SPECIAL:
FOAMING

Because Nitrogen Weighs (Almost) Nothing

KraussMaffei and Gealan Test the Limits of the MuCell Foam Process

The plastics processor Gealan Formteile GmbH manufactures lightweight parts for the automotive industry by thermoplastic foam injection molding. In the process engineering, as well as in the secondary finishing of the injection molded parts, the company is continually extending the limits of what is feasible. Also on the agenda is the welding of foamed parts and applications with visible parts.

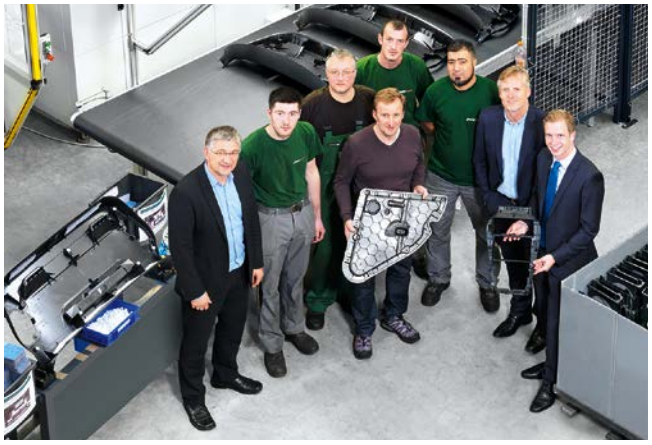
MuCell part with FIPFG gasket, metal rivets and thread insert: the door module for the Mini. Compared to non-foam injection molding, the required clamping force is a third lower (figures: KraussMaffei)

Warpage reduction by up 70 % In the case of the function support for the center console of the Ford Lincoln, this was the deciding factor for using MuCell technology

More lightweight, more environmentally friendly, more efficient. Many of the manufacturing trends that are currently in the spotlight are combined in one process: physical foam injection molding. Despite its many technical and economic advantages, the market penetration of this technology, including of the market-dominating MuCell foam process, is not yet so extensive as was predicted a decade ago.

As an official partner, KraussMaffei Technologies GmbH, Munich, Germany, offers complete injection molding systems with the technology of the U. S. developer of MuCell, Trexel Inc. Premium manufacturers in the automotive industry currently use vehicles produced in relatively small numbers in field tests in order to transfer the technology to high-volume models at a later date. And the process could also be attractive for industries with products for which fluid technology plays an important role.

It is all the more important for committed development partners such as Gealan Formteile GmbH, Oberkotzau, Germany, to investigate the MuCell process in detail and continually extend its technical limits. The welding of foamed parts and the use of such parts in visible areas, too, are no longer a taboo.



The Gealan team with (from left) Lutz Fischer (technical manager), Thomas Geier (machine operator), Erich Geissler (shift leader), Raimund Wohn (machine setter), Mourad Dhifalli (material conditioner) and Gerhard Laubmann (managing director). Alongside, Robert Weber (KraussMaffei), front Jörg Püttner (department head plants and building) with the Mini door module. Shown at the right, a view of the complete manufacturing cell

(figure: KraussMaffei)

The Process in Brief

In plastics processing, MuCell designates a particular physical foaming process using nitrogen (N_2) or carbon dioxide (CO_2) as blowing agent. The gas is first transformed into a supercritical state, in which it is incompressible like a liquid but has the diffusion properties of a gas, and is then metered into the plastics melt in the screw.

After injection of the polymer-gas mixture into the cavity, a foam structure develops in the interior of the part, which requires technical and economic differences compared to conventional parts. For example, less material is required to fill the cavity. The weight saving may be up to 20 %, depending on the part geometry and modification. In auto applications, this also benefits the end user, who benefits from lower fuel consumption.

So that the cells are as finely distributed as possible in the foam structure, injection must take place very rapidly, about 15 to 30 % faster than with solid plastic parts. The most important cycle time advantage results from the elimination of the holding pressure time, which is replaced by the foaming in the cavity. In addition, the machine may have lower clamping forces, since the gas in the plastic melt reduces its viscosity and the holding pressure is eliminated.

The foaming process also offers advantages for designing the part geometry. It provides stability directly where it is required, so that other regions that require less stability can be more delicately structured. The flow paths and walls can be made thinner at these points. Where the walls and ribs meet, the sink marks are less pronounced, since there is less material accumulation. In addition, the foaming pressure, unlike the holding pressure, also acts in areas remote from the sprue.

Due to the nature of the process, the more balanced pressure distribution and the uniform shrinkage in the longitudinal and transverse directions reduce stresses and warpage tendencies in the part. The foam structure can therefore only be seen if the plastic components are cut open, since, at places where the melt is in contact with the mold, a closed, non-foamed skin forms, which, however, does not usually meet aesthetic requirements due to streaks on the part surface.

