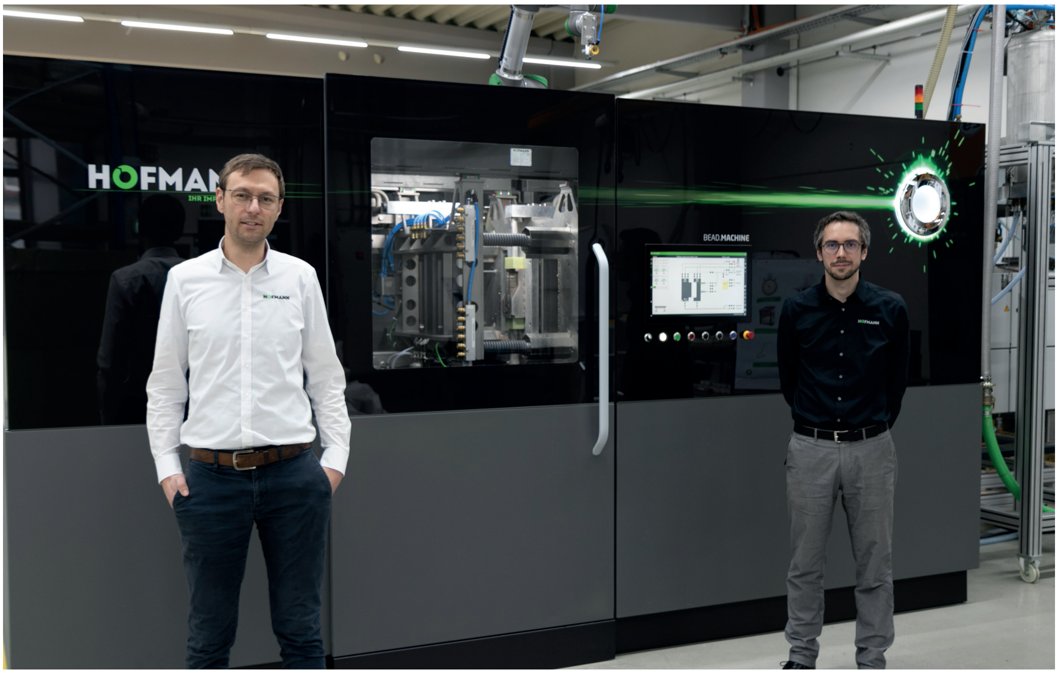


Managing Director Stefan Hofmann (left) and Project Manager Johannes Schütz in front of the prototype of the new "Bead.Machine", the development of which started a good two years ago © Hofmann

The Impulse Machine

On the Launch of a Molding Machine for Particle Foams

Closing the circle: a tool manufacturer with a long track record in injection molding is taking particle foam processing to the next level. A new machine and highly efficient molds are intended to streamline the technology and make it interesting even for injection molders.

In plastics processing, there is nothing new about a development chain in which the mold is to be designed specifically for a defined product, with all its demands, and combined with a machine with the correct performance parameters. But first having to develop and build a new machine for a highly efficient mold, in order to exploit the mold's full potential is probably somewhat rarer. This is the story of the innovative "Bead.Machine", with which Werkzeugbau Siegfried Hofmann GmbH wants to open a new chapter – in particle foam processing, as can be inferred from the term "bead."

Due to the pandemic, we were only able to pay a virtual visit to the premises of the "Impulsgeber" ("driving force") – this is the slogan that, with mock modesty, the company, based in Lichtenfels, Upper Franconia, Germany, has taken its decades-long innovative strength out into the world. Here, we were given a presentation of the machine prototype by the masterminds responsible for its development. "Version 2.0" is to be presented in fall of this year. For the time being, a second prototype is running at the project partner WSVK.

The Origins in the Injection Mold

The story actually begins almost 20 years ago, when Hofmann first became involved in additively manufacturing inserts for injection molds with a powder bed-based laser-melting process. Perhaps due to its geographical proximity to the recently launched Concept Laser GmbH, and its family-like ties to its founders, a profitable business in conformal cooling for geometrically complex parts soon developed, e.g. to eliminate hotspots. "The cooling channel design of the 3D-printed steel inserts could not be implemented conventionally with bores," explains Stefan Hofmann, Managing Director of the third generation.

The so-called LaserCusing method of Concept Laser, a variant of selective laser melting (SLM), subsequently formed the basis of the development of 3D-printed particle foam tools. Particle foaming is an energy-intensive process in which the part is made by welding together foam beads in the mold with steam. Jonas Beck, responsible for the business field development at Hofmann, describes the beginnings: "Because 90 to 95% of the input energy in particle foam processing is lost in the ancillary equipment or mold, and only 5 to 10% arrives in the part, our basic idea was to save material directly at the cavity wall, to bring the heat to the part as fast as possible, and thereby also to reduce the cycle time and energy consumption."

