The Liquidmetal process permits extremely fine structures to be produced efficiently by means of injection molding (figure: Liquidmetal Technologies)

Hard and Elastic – Simultaneously

Efficient Injection Molding of Metal Alloys in Top Quality

Powder injection molding has been used for processing metals for many years, but in terms of efficiency and product quality, the process is not on par with plastic injection molding. Only since the development of new alloys, has metal injection molding reached the high levels of reproducibility and freedom of design accustomed from plastics processing, together with the possibility of simple integration of component functions and processing steps. Consequently, the prerequisites for efficient series production have been fulfilled.

The brand name "Liquidmetal" stands for a group of alloys that can be injection molded in a similar way as thermoplastic materials, as well as permitting completely new component properties. Zirconium alloys – so-called metallic glasses – have an amorphous, i.e. non-crystalline structure, which makes them extremely hard and simultaneously highly elastic.

While steel exhibits an elasticity of 0.2 %, and titanium 1 %, the value for components made of Liquidmetal alloys is around 2 % – a value that is combined with an excellent recovery behavior. What's more, the materials feature a low specific weight plus high corrosion resistance. Thanks to these properties, the alloys are predestined for use in precision components subjected to severe mechanical loads (**Title figure**).

The materials were developed by Liquidmetal Technologies Inc. in Rancho Santa Margarita, California/USA, who also issues the licenses for the new process. As Liquidmetal's exclusive machine engineering partner, Engel Austria GmbH in Schwertberg, Austria, is the only supplier worldwide offering system solutions »

Fig. 1. The new injection molding machine is based on a fully electric Engel "e-motion" (figure: Engel)

Fig. 2. "Green" Liquidmetal parts are singulated automatically, and then fed to the melting chamber (figure: Engel)

to the licensees for injection molding Liquidmetal materials. Liquidmetal Technologies establishes the contacts with mold-making partners, and provides support during the design and construction phases. The alloys are marketed by Materion Corporation, in Mayfield Heights, Ohio/USA.

Fast Cooling under Oxygen Exclusion

Based on their fully electric "e-motion" machine range, Engel has developed a new injection molding machine for processing the Liquidmetal material (**Fig. 1**), whereby the main differences to a conventional machine for plastics processing are found on the injection side. Delivered in the form of round bars cut to length, the raw material is automatically fed to a melting chamber (**Fig. 2**), where it is induction-melted under high vacuum.

Instead of a screw, the machine is fitted with a piston, with which the molten metal alloy is injected into a tempered mold. The melting temperature of Liquidmetal alloy LM105 is 785 °C, i. e. it is consid-