To fully exploit the advantages of the process, specially designed molds are required. Special attention should be paid to venting and cooling, since the molds are operated at a lower temperature than with non-foamed injection molding.

Quality Monitoring with the Aid of the Machine Control System

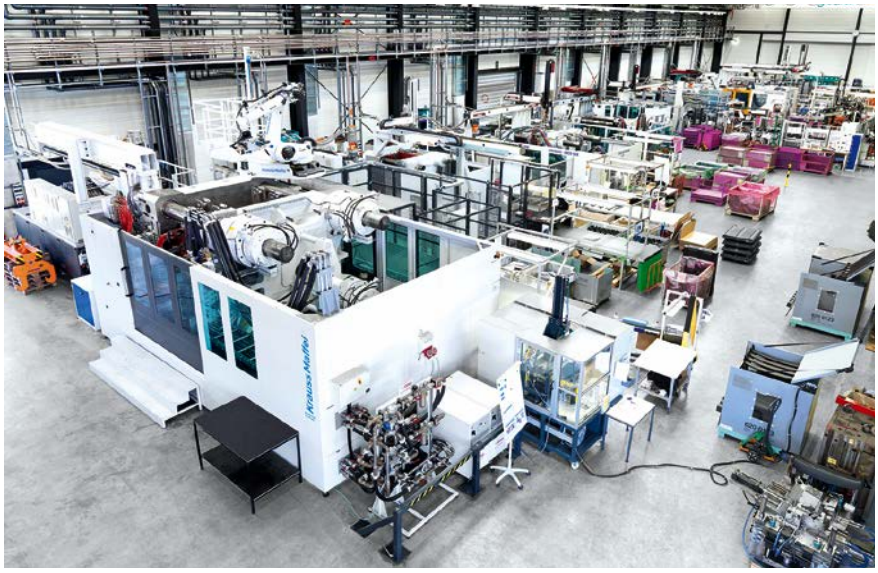
To extend the limits of a process, it is important to have a full grasp of it. Gealan currently produces about 15 different articles in series using KraussMaffei MuCell machines, and considers the process an important building block in its product portfolio.

KraussMaffei has made it extremely easy to operate its turnkey MuCell plants: with the intuitive MC6 machine control system, the user can make use of all the known possibilities for quality monitoring and documentation. For example, a tolerance band can be superimposed on the significant pressure drop of the supercritical fluid, which occurs during gas injection. Deviations from this tolerance can then be linked to specific action instructions to the machine.

Series Applications: Economic vs. Technical Motivation

In its various projects, Gealan acts with different motivations when it employs physical foaming. In the case of a function carrier for the center console of the Ford Lincoln, which runs on a GX 650 injection molding machine, the focus is on reducing stress. With the polyphthalamide (PPA) containing 50 % glass fibers that was used, warpage could be reduced by up to 70 %. In addition, a weight saving of 8 % was achieved, which is particularly worthwhile in this case: the material is high quality and therefore very expensive.

The decision by the processor, tier-one customer and OEM regarding the door module of the BWM Mini was primarily for economic reasons (**Title figure**). Besides an 8 % weight saving, it was also possible to manufacture the part on an existing 10,000 kN machine – a clamping force of 15,000 kN was have been necessary in the conventional process. One third lower clamping force means re- »



State-of-the-art equipment: view into one of the Gealan production halls. Here, the producer currently manufactures 15 different MuCell articles in series (figure: KraussMaffei)

duced stress on the mold and a lower outlay for energy and other resources.

The saving in the cycle time is also impressive: It only takes 1 s until the glass-fiber-reinforced ABS part is completely filled – about a third of the conventional time. Lutz Fischer, technical manager at Gealan, said: "The savings potentials won over our customers, and we have manufactured the parts in series since 2012."

KraussMaffei has already taken into account the use of such challenging materials in its development work, in particular in the design of the plastication units: Since the system supplier produces the MuCell screws in-house, it was able to improve, among other things, the wear resistance and closing characteristics of the non-return valves. New coatings reduce abrasion, particularly in the processing of glass-fiber-reinforced materials, and thereby prolong the service life – to the benefit of efficiency and process reliability.

Door Module Completely Redesigned

To explain the advantages of the MuCell process to its customer in the initial phase of the mini-project, Gealan completely redesigned the door module. At this point, the Gealan subsidiary CAXsolutions stepped in, which, with 35 employees, offers engineering services. The X in the name can be read as a variable that stands for the wide bandwidth of questions that are investigated with the aid of the computer. From pre-development and innovation management, through part design and mold design, the pallet also includes simulation of material aging and lifetime and from part dimensioning through structured-light 3-D scanning, to prototyping in 3-D printing.

