The liquid polymer is injected into the mold under high pressure. The heat generated by the process has to be evacuated in a matter of seconds, so that the injection molding machine can be used to cast the next component. The ever-shortening cycle times of today’s processing machines present a difficult challenge for mold manufacturers: Tool inserts have to be more resistant, and need to have exceptional qualities compared to standard designs. The ideal material would be as hard as steel and as heat-conductive as the relatively soft copper – properties that no conventional tooling material can reunite without some serious modification.

Tools are subject to wear. Tool manufacturers are therefore constantly looking out for new, long-lasting, hard-wearing combinations of materials. Laser-assisted processes provide a rapid means of manufacturing tool inserts with tailor-made attributes.

During laser cladding, the laser beam melts powder filler materials to a precisely specified form. A gradient material develops if the composition of the filler material is altered while building up the layers. The resulting tool has a core of an entirely different material from that of the outer layers. ILT scientists have developed a tool insert consisting of an inner core of special steel protected by an outer coating made of a wear- and corrosion-resistant steel alloy. This has the advantage that the material core inside is tough and can absorb high loads, which in turn prolongs the service life of the mold component. A further advantage is the gradual transition from one type of material to the other: “By selectively dosing the filler materials we can obtain a smooth cross-over in the component,” explains Weisheit. This is particularly important in cases where the temperature fluctuates widely at the production machine’s processing zone. A tool consisting of different materials superimposed in a sandwich-like structure is more likely to suffer from the effects of fatigue. “The heat causes the layers to expand to different degrees, creating pressure between them,” Weisheit points out. By contrast,
graded layers with a ‘soft’ transition between them are able to compensate for such opposing movements. This explains why tools with a heterogeneous structure based on continuously graded layers of material are more resistant: There are fewer internal stresses, and thus a reduced risk of fracture or cracking.

Another variant among the laser-assisted rapid manufacturing techniques is selective laser melting – SLM for short. This involves melting powder particles with the heat of the laser beam. The components, whose shape is predetermined in a computer model, can then be built up layer by layer from the liquid melt. Service providers are already using this technique today to build very delicate parts with numerous near-net-shape cooling channels and complex hollow structures. The researchers are taking a new approach: By selective laser melting, they create a thin shell of wear-resistant tool steel, while the hollow space inside is filled with a heat-conductive copper or aluminum alloy by casting. This has the advantage that the protected mold insert remains uniformly cool during processing and requires only a small number of cooling ducts.

This new production technique is currently undergoing trials and is being tested for its practical suitability together with the Foundry Institute at RWTH Aachen University. There are many aspects in favor of its industrial use. The time needed for manufacturing the tool is greatly reduced thanks to the excellent thermal conductivity of its core. “Depending on the type of application,” says SLM expert Wilhelm Meiners of the ILT, “we could probably even do without cooling ducts altogether.”

High-end tools for high-end products

Meanwhile, the Fraunhofer researchers are continuing to develop the various rapid manufacturing technologies. “If you want to make high-end products, you have to work with high-end tools,” explains ILT researcher Weisheit. This is the only way for industry to continue to use its competitive advantages in the future. Laser-assisted rapid manufacturing enables the construction of high-quality tools made of either composite or gradient materials with virtually unprecedented attributes. The laser specialists in Aachen are already contemplating building new SLM plants that spray the powder material onto a substrate plate like an ink-jet printer and, from that powder, build up solid bodies of material with a thermally conductive core and a corrosion-resistant shell by laser.

However, a number of obstacles still have to be overcome before that can happen: The standard type of SLM plant only has a dosing system for one type of powder material. In order to obtain different properties in specific parts of the component, a dosing system equipped with a number of powder nozzles has to be used, each of which supplies the required material at the appropriate time. Although SLM plants process specifications obtained by computer aided design, they lack the ability to apply different materials in a single process step.

But that can change. Wilhelm Meiners is confident that the trend towards suitable material combinations and innovative process control systems is on the increase. “There are many possible applications for combined and gradient materials in tool construction.”

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