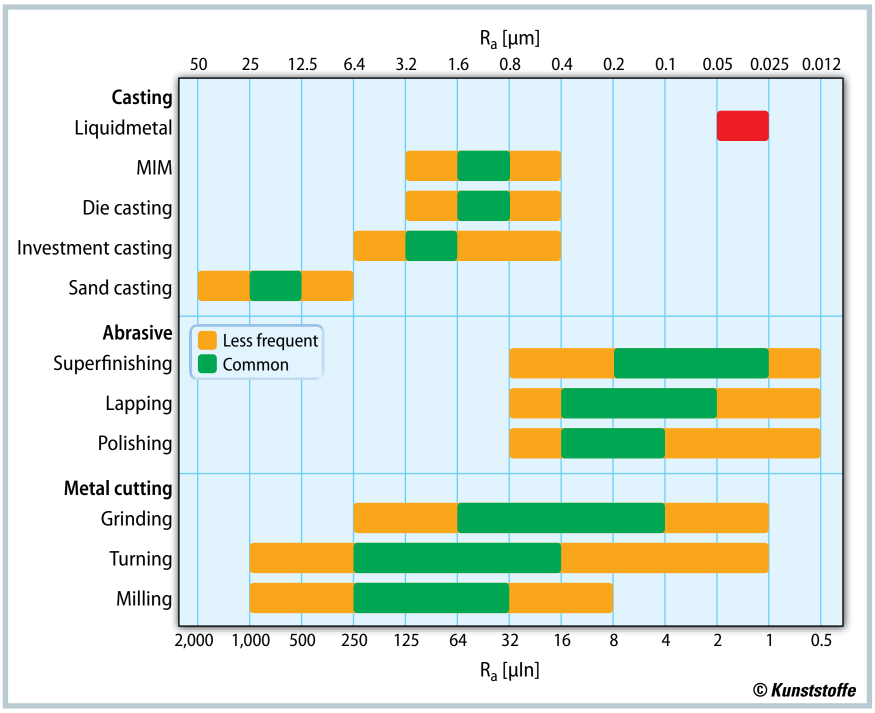

Fig. 3. The Liquidmetal process creates components with high surface quality that require no rework, and its high efficiency sets it apart from alternative methods (source: Liquidmetal Technologies)

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- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de* erably lower than that of most other metals. For example, the melting temperature of titanium is 1,668 °C.

Due to the fast cooling under oxygen exclusion in the evacuated mold, an amorphous structure is formed, which is responsible for the outstanding properties. Standard robots – e.g. from Engel's viper series – are used to remove the components. The sprue can be removed with a water jet cutter, mechanical shears, or some other means. In this way, components with wall thicknesses between 0.6 and 4 mm, edge lengths up to 100 mm, and shot weights up to 100 g can be manufactured.

Finished Components in a Single Step – from Medical Technology to Aerospace

In just one working step, the Liquidmetal method produces ready-to-use components, thereby offering significant advantages compared with two alternative processes. With CNC processing, the metal components are machined from a metal block by means of milling, drilling, grinding, and turning. This method permits demanding three-dimensional precision parts with high-quality surfaces to be manufactured. However, compared with injection molding, CNC machining is very time and cost intensive.

Although the MIM process (metal injection molding) is an injection molding procedure, it does not use metal alloys, but a metal powder mixed with a binding agent. After the molding stage, the binding agent must be removed thermally, and the resulting 'green part' must then be sintered to obtain a finished product. Moreover, the surface is roughened during sintering, so that subsequent surface treatment is frequently required. Depending on wall thickness, these additional processing steps can involve a great amount of time.

The use of Liquidmetal materials avoids these disadvantages. It permits the efficient and economic manufacture of precision parts with high surface qualities. For example, the R_a values are less than 0.05 µm (**Fig. 3**), and cycle times lie between 2 and 3 minutes, which is considerably shorter than those of CNC machining centers. Another advantage of processing metal alloys is the absence of waste, because the sprues are recyclable.

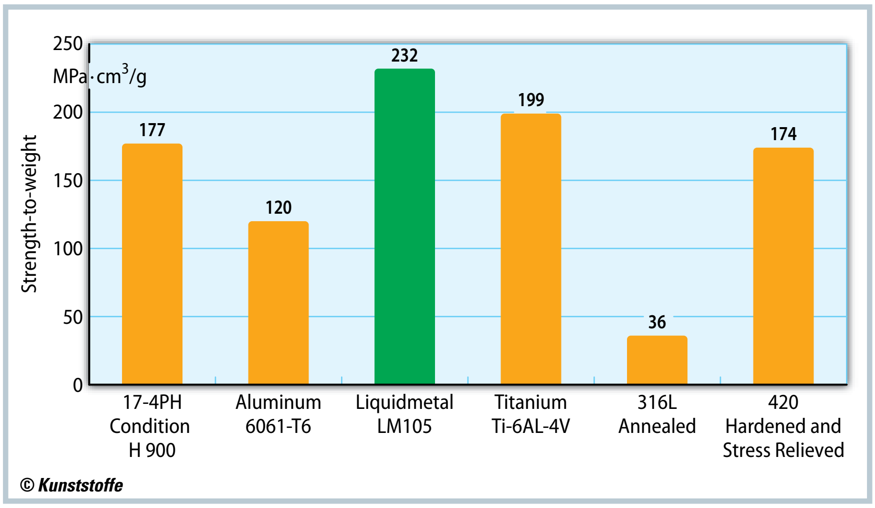


Fig. 4. Strength/weight ratio: The metal alloys permit the production of extremely robust components with a comparatively low weight (steel type descriptions acc. to US standards) (source: Liquidmetal Technologies)