In the door module, for example, the honeycomb structure on the reverse side could be redesigned. The MuCell process now allows a wall-thickness/rib ratio of 1:1, where a ratio of 2:1 is conventional by conventional injection molding.

The Mini module also shows the processor's manufacturing depth. After the MuCell process, it is provided with a foamed PU gasket by the FIPFG (formed-in-place foam gasket) process. The parts where the screw mounts will subsequently be located are reinforced with metal rivets, and a screw thread insert is also used for fastening.

The module is subsequently provided with a bonded insulating mat, and is then ready for installation in the car, where it completes the carcass and is mounted behind the door trim. Gealan is well-equipped to handle large lightweight construction applications: An existing machine with 25,000 kN clamping force, which produces rear trim for the BMW 2 series, can also be fitted with MuCell technology.

Cost-Saving Developments for Fluid Systems

Series applications must run stably. However, it becomes exciting when you try to

MuCell Entry

Since users entering MuCell technology must satisfy a range of technical conditions, they require an experienced partner. KraussMaffei offers interested parties the option of exploring the foaming process in with existing applications at its own pilot plant. For this purpose, it offers complete systems with clamping forces from 1,300 to 16,000 kN – clamping forces up to 54,000 kN are even possible with external partners. If required, KraussMaffei also supports its customers with article and mold design.

- www.kraussmaffei.com/en/cellform.html

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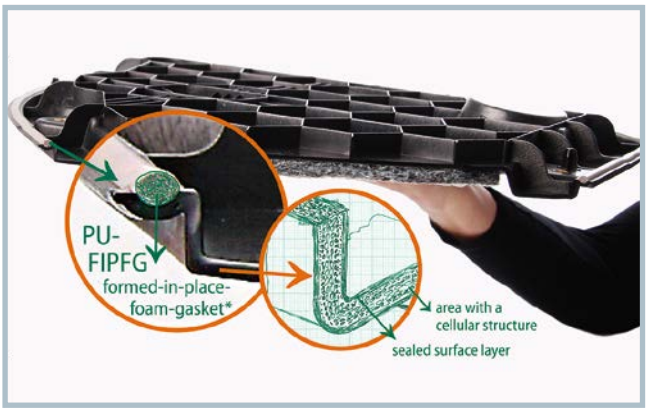

Cross-section through a physically foamed injection molded part with FIPFG PU-gasket; * foamed in height-width ratio 1:1
(figure: Gealan)

do things that are supposed to be impossible. Exploring and extending the limits of the MuCell process are the declared aims of the Gealan team. MuCell tests were therefore also performed with twelve applications of conventional design, and data such as the clamping force and cycle time were documented. Surface components in visible parts, such as glove compartments, were included as well as water-carrying fluid systems, such as the internal parts of a flow heater with heating elements and hydraulics.

After all, besides the automotive sector, fluid systems are another of Gealan's mainstays. The issue here is replacing metal parts with plastic, for example in heat exchangers of wall-mounted gas boilers, in three-way valves or flow meters, which are used to supply the correct amount of heating energy for the desired water temperature. Gealan also sees a particularly interesting field for foam injection molding here for two reasons: on one hand due to the low stress and low warpage of the foamed parts, and on the other hand due to the huge price of high-performance plastics, which may be over EUR 7/kg.

For fluid parts, crosslinked polyphenylene sulfide (PPS) or PPA is predominantly used, which have reliable strength over the entire lifetime of a boiler – about 15 years – and are also resistant to chemicals, as well as to oxygen. High-quality materials are used particularly where service water, not only heating water, flows through the pipes. Physical foaming then allows considerable savings potential to be unlocked due to weight reduction, and Gealan is consequently actively pushing forward the tests in this area – it reports that the first tests are promising.

Since Gealan not only supplies parts, but also development services for its customers, CAXsolutions even maintains a special water lab for the fluid technology area, in which data for material aging can be determined with an in-house-developed test sample. These data are then used in simulations for the lifetime of parts, and provide more reliable results than computations using the manufacturers' material datasheets.

Experience at the Frontiers: What Is Possible with MuCell?

Another focus of the experiments was the processing of physically foamed parts. For example, MuCell parts can actually be welded provided that certain guidelines are followed and the process is also adapted to the technical circumstances of the foamed parts. At Gealan, this test portfolio now forms a rich pool of experience for future projects.

KraussMaffei, too, is active in this direction: besides welding, the machine manufacturer has also paid particular attention to visible surfaces in its own tests. Development work is progressing apace and the project team is optimistic that it will be able to give users more reliability in the surface parts market segment, which is still largely untapped. This not only includes high-gloss surfaces generated by means of dynamic mold temperature control, but also the topic of visible surfaces in general, such as matt, textured or post-treated surfaces. ■