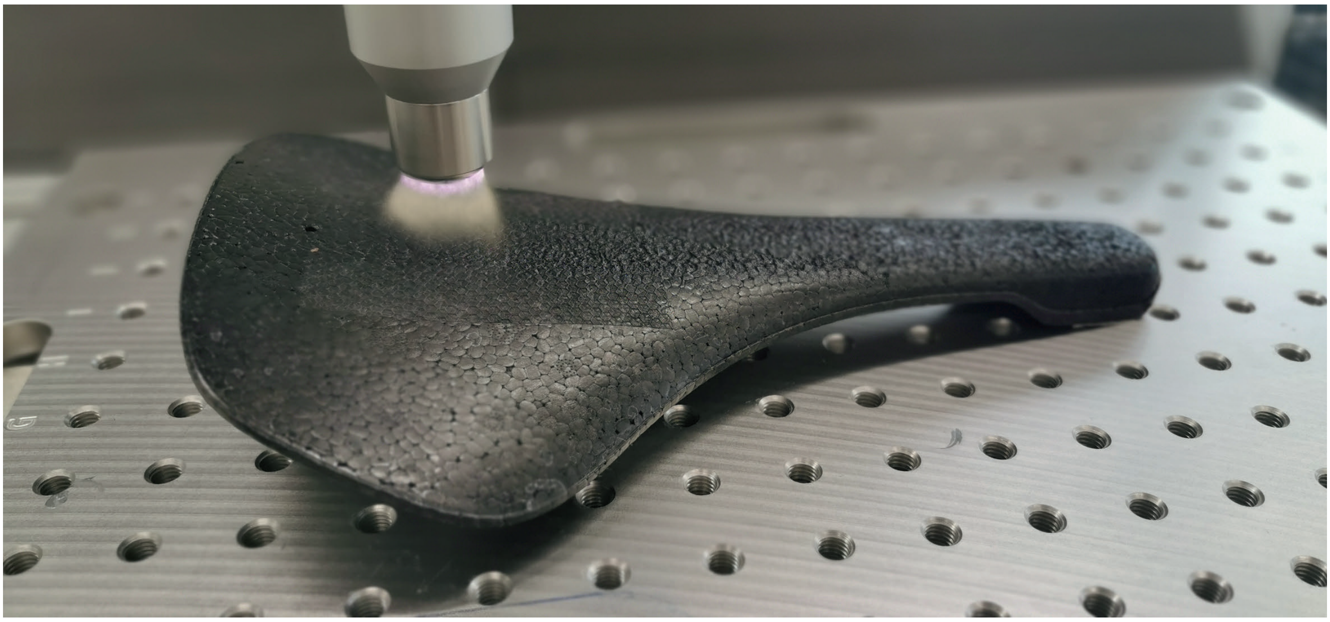
Foam Beads in Gliding Flight

A Glossy Surface Quality for Particle Foam Components

The particle foam crowd cannot complain about a lack of interest by potential users. At least as far as demand for products with high-quality functional and optical surfaces is concerned. However, development has stagnated since the joint research project SamPa sponsored by the German Federal Ministry of Education and Research reached its conclusion. There is an urgent need for action.



Before flow coating with PU, the EPP surface must be activated (© Plasmatreat)

One year after the status report "Schaumperlen im Aufwind" (***Kunststoffe*** 2/2019, pp. 21–28, only available in German), it is time to take stock. Even after the SamPa joint research project (Integral Production of Hybrid Lightweight Sandwich Structures by Multicomponent Particle Foam Injection Molding for Large Series, Forel Platform) came to an end, the work is continuing – with new partners – though behind the scenes and in "gliding flight." A key role in this is played by the ThiM network, founded in summer of last year (**see Box p.46**). It attempts to answer the market's questions through its own initiatives in order to pave the way for further developments.

The background is that the first results produced in the SamPa project do not yet meet the generally high standards set by potential users. These include, e.g., topics such as surface quality, process reliability, accuracy specifications, simulation and visualization, fire safety or the complex topic of quality assurance. However, the first interim results are now appearing.

