The New Process for Lightweight Foaming

Granulate Is Impregnated with CO_2 in an Autoclave and Processed on Standard Injection Molding Machines

The e-mobility trend is driving increased efforts in lightweight construction. Now the Kunststoff-Institut Lüdenscheid and Linde AG have developed a new physical foaming process that does not require costly retrofitting or conversion of the injection molding machine. This flexibility makes the process equally attractive for small batches and large production lots. ProTec Polymer Processing is the partner developing a system for industrial application.

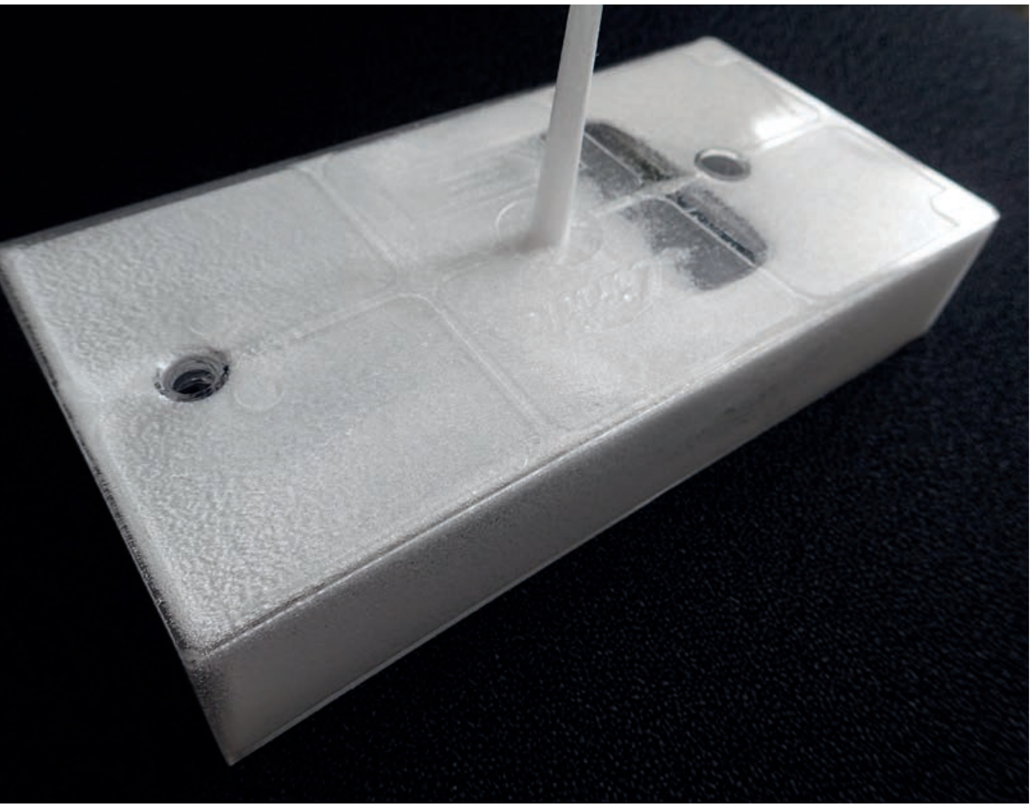
Many OEMs are exploring the lightweight construction potential in the assemblies for their vehicles. Driven by legal requirements to reduce harmful substance emissions and the discussion surrounding the range of electric vehicles, the respective plastic components are also being examined. Foaming for example is an effective way to reduce the weight of injection molding parts. While weight reduction is the primary focus in the automobile industry, other industries tend to have an interest in foaming because it reduces the use of material and therefore lowers the cost.

Foam injection molding also has process technology advantages. These are due to the considerably lower viscosity and resulting better flowability of the melt. Since lower filling pressures are adequate with foamed materials and a definitive holding pressure phase can be eliminated to some extent, the requirements for the clamping force of the injection molding machine and the mold stiffness are reduced.

Using smaller injection molding machines and injection molds with reduced weight harbors significant potential savings. A large component that requires a sturdy mold made of steel in compact injection molding could for example be produced in an aluminum mold when foam injection molding is used.

