing machine cover plate described in [1], close to a third of the total weight saving of over 30 % was eventually due to the fact that component design had been worked out previously to fit the foaming process. Only the remaining share of weight saving can be attributed to the foam structure itself. To better utilize the potentials of the FIM process, it is worthwhile to make sure molding design fits the requirements of the foaming process. To fully understand this, the designer needs to know three basics.

Three Basics of Molded Part Design to Fit the Requirements of Foaming

First: During filling a single-phase solution consisting of super critical fluid (of either N_2 or CO_2) and matrix polymer expands into the cavity. In doing so, the solution sort of builds up its own pressure. From the machinery point of view (**Fig. 3**) the relatively low clamping force to partially fill the cavity in the filling phase is sufficient. In addition, the holding pressure phase can be dispensed with. The component designer must be aware of the fact that the rules known from compact injection molding change, according to which cavity filling of component geometries in general, and of ribs, in particular, should be from "thick to thin". There is none of the usual warpage in foamed components, because pressure build-up is perfectly homogeneous inside the cavity during expansion.

The second basic results from the weight-related mechanical characteristics of the foamed components. During FIM processing, integral foams are generated (**Fig. 4**). Due to physical reasons, the thickness of the compact outer layer is the main factor to determine the flexural modulus. Based on this knowledge, components can be designed according to the respective demands of load and low weight.

Basic information number three refers to the rheological properties of the single-phase solution homogenized out of the blowing agent (SCF, super critical fluid) and the polymer. Other than pure plastics, these solutions change their character, becoming an easy-flow material. As a result, the designer can achieve high- »