Electromagnetic Waves instead of Steam

A major step in this direction has been taken by Kurtz GmbH, Kreuzwertheim, Germany, which celebrated a world premiere at K2019 with the presentation of the Wave Foamer (**Fig.1**). The new automated molding machines do not operate with steam like conventional machines, but with electromagnetic waves. Here, a dielectric alternating field (radio frequency with 27.12 MHz and high voltage up to 10,000 V) causes polar molecular chains to oscillate, and the friction this creates generates heat. For processing non-polar material, polar additives are used.

The process is suitable for new materials with process temperatures up to 250 °C, corresponding to a steam pressure of up to 40 bar. In contrast to the steam process, welding takes place from the inside outward. RF technology is now in the market introduction phase; the first laboratory machines are already available.

Skin Forming for Better Surface Quality

The surface quality of particle foam components often causes headaches for designers and technicians alike. The problems do not only include the visible particle structure with steam nozzle imprints, interstices as well as color differences in isolated cases. In addition, there is the sensitivity of the particle surfaces to abrasion and damage, as well as the fact that liquid could penetrate into the »

The ThiM Network

Five industrial partners,

- KraussMaffei Technologies GmbH,
- Kurtz GmbH,
- Kaneka Belgium NV,
- T. Michel Formen GmbH & Co. KG and
- Werkzeugbau Siegfried Hofmann GmbH,

along with two German research institutes – Neue Materialien Bayreuth GmbH as well as the Institute of Lightweight Design and Plastics Technology at the Technical University of Dresden (ILK) – initiated the open platform "ThiM" (Technology Platform for Hybrid Innovative Material Foam Systems) in mid-2019. Its goal is to develop new plastics processing technologies and foam systems, and combine them with one another, build innovative tools and systems, make processes more economical and generate new applications. It focuses on particle foams, whose range of applications is very varied due to their outstanding properties. The network brings together expertise on the questions and requirements of the market, and provides targeted answers.

➘ **www.thim-network-factory.com**

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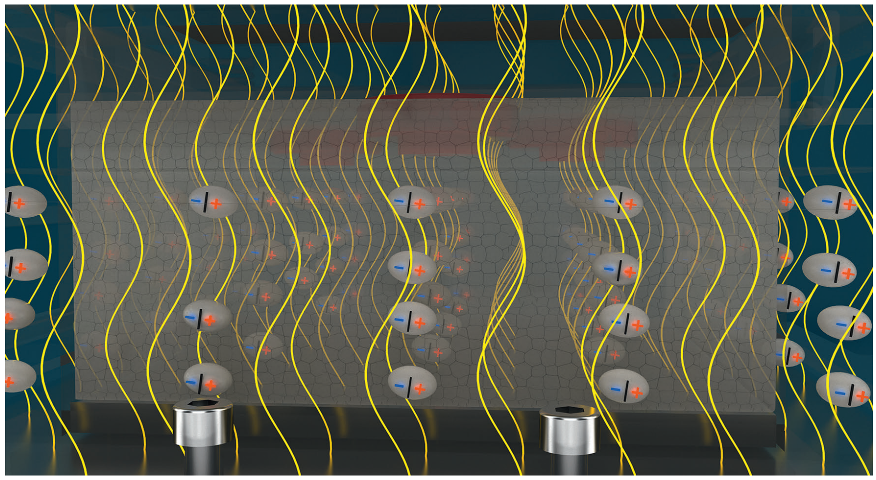

Fig. 1. In the Wave Foamer, electromagnetic waves cause the polymer chains to oscillate, so that the foam beads are heated from the inside outward (© Kurtz)

part. A key market requirement, however, is an unbroken, scratchproof surface, which additionally gives a high-quality optical impression and, ideally, is not significantly different from an injection molded part (**Fig. 2**).