Improved Dimensional Accuracy through Foaming

Foaming has a positive influence on component quality as well. Anisotropic shrinkage of many plastics is one of the main causes for component distortion and inadequate dimensional accuracy. Since foaming reduces shrinkage because the gas



The foamed PC component weighs about 16 % less and has a smooth surface thanks to using the gas counter-pressure process

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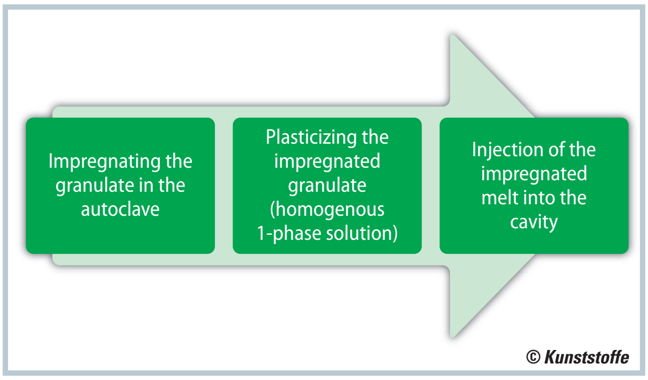

Fig. 1. Sequence of the new foaming process: In contrast to other physical foaming processes, the granulate is impregnated with the blowing agent prior to treatment in the machine (source: Kunststoff-Institut)

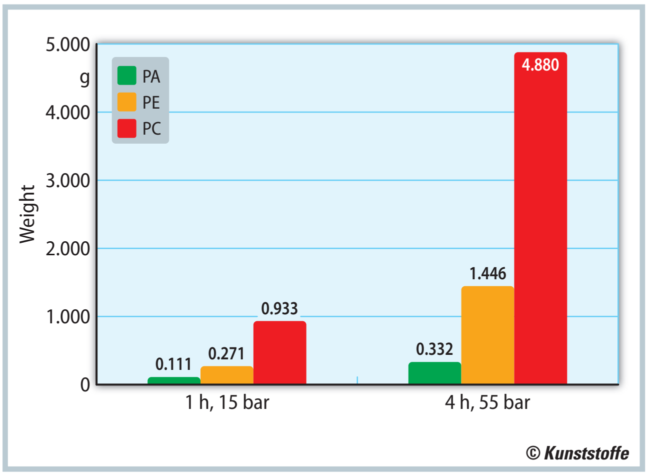

Fig. 2. Weight increase of 100 g plastic, respectively with two different impregnating times; the pressure increase has a clear effect (source: Kunststoff-Institut)

bubbles produce a sort of intrinsic holding pressure in the component, the potential for shrinkage differences is also reduced and the dimensional accuracy of the components improves.

For all of these reasons there are currently several foaming processes in the market. Here one differentiates between chemical and physical foaming processes.

Chemical vs. Physical Foaming

In the chemical processes, a foaming agent is mixed with the plastic granulate, usually in the form of a masterbatch with 0.5 to 2 wt. %. Benefits of chemical foaming include easy handling and implementation on existing standard injection molding machines. Disadvantages compared to the physical processes are the low foaming pressure, which limits the degree of foaming that can be achieved with smaller wall thicknesses, and the decomposition products created by the chemical reaction that can lead to the formation of deposits in the mold.

A nozzle or tip closure system is required on the mold or injection molding machine, preventing the foaming synthetic material from oozing out of the plasticizing unit. Position control for the screw is required to run a reproducible process. Otherwise the material foaming in the space in front of the screw can put uncontrolled back pressure on the screw after dosing. These two requirements should also be met when a physical process is used.

In addition to the requirements for the injection molding machine defined above, the known physical foaming methods demand additional modifications of the injection unit and screw as well as added peripherals for a controlled gas supply. These differ according to the process. That is why special plasticizing units adapted to the respective process are needed.