Two identical molded parts can be plugged together to form a box © Hofmann

Up to 8000 Mini-Nozzles in a Cavity

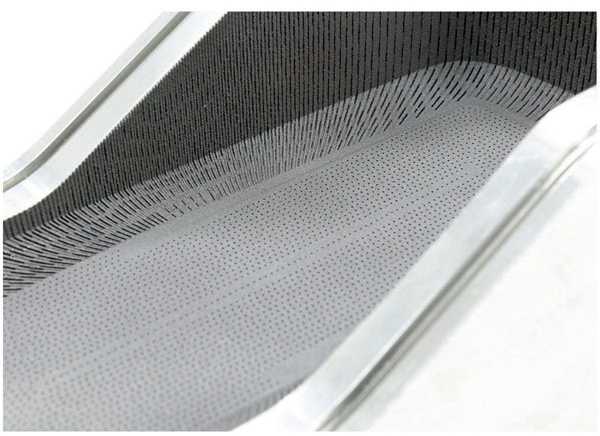
The cavities of conventional aluminum molds, such as are used in particle foaming, with steam nozzles driven into corresponding bores, and connected to a large steam chamber, have a wall thickness of 10 to 20 mm. The additively manufactured steel mold inserts have wall thicknesses of only 1.5 mm. They include a lattice structure, which fulfills multiple functions, as is explained by Johannes Schütz, who has been responsible for the development of the bead machine since the end of 2018: "First, they must support the very thin cavity wall against the process forces and, second, they must be permeable and may only pose a low flow resistance to steam, water and air isotropically, i.e. in every direction."

In addition, the grid structure acting like a heat exchanger is key to a uniform steam release into the cavity and temperature control of the cavity surface. "This is because we can position the nozzles completely freely in the mold wall and geometrically shape them. Thus, as with 3D printing of these structures, we can not only greatly reduce the flow losses, but also use the mold surface as a design element," says Schütz. The up to 8000 mini-nozzles in the cavity of a two-part box about the size of a smartphone can be easily hidden by texturing the surface. To obtain a similar effect to that of conventional aluminum molds, this must be done by graining or laser ablation – both very expensive processes.

A Small Efficiency Miracle for Oversized Machines

From the very beginning, not only a research institute, but also the particle foam processor WSVK was involved in the development. The latter is known, e.g., as a manufacturer of the Blackroll massage roller, and is now testing the new machine. The first milestone, a lightweight mold in which only a small mass needs to be heated, was quickly reached and was tested in practice with various molded parts. In the next development step, it was possible to integrate the large external steam chambers, which are heated in each cycle and have to be cooled again (by spraying with water) into the printed lattice structure in a compact design. Hofmann first presented this trick at Impulstage 2018 event using a mold for a knob handle. At the company's own conference with in-house exhibition, a question also arose, and, with the question, a problem.

The question was "Why don't we only sell such functionally and power-flow optimized molds?" says Stefan Hofmann, in retrospect. "At least since they are still unsurpassed for efficiency of particle foam processing. That is evident in the steam »



Several thousand slit and punctiform nozzles are printed into the cavity surface (left). Behind the mold wall there is the lattice structure (right), which also forms the space for the steam chamber and cooling water feed © Hofmann

One mold half, weighing only a good 2 kg with molded part. At the front, between two small fastening threads, the inlet for the process media (steam, water, air) can be found, the outlet is at the opposite side © Hofmann

consumption just as much as the cycle time." But, initially, the beautiful plan bumped up against hard reality. The little economy miracle – more about that below – wasn't at all compatible with conventional large machines. An impression of this was gained by those visitors to the K2019 trade show who saw what contortions are necessary to adapt one of the new types of mold to such machines.

Exploiting All the Digitalization Means

Even to laypersons, it was obvious that classical systems are set up for entirely different mold types – "as regards media supply, valve control and the size of the platens and the steam chamber," says Hofmann. The 39-year-old jokes: "Our molds probably weigh less than the valves that control the steam feed." The trade show exhibit with its overdimensioned media lines required maximum throttling to operate at all, since the mold only needed a fraction of the conventional amounts of water and steam. It therefore immediately became clear to the developers at Hofmann that "we can only manage this challenge if we build a molding machine that is compatible with our molds."

Here, Hofmann benefited from the fact that, years ago, the company had already extended its field of activities to special mechanical engineering and automation. What began with contract manufacturing for customers according to their design data ("build to print") and soon led to its own approaches to solutions in mechanical engineering, ultimately "laid the foundation" for the development of this machine," according to Stefan Hofmann. Its partner WSVK defined the requirements on the Bead.Machine in intensive detail work. This touched on points such as plane parallelism, closing accuracy and mold protection, as well as reliable reproducibility – other weaknesses in the current plant technology, besides the sheer size. The low sensitivity of conventional molding machines was the reason why some of the molds delivered by Hofmann were damaged in production.