To enhance the surfaces of particle foam parts, various processes are available. A technically challenging option is the backfoaming of textile and decorative films. Covering with films and printing or painting are also possibilities for laminating foam parts. And, ultimately, the surfaces can be decorated with laser structures in the mold, though the resulting surface is not closed.

As part of the current development work, the ThiM network investigated skin formation and the flow coating of particle surfaces with polyurethane.

Skin formation is the liquefying or melting of blown particle foam beads on the inside of the cavity to generate a part with an unbroken, smooth and homogeneous surface in one step. However, the uniform melting and welding of the beads with steam is critical because of the high wear to the molds due to the high temperatures and high steam pressure. A solution that is still employed today is to use resistance heaters to transfer the energy from the outside inward, closer to the cavity.

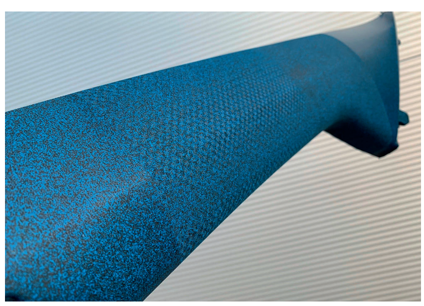

Fig. 2. A-pillar of particle foam with textured surface (© T. Michel)

Advantages of Variotherm Mold Temperature Control

A forward-looking alternative is skin formation in conjunction with variotherm conformal temperature control of the mold (**Fig. 3**), as presented by T. Michel Formenbau GmbH & Co. KG, Lautert, Germany, and gwk Gesellschaft Wärme Kältetechnik mbH, Meinerzhagen, Germany. The principle of variotherm mold temperature control as conformal temperature control, close to the cavity, is well known in injection molding.

For skin formation, after mold closing, EPP foam beads are blown onto a previously thermally overheated cavity surface into the mold by means of a special filling process. When the material meets the hot metal surface, the cell structure of the beads disintegrates, they melt. Due to the constant holding pressure and continued filling, a pressure builds up in the mold, with the material being pushed forward toward the overheated surface. A skin of molten EPP forms, which may be 1 to 1.2 mm thick at most. After the skin formation, a standard particle foaming process takes place, with the steam in this case flowing behind the skin through the foam beads in order to weld them. Ultimately, an integral, single-material bond is formed in this way.