With the physical foaming processes offered in the market to date, the blowing agent is mixed with the granulate or melt di-

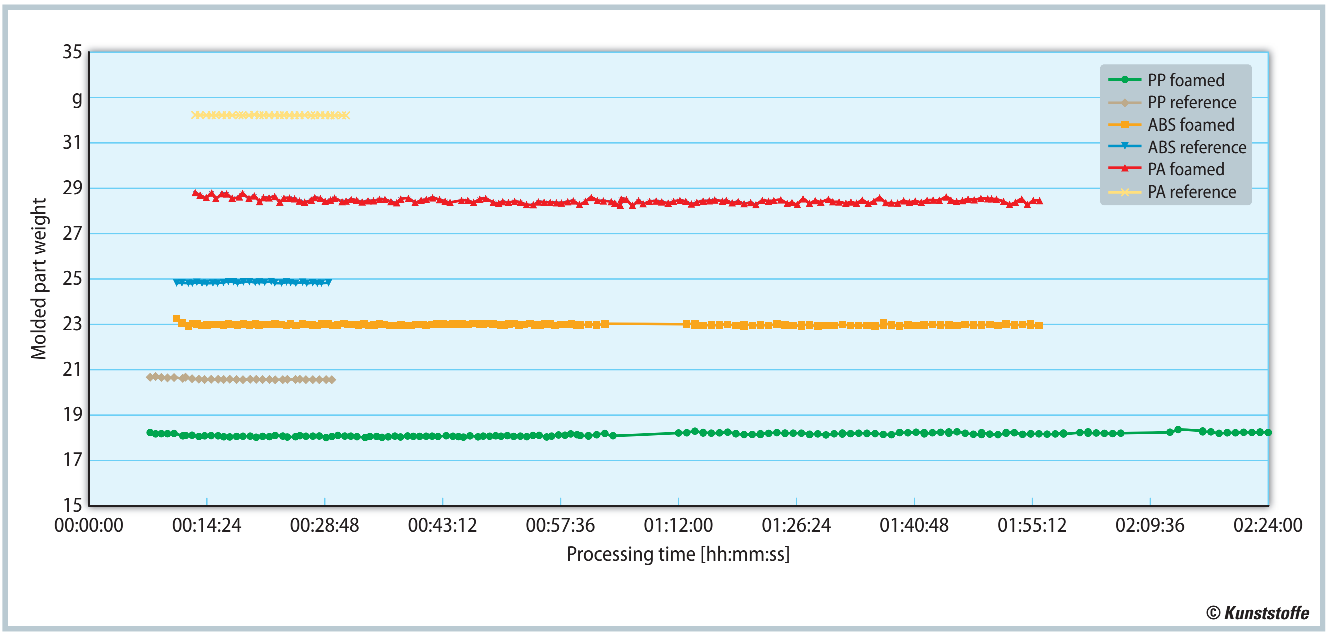

Fig. 3. Continuous weight measurement on foamed components made of various plastics (reference: compact part). Each point corresponds to a component; reproducible use of the impregnated granulate is confirmed over several hours (source: Kunststoff-Institut)

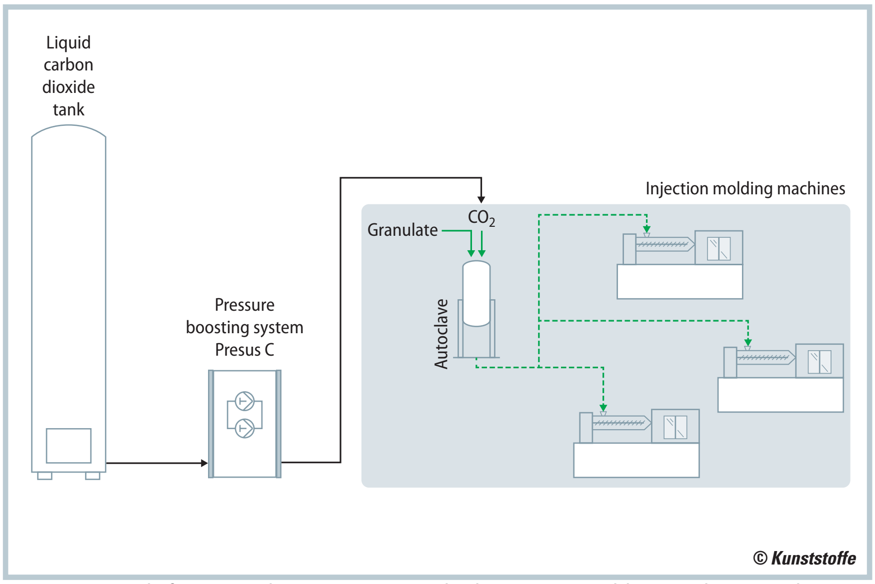

Fig. 4. Gas supply for material impregnation. Multiple injection molding machines can be supplied by one autoclave (source: Linde)

