PRESS RELEASE

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Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University

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Efficient cutting fluid supply in additively manufactured milling tools

Use of novel tool concepts enables economic and ecological cost reduction in heavy-duty machining

The use of cutting fluid (coolant, MWF) is indispensable in the milling of demanding, difficult-to-machine materials and components, such as aerospace structural components made of titanium alloys. Productive milling using cutting fluid at high supply pressures presents the manufacturing industry with major challenges for reducing economic as well as ecological costs. In particular, increasing tool life and reducing the necessary use of cutting fluid can make a significant contribution to sustainable, resource-saving and competitive manufacturing in Germany. The production of complex, process-individually designed internally cooled tools using conventional manufacturing processes is very complex, cost-intensive and only possible to a limited extent.

The geometric freedom of design of additive manufacturing processes offers enormous potential in terms of individualized, focused and low-loss cutting fluid supply. By processing metallic powder materials, the Laser Powder Bed Fusion (LPBF) process can be used to redesign the cutting fluid supply of indexable cutting tools. These possibilities were explored in the BMWK-funded TaCoMA project (AiF) at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University. The aim was to exploit the potential of additively manufactured milling tools using the LPBF process with regard to an adapted cutting fluid supply to increase tool life and process reliability. Using the example of indexable milling tools with tangential insert seats, the possibilities and limits of optimized fluid supply channels and a focused nozzle design were demonstrated. The project ended in March 2023 after a three year term and collaboration with the Fraunhofer Institute for Laser Technology ILT and a broad consortium of participating companies from the fields of tool manufacturing, machine tool production, applications and cutting fluid peripherals.

In the TaCoMA research project, single-row and multi-row indexable milling tools with low-loss and focused cutting fluid supply were developed, manufactured using the LPBF process and analyzed in machining experiments. The findings were made usable in design guidelines and recommendations for SMEs. After qualification of a low-alloy case-hardening steel 18MnCrMoV4-8-7 in the LPBF process, suitable channel and nozzle geometries were identified in fluid-mechanical investigations. By utilizing the geometric freedom of design, it was possible to reduce volume flow losses by up to 21% and to shape the cutting fluid free jet in a more focused manner by means of adapted nozzle shapes.

The results were then used in the design of an adapted fluid supply system in the milling tool. The design was supported by numerical CFD simulations in order to be able to make statements about the performance capability even before the experimental validation. By testing a wide variety of supply variants with high geometric complexity and diversity in additively manufactured milling tools for roughing of the heat-treated steel 42CrMo4+QT and the titanium alloy Ti-6Al-4V, suitable variants were extracted and findings for optimum cutting fluid supply concepts were obtained. The focused and low-loss supply of the cutting fluid to the cutting edge of the tool, which is subject to high mechanical and thermal loads, resulted in tool life increases of up to 70% compared with the reference tool. At the same time, the volume flow rate was almost halved, thus significantly reducing the electrical power requirement of the machine tool.

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The enormous increase in efficiency and performance in use can compensate for the additional economic and ecological costs in the manufacturing process of additively manufactured cutting tools. In an exemplary cost calculation, the tool price for the additively manufactured tool was estimated to be almost 50% higher than for the conventionally manufactured reference tool. Taking into account the entire service life of the tool, the operating costs for LPBF-manufactured tools were 39% lower than the costs calculated for the tool according to the state of the art. The results of a life cycle assessment according to DIN EN ISO 14040/44 also showed the potential for a reduced environmental impact during the tool use. The CO2 footprint calculated for the tool service life was reduced by 20% due to the more efficient use of cutting fluid and the extended tool life of the cutting inserts.

The applicability of LPBF-manufactured indexable cutting tools for heavy-duty machining in an industrial environment was demonstrated on a multi-row demonstrator tool. The 16-flute helical milling cutter with low-loss and focused cutting fluid supply was tested in the production environment of the aircraft manufacturer supplier Premium AEROTEC for roughing of Ti-6Al-4V. Compared to the conventionally manufactured catalog tool, the fluid volume flow was reduced by 25%, tool wear was reduced by 27%, the chip volume was reduced by 25%, and chip removal was thus improved. Due to the improved functionality, additively manufactured milling tools with adapted cutting fluid supply can represent a sensible alternative to the state of the art. The knowledge gained in the project can be used by tool manufacturers, end users as well as machine tool and peripheral manufacturers.

Multi-row demonstrator tool with low-loss and focused cutting fluid supply for use in aerospace structural components made of titanium alloys (©Fraunhofer ILT, Walter AG, Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University)

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Laboratory for Machine Tools and Production Engineering (WZL)

The Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University enhances the innovative strength and competitiveness of the industry with trend-setting basic research, applied research and the associated consulting and implementation projects in the field of production technology. In the research fields of manufacturing technology, machine tools, production engineering, gear technology as well as production metrology and quality management, practical solutions for rationalizing production are developed with industrial partners from a broad range of branches.