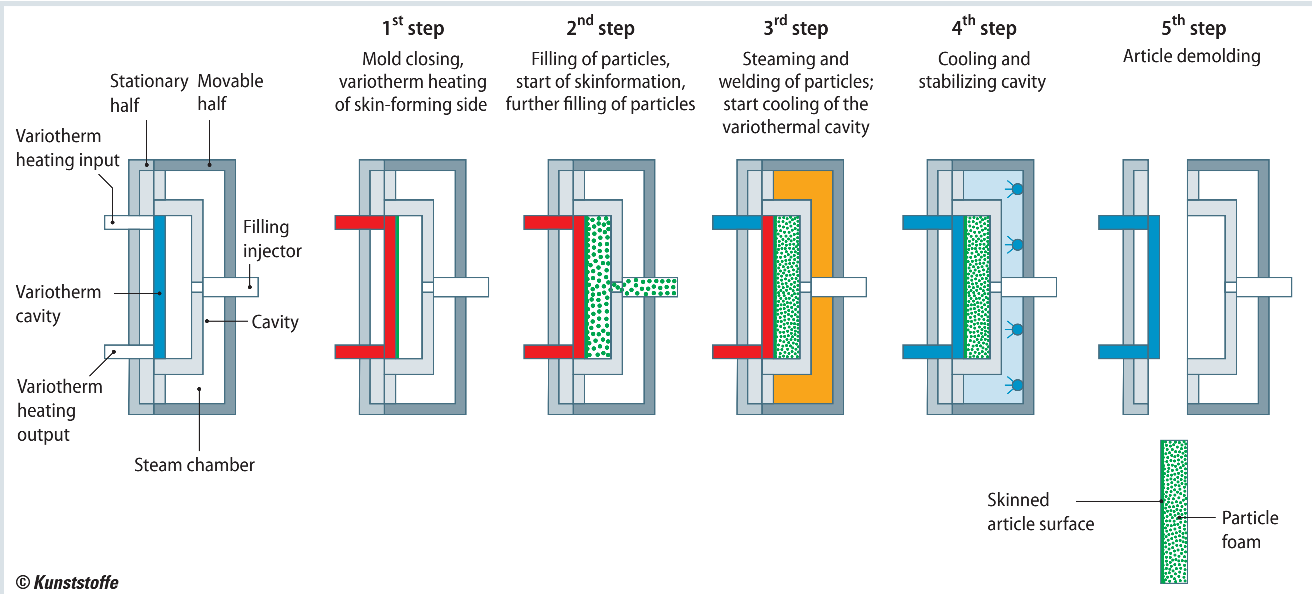

Fig. 3. Schematic representation of the skin formation in five steps (source: T. Michel)

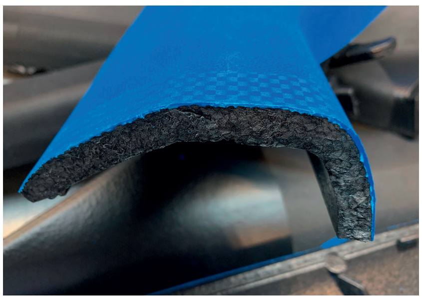

Fig. 4. Section through an A-pillar produced by the IMPFC process (© T. Michel)

An enhanced version of this principle, developed by T. Michel, is the patented IMPFC process (in-mold particle foam coating). In this process, a feed system first introduces a plastic layer into the mold, forming a homogeneous surface layer. Immediately after this, the particle foaming process starts. In one operation, an integral monomaterial bond is formed (e.g. PP/EPP or PS/EPS) with an unfoamed, dense outer layer, which can be produced with different textures. With a free choice of colors, this layer can also be manufactured with various material modifications (**Fig. 4**).

Using Plasma to Render EPP Surfaces "Compliant"

The SkinForm and ColorForm special injection processes developed by KraussMaffei Technologies GmbH, Munich, Germany, for manufacturing parts with very high quality surfaces, have been the established state of the art for years. While the SkinForm process was developed for soft-touch surfaces, the ColorForm process is especially suitable for scratchproof, high-gloss and colored surfaces. In both processes, a thermoplastic body is flow-coated with polyurethane (PU) in the mold. It is therefore logical to transfer the principle to particle foam parts. The background to this is the OEM's specifications for corresponding surfaces.

To exploit this option, the ThiM network recruited two external partners, Plasmatreat GmbH, Steinhagen, Germany, and Rühl Puromer GmbH, Friedrichsdorf, Germany. As a technology demonstrator, a bicycle saddle of EPP was chosen. The material was provided by Kaneka Belgium NV, Westerlo-Oevel, Belgium.

Since EPP is a non-polar plastic, treatment is necessary before flow-coating with PU, in order to activate the material surface and increase its wettability. The reason is the inadequate surface energy with low polarity. The prerequisite for reliable bonding, however, is that the surface energy of the solid material is greater than the surface tension of the liquid to be applied – PU in this case.

To activate the EPP surface, so-called open-air plasma was used, which is generated under normal ambient conditions (**Title figure**). On plastics, it performs fine cleaning, static discharge and activation of the material surface in one step. The plasma parameters can be modified to adjust the wettability for different media (**Fig. 5**).