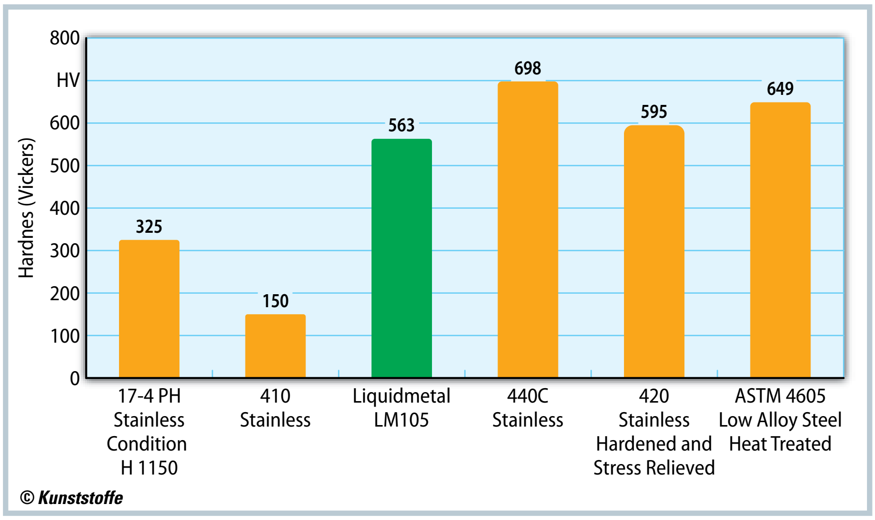


Fig. 5. Contrary to Liquidmetal, steels require extensive post-production thermal treatment to obtain a high Vickers hardness (steel type descriptions acc. to US standards) (source: Liquidmetal Technologies)

During a symposium in June 2015 in St. Valentin, Austria, Engel introduced the new technology with the production of medical clamps – the producers see great application potentials in medical technology. For example, endoprotheses such as artificial hip joints or stents are conceivable, as the material's outstanding mechanical properties enable very high strengths to be achieved, also with small wall thicknesses. The alloys have already passed the compulsory bio-compatibility tests in all fields.

Further innovative applications are expected e.g. in the sports equipment, aerospace, and electronics industries. In the field of consumer electronics, Apple is the exclusive licensee. For the watch-making industry, an exclusive contract exists with the Swatch Group.

Extremely Robust and Resilient

All the applications implemented so far involve precision components subjected to severe mechanical loads, whereby the Liquidmetal process makes a decisive contribution towards combining durability and performance with high demands on design and economic production. Thanks to the very favorable strength/weight ratio, lightweight and simultaneously robust components can be manufactured (**Fig. 4**).

With a density of 6.57 g/cm³, LM105 lies at least 13 % below the density of »