For example on the precisely executed vertical flash faces. This precision is a prerequisite for producing even challenging parts off-tool in corresponding (flash-free) quality. "And this is our aspiration, of course," adds Hofmann. The developers focused especially on the machine control. According to project manager Schütz: "This gives the customer the option of parallelizing all partial steps that can be parallelized." In order to save cycle time, e.g., back purging is performed while steaming is already underway. "We programmed the control 100% in house, writing about 15,000 lines of program code. We are thus engaging in the control technology in-depth," continues Schütz. For example, the control behavior of the valves can be adapted to the specific mold, in order to respond to the differences in dynamics between larger and small molds.

Hofmann also works in development using the means of the digital twin and virtual commissioning, so that the project risk remains calculable. And the development will continue as far as fully automated production: "Unmanned particle foam processing is not possible yet as far as we understand. We want to make our machine smarter step by step, so that sooner or later it will be self-correcting," is how Stefan Hofmann describes his vision. The machine is designed for a steam pressure up to 5 bar, and is thus suitable for different materials subject to high technical demands.

Advance into Injection Molding Dimensions

There are no limits to the imagination as far as applications are concerned – as example, Johannes Schütz mentions structural parts and panels for automotive engineering, housing parts for household equipment or toys and sports equipment – provided that the corresponding material is available. "Even parts for which we currently face the problem that particle foam has not yet achieved the optical and tactile properties and accuracy that we are used to from injection molding," adds

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Jonas Beck, and continues: "That is possible with our combination of mold and machine."

A current demonstrator is an etui-like container made of two identical 185 mm-long and 80 mm-wide moldings that can be assembled laterally reversed. The entire mold with the adapter pieces for steam supply weighs less than 6 kg; for comparison: the corresponding mold in a classical design weighs in at 20-times that. The process parameters and consumer values speak a clear language: while the 3D-printed mold with 155 °C hot steam can be heated to temperature within 2 to 2.5 s, it takes over 10 s for the conventionally manufactured aluminum mold, with its 10 mm-thick cavity wall. Together with the more effective steaming from the several thousand mini-nozzles as well as the faster cooling by drenching the lattice structure with cold water, this results in an advantage of 45 % in cycle time, according to WSVK.


In 3D printing, the steam nozzles are partly executed as design elements and partly concealed in the texture. At the side of the etui-like sample part, they are identifiable as linear structures, on the flat surface, as fine dots © Hanser/C. Doriat

A Simple Infrastructure Lowers the Barrier to Entry

After over 30,000 cycles, the particle foam processor has also drawn up an initial energy balance: for one part (16 g), the new molding machine consumes less than 1 kg steam for welding the foam beads and about 2 l of water for cooling. All these effects add up to a total energy saving of at least 75 % compared to a standard system. In addition, all the indicators speak in favor of high reproducibility of the part quality, which is also confirmed by the data that have been gathered to date.

The part already makes high requirements on the surface quality and dimensional stability such as are rather atypical for particle foam processing. Johannes Schütz comments: "Where we are used to tolerances of the order of a hundredth of a millimeter in injection molding, for particle-foam parts we don't even speak of tenths of millimeters but, of millimeters." And here we come to the point: "By manufacturing with such accurate reproducibility, we also want to inspire injection molders about this technology," says Stefan Hofmann. "It is our clear goal to use our system to open up new markets – both in terms of applications and of users." While particle foam still has great potential for new fields of application solely because of its properties – the material is lightweight, insulating, has good tactile properties (it feels warm) – the circle of users has nevertheless remained limited.

And there is a reason for that: "It is this slew of ancillary equipment, which cannot be easily integrated into an existing manufacturing plant, for either lack of space or of know-how," says Hofmann. You only have to think of the large steam generators that are necessary to operate traditional plants. The boiler house for this is often mounted outside the production area, with correspondingly long and large-sized pipes. "Because of the low media consumption, we manage with a very small complement of ancillary equipment," says the managing director. And in truth, there is only a small electric steam generator in the pilot plant, directly next to the machine, similar to a larger temperature-control unit standing next to the injection-molding machine. According to Hofmann, "A simple water connection and a plug socket are all that are needed – that is plug and produce.'"

Thanks to the simpler infrastructure alone, production should be less trouble-prone. In addition there is the twofold major advantage: "Compared to a system by another manufacturer with the same mold-mounting area, our molding machine has only half the footprint. And the 3D-printed molds are so small that they do not take up much storage space," explains project leader Schütz. The entry barrier compared to classical particle foam processing is thus significantly smaller. The evidence will be provided from next fall. ■

Dr. Clemens Doriat, Editor

The user interface of the control unit programmed by Hofmann itself is very easy and intuitive to use, according to the project partner WSVK © Hofmann