For the subsequent feasibility studies, sample parts were flow-coated with dif-

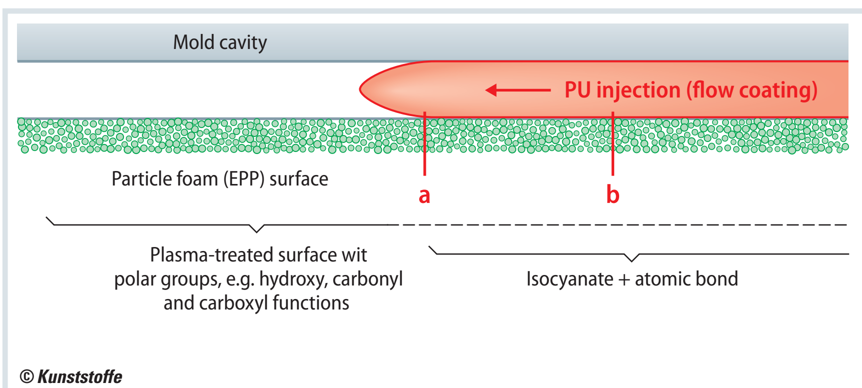

Fig. 5. To activate the EPP surface, the chemical and physical interaction between the plasma and plastic causes, a) reaction of an isocyanate functional group with the PU layer, and b) a fixed atomic bond between the PU layer and EPP (source: Plasmatreat)

ferent PU formulations that were prepared with an internal release agent. Lacquers (type: Puroclear in piano black and red-pigmented clear coat) as well as a semi-rigid foam (type: Puroskin) from Rühl were processed. The aim was to demonstrate that particle foams with optically attractive surfaces, including a 3D depth effect, can also be enhanced. With the example of a flow-coated printed circuit, the functionalization of particle-foam components was also investigated (**Figs. 6 and 7**).

Fig. 6. After pretreatment with plasma, EPP can be flow-coated with a semi-rigid foam, with which this pattern is flow-coated with a further PU system (© ThiM-Netzwerk)

Fig. 7. EPP saddle as a technology demonstrator: functionalized with a printed circuit and flow-coated with clear coat to investigate the depth effect (left); flow coated with "piano black" PU (right) in different layer thicknesses (0.5 mm, 1.5 mm and 2.5 mm), in order to illustrate the color intensity (© ThiM-Netzwerk)

Process Monitoring Requires Complex Sensor Technology

Beyond the specifications for the particle foam material, the OEM also requires process reliability and process transparency comparable to injection molding. This affects the topics of quality assurance and quality management, as well as process data acquisition and ultimately also a linking of mold and machine.

As part of investigations with skin formation, various sensors were installed in the mold. During filling of the cavity, the cavity pressure is monitored. Filling stops as soon as a predetermined interior pressure is reached. The layer thickness of the skin and its surface quality depend on the bulk density of the foam beads, the duration of filling, the cavity pressure, temperature and, not least, the heating time.

Throughout the process, the cavity pressure and the temperatures of the particle foam are measured and recorded: the temperature of the stationary mold half, by means of temperature sensors from gwk, all other data with Mic Probe sensors, developed in-house by T. Michel. In addition, a foam pressure sensor is used to measure the foam pressure. The steam pressure and temperature are also measured and recorded.

As a next step, the ThiM network plans to set up a pilot plant to investigate the process monitoring in a near-series process and provide evidence of its quality. This includes further improving the simulation and visualization of the manufacturing process. For this, members of the network together with their external partners are currently developing suitable molds and software models.

Outlook

Current examples of parts with skinned surfaces are shipping boxes, which frequently have an internal skin, such as medical or food transport containers. The air distribution and chin sections of bike helmets also have a skin. In automotive engineering, various applications are conceivable, such as door linings or A-, B- and C-pillar trims in the interior, but also spoilers and rocker panels; bumpers also come into consideration. In short, everything that requires a functionalized, optically attractive surface, is required to be lightweight, and can be produced in one operation.

Different densities within one component can also be produced in a targeted way, since mono-material systems like this, with graded properties (e.g. density), open up completely new perspectives in terms of their spectrum of uses. They are of interest in conjunction with their recyclability. At the material side, the focus is on developing flameproofed formulations, which are a prerequisite for use in aircraft or rail vehicles. ■