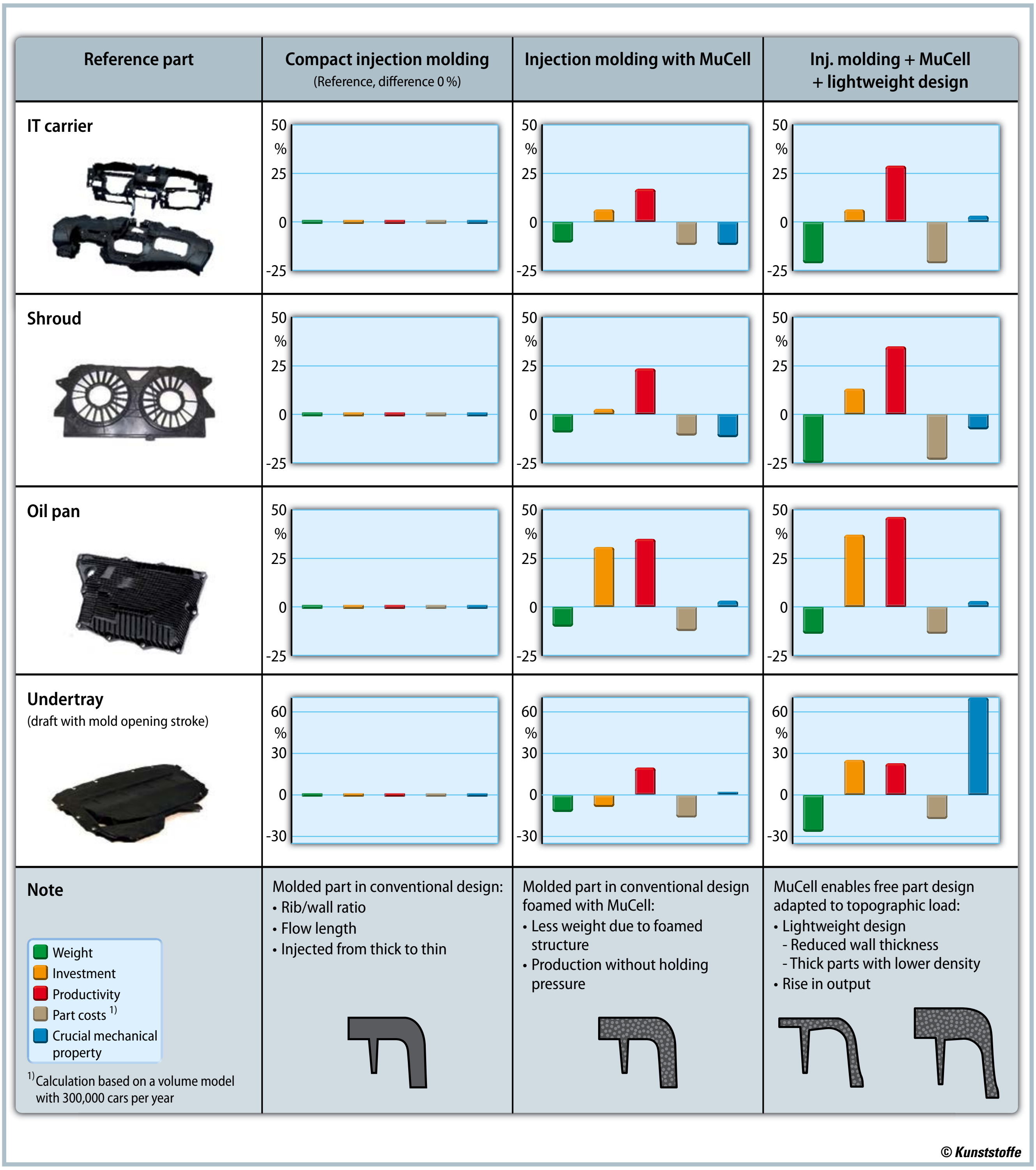

Fig. 2. Potentials of thermoplastic foam injection molding as compared to compact injection molding. Processors can achieve the greatest benefit if making sure design fits the foaming process (figure: Trexel)

Frame	PP-T20	non-visible range
Air duct	PP-T20	non-visible range
Top side cover (R+L)	PP-T20	film laminated
Flap cover (R+L)	PC+ABS	film laminated
Frame for central bin	PA6-GF30	grained eroded structure
Armrest bracket	not specified	non-visible range

Table 1. Material selection and surface design of the foamed single components as part of the center console design

er flow path/wall thickness ratios. Or, in other words, the designer can create thinner walls to save component weights. At an expert meeting held at the IKV Institute of Plastics Processing in Aachen, Germany, [2] this complex of issues was discussed. The attendants agreed to work out design guidelines to pave the way for test »

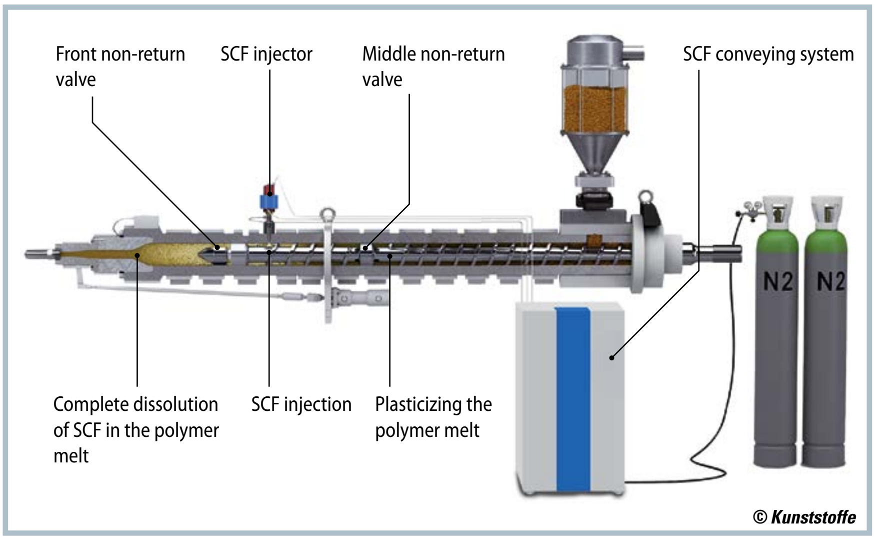

Fig. 3. The MuCell plant with adapted screw design and additional equipment to generate an easy-flow single-phase solution between SCF (super critical fluid; N_2 or CO_2 in a supercritical phase state) and polymer melt (figure: KraussMaffei)

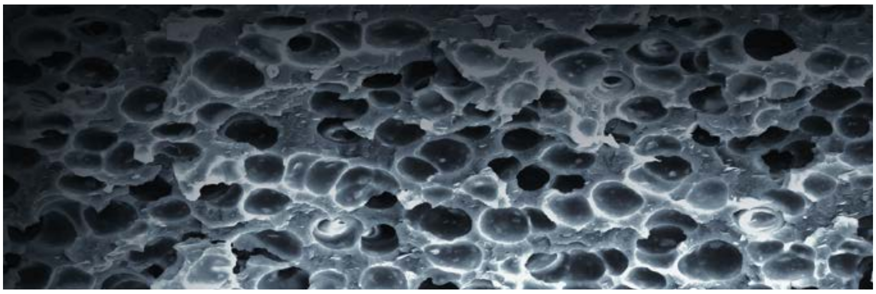

Fig. 4. A typical MuCell foam structure consists of bubbles with a 50 to 100 µm diameter (figure: Trexel)