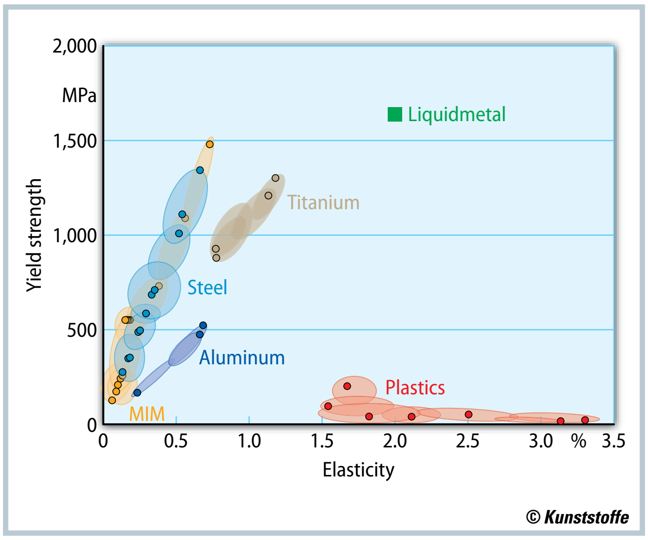


Fig. 6. Simultaneously hard and elastic. With this combination of properties, Liquidmetal closes a gap in the materials spectrum (source: Liquidmetal Technologies)

common materials such as hardened stainless steel 420 (7.74 g/cm³). In terms of Vickers hardness (**Fig. 5**) there are steels that are comparable with LM105, but contrary to LM105 they require several post-production steps, which make the manufacturing process more complex and expensive. In addition, every form of heat treatment affects the atomic structure, and can change the component's properties.

LM105 has an elasticity of 1.8 %, which is probably the most impressing property in view of the high hardness and low density (**Fig. 6**). During the material's development, clamping springs were manufactured and tested in comparison with steel springs. While steel springs exhibited signs of fatigue after 100 cycles, the Liquidmetal springs achieved 1,240 cycles before showing fatigue signs.

In order to confirm the corrosion resistance of the new injection molding material, parts made of Liquidmetal were subjected to a salt spray test acc. to ASTM B117, and also to a 30-day immersion test. The subsequent surface examination with an electron microscope and 5,000-fold magnification revealed no changes.

Summary

With Liquidmetal technology, Engel has opened up a new application area, and has expanded the operational field of injection molding technology. The positive properties of the metal alloys permit product designers to investigate new component functionalities and product qualities. ■

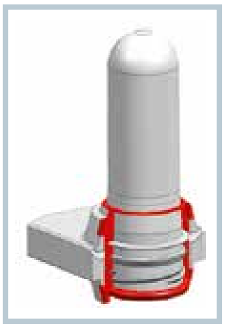
Self-Cleaning Mold for PET Preform Production

Seconds instead of Hours

Clean molds at the push of a button: A procedure that frequently takes several hours is now claimed to be possible within seconds, thereby considerably extending the inevitable maintenance intervals. At least that is how **Husky Injection Molding Systems** in Bolton, Ontario/Canada introduced a self-cleaning technology for injection molds at the NPE 2015. The new cleaning function is part of a package solution for the HyPET HPP5 preform production system, enabling it to operate for half a million cycles without downtimes for cleaning and greasing.

The announcement is all the more astounding, as one would expect higher mold maintenance costs and a shorter service life in view of the increasingly shorter cycle times. This apparent contradiction is overcome by the HyPET HPP5 system: According to the manufacturer, mold self-cleaning can eliminate up to 400 hours of maintenance work per year, which translates into a 5 % increase of production time. The fully automated self-cleaning cycle is started at the push of a button, whereby the dust accumulated at the vents is collected and removed without the operator having to work in or on the machine. Cleaning can be performed as often as necessary, as production continues practically without downtime.

Moreover, the equipment shown at the NPE was fitted with Husky's mold alignment system. Six sensors compare the positions of the two mold platens, i. e. it is a realtime 3-D alignment measurement, with the results individually displayed on the HMI for every cycle. If misalignment occurs, the HMI provides specific instructions to resolve it. This enables the operator to re-align the mold with a resolution of a few microns, before the offset can cause excessive wear and impact product quality.



New self-cleaning technology makes it possible to clean molds (affected zones shown in color) in seconds instead of hours at the touch of a button (figure: Husky)

The machine demonstrated at the NPE produced lightweight preforms (part weight: 10.89 g) for carbonated water using a 96-cavity mold with a 5.5-second cycle time. With this application, HyPET HPP5 is some 50 % faster than the industry average, says Husky.

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To the manufacturer's product presentation:
www.kunststoffe-international.com/1059159