rectly in the injection molding machine. The most well-known representatives of this species are the ProFoam process (Arburg/IKV), in which the plastic granulate is enriched with the foaming agent in a granulate valve and drawn under pressure into the screw that is sealed at the rear, and the MuCell process (Trexel) in which the blowing agent is added to the melt in a modified plasticizing unit.

Since no chemical reaction takes place here so that no decomposition products are produced, deposits do not form in the mold. Another benefit of the physical processes is the high foaming pressure, which also enables a good degree of foaming with lower wall thicknesses.

A Simple New Physical Foaming Process

Now a new physical foaming process, jointly developed by the Kunststoff-Institut Lüdenscheid and Linde AG, combines the benefits of simple chemical foaming with those of the more effective physical foaming.

Here an additional step precedes the process in the injection molding machine: After drying, the material is impregnated with carbon dioxide (CO_2) as the propellant in a pressure vessel (**Fig. 1**). The amount of gas taken up by the granulate varies depending on the plastic material, temperature, impregnating time, and pressure. According to the current state of knowledge, the uptake is particularly pronounced with polycarbonate (**Fig. 2**).

The fact that CO_2 diffuses quickly into and also through plastic has been known at the latest since the emergence of PET bottles for beverages containing carbon dioxide. Joint-studies at the Kunststoff-Institut Lüdenscheid and Linde AG however showed that CO_2 remains in the granulate for a surprisingly long time after loading and pressure relief, in some cases for 2 to 3 hours even with open storage.

With many of materials studied to date (**Table 1**), this makes a reproducible foaming result possible over several hours. Only when the gas gradually escapes from the granulate do the parts slowly start to get heavier again (**Fig. 3**). What is even more exciting is that this physical process, like chemical foaming, works on conventional injection molding machines for many of the materials that were studied.

Similar to central drying, an autoclave can be loaded with material for several injection molding machines (**Fig. 4**). In addition to further material studies an integrated system for drying and impregnation, is currently being developed with ProTec Polymer Processing, a partner with experience in peripherals engineering. The commercial launch is slated for 2018.

Improving the Component Surface with Gas Counter-Pressure

A disadvantage of all foaming processes is that gas bubbles burst at the melt front, causing streaks to form on the surface of the molded part (**Fig. 5**). Similar to preventing visible flow lines, variothermic processes are suitable in which the tool wall temperature for the injection and holding pressure phase is briefly increased so the melt that has burst is compressed again before it solidifies on the cavity wall.

These results in closed surfaces that are comparable to compact injection molded components, and in many cases actually better in the area of flow lines and sink marks. The related costs incurred for the mold, peripherals, and energy call the implementation into question depending on the material, component geometry, mold concept, and cycle time requirements.

An alternative is the gas counter-pressure process that is rarely used to date and prevents the bursting of gas bubbles on the melt front (**Fig. 5**). This slightly reduces the degree of foaming, but a closed surface is obtained even with conventional mold temperature control (**Title figure**).

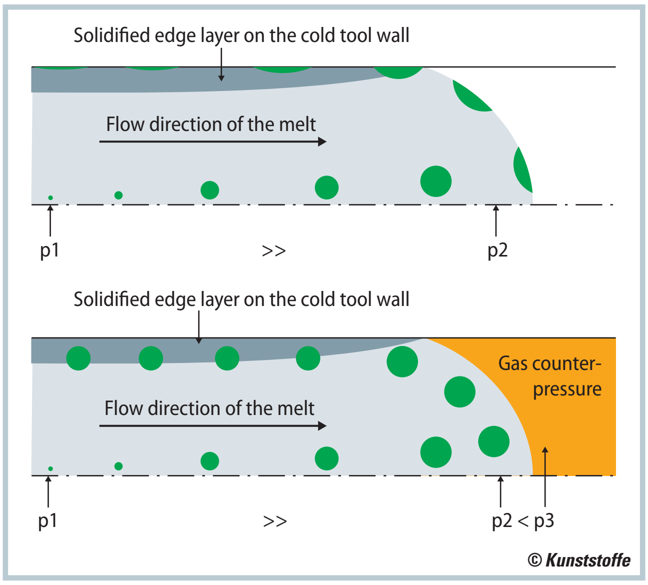

Fig. 5. When gas bubbles come to the surface, this causes streaks to form (top). The gas counter-pressure process (bottom) prevents gas bubbles from bursting at the melt front (source: Kunststoff-Institut)