Practical Benefits

Lightweight construction is still the driving force of thermoplastic foam injection molding, even though, thanks to changes in process management, the technique today offers a wide range of additional options to meet the specific requirements of components more easily and precisely. It is crucial to understand the basics mentioned in the article. Provided, they are applied correctly, these basics can help

- simplify mold design to save costs,
- reduce cycle times and costs by enabling the use of alternative mold materials,
- use specifically differences by the thermal expansion of alternative mold materials to equalize shrinkage-induced component dimensions via temperature in the mold.

FIM for Visual Parts

All types of foaming techniques cause process-induced streaks on the component surface that are more or less pronounced. To achieve acceptable surfaces in the visual range, the operator must therefore take demanding measures, for example:

- Designing material and mold surface to fit each other,
- posterior modification by, e.g., varnishing or laminating,
- modification during the injection molding process by, e.g., backmolding or in-mold decoration,
- application of variotherm mold temperature control.

Many inquiries for MuCell specify high surface qualities. This is remarkable, considering the fact that a vast number of components can be produced in the FIM process faster and more easily. These include, for instance, reinforcing parts, clamps, non-visible parts, parts with a film backmolded, i.e. parts where the benefits of this technique can be utilized without additional development work.

standards for foamed injection molded parts in the future.

Center Console with Six Different Foamed Part

Grammer AG in Amberg, Germany, developed the center console of the new Mercedes-Benz C-Class car (**Title figure**). It is produced using the MuCell technique [3], representing an impressive example of state-of-the-art physical foaming. Being a leader in interior design, the company laid out the processing units along the entire design chain according to a strategic approach, thus achieving optimum productivity and weight saving.

Component design considers all design guidelines aimed at achieving weight-optimized design in the MuCell process under economic aspects. The center console assembly group comprises six different MuCell molded parts, with the total number of parts being higher subject to the actual right/left variant (**Table 1**). According to its respective position in the assembly group, each component was produced applying the best suited design and material.

The thin-walled components meet Daimler's high quality demands, especially because warpage and sink marks are excluded. For the design at hand, this would have been impossible without the method of physical foaming. The components of different standard materials of the automotive industry depending on the respective requirements, were foamed using nitrogen (N_2) inert gas as a blowing agent. The visible parts, e.g. side covers, are designed as thin-walled parts with a wall thickness/rib ratio of 1:1. For optical reasons, they carry a laminar film.

Most of all, frame and air duct of the center console benefit from the filling option, which enabled load-related design of part topographies. Wall thickness is 1.5 mm in areas with a minor load, whereas the part is 1.8 mm thick only in those areas requiring a higher stiffness. Applying the technique of thermoplastic foam injection molding, the designer has this additional freedom, without having to pay attention to the restrictions involved in compact injection molding.

The parts manufactured in the MuCell process can be integrated into the assembly and downstream processes usually applied for such types of engineering components. These established processes comprise laminating with different surface materials, as well as connecting physically foamed elements by the usual welding techniques.

At last, the system supplier was able to reduce the weight of the center console by 20 % as compared to the compact variant. While the actual degree of foaming only accounts for less than half of this weight reduction. Another aspect that might tip the scales of efficiency in favor of the MuCell process is the fact that it allows for processing on smaller injection molding machines with lower clamping force.

Conclusion

For non-visible and some visible parts, the alternative of foam injection molding is more efficient than traditional compact injection molding. To achieve this higher efficiency, the designer must understand the three basic facts mentioned above. Especially, if designing the parts according to the requirements of foaming, between 20 % and 30 % of materials can be saved.

On the basis of the knowledge mentioned, and if applied with due creativity, the process offers a wide range of designs and solutions for many different types of challenging components. The holding phase can be dispensed with, while smaller injection molding machines with lower clamping forces can be employed. These facts add up to improving the productivities of injection molding plants. ■

The Authors

Dipl.-Ing. (FH) Harald Heitkamp is Sales Manager and Technical Consultant for MuCell at Trexel GmbH in Siegen, Germany; h.heitkamp@trexel.com

Dipl.-Ing. (FH) Markus Betsche is Sales Manager and Technical Consultant for MuCell at Trexel; m.betsche@trexel.com

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References & Digital Version

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