Polymer	Trade name	Reference weight [g]	Foamed [g]	Weight reduction [%]
PC	Mitsubishi Xantar	25.604	10.196	60.2
ABS	Regran R	24.838	19.218	22.6
PA-GF30	Altech PA6 A 2030/109 GF30	31.913	26.957	15.5
PP	Moplen EP 448T	31.321	22.930	26.8
PP	Hifax TSOP EM1 R299	22.803	14.396	36.9
PP	Finalloy	26.473	18.596	29.8
TPE	Bexloy GPV6385	28.532	20.997	26.4
PLA	RTP 2099 X 124790 A	35.413	30.633	13.5
PTT-GF15	Sorona 3015G BK001	33.551	30.710	8.5

Table 1. The degree of foaming achieved for different plastic materials fluctuates between nearly 10 % to a maximum (PC) of 60 % (source: Kunststoff-Institut)

What sounds simple at first glance is not trivial from a sealing and process technology perspective. Provided the mold can be adequately sealed, the gas counter-pressure has to be controlled to adapt it as the cavity is filled. Thus, the gas (nitrogen) pressure not only has to be reproducible and built up quickly, but also has to be reduced again just as quickly in a controlled manner.

A pressure control module similar to what is known from internal gas pressure technology can be used here (**Fig. 6**). As soon as the mold is closed, the control unit of the pressure control module receives a signal and the required gas pressure is built up in the cavity before the start of the injection phase. To prevent the melt from increasing the pressure further as it flows in, thereby causing filling problems, the control valve of the pressure control module has to respond quickly and keep the counter-pressure constant to the end of the flow path by releasing gas. Here the correct location of the valves and/or venting channels is important in addition to the pressure control module.

Fig. 6. The pressure control module (Linde) has to respond quickly and keep the counter-pressure constant to the end of the flow path by releasing gas as the melt flows in (© Linde)

Conclusion

Today's industrial enterprises need to conserve resources. In automotive engineering, this can only be accomplished by reducing the vehicle weight. It therefore seems likely that the demand for foamed plastic components will increase in the future.

The process developed by the Kunststoff-Institut Lüdenscheid and Linde AG could close the gap between chemical and physical foaming processes, thereby allowing many polymer processors to implement physical foaming with existing injection molding machines. In the opinion of the authors, the new possibilities – for example to produce seals in 3D and the further development of pressure control modules – make the gas counter-pressure process interesting as an alternative to the variothermic process in the future. ■

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Company Profile

The **Kunststoff-Institut Lüdenscheid** has been advising its clients on matters related to plastics processing for 30 years. **Linde AG**, one of the world's largest suppliers of industrial gases, develops solutions in the fields of gas (assisted) injection molding technology, spot cooling, extrusion, and PU foams under the Plastinum brand. The two companies have been cooperating in joint development projects and patent applications for more than 15 years.

Peripheral system from ProTec

The peripheral system which will allow the new physical polymer foaming method to be straightforwardly integrated into existing injection molding systems is currently being developed by ProTec Polymer Processing GmbH from Bensheim near Darmstadt, Germany. Processors will in future be able to quickly integrate this solution, consisting of a dryer, autoclave and conveying unit, into their manufacturing line. Depending on model, existing injection molding machines will need little or no modification. Loading the pellets with CO2 and feeding are completely automatic. Since the system can supply a number of machines simultaneously, manufacture of both small and large batches is economically viable. The integrated unit is operated via a network-compatible PLC controller which is already fitted to all dryers and dosing units from ProTec's SOMOS product lines.
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German Version

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