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New standards in micromachining

Analyzing highly dynamic forces

TU Dortmund tests new MicroDyn dynamometer from Kistler

technische universität dortmund

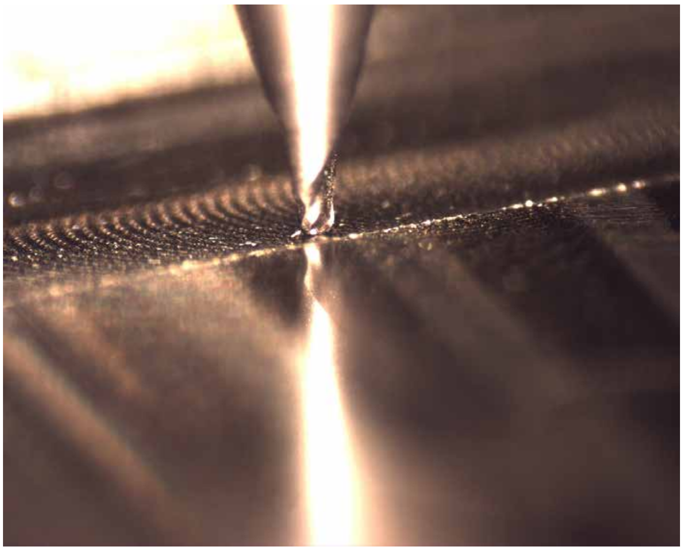
Research into machining using micro tools is conducted at the KERN HSPC 2522 micromachining center

The Institute of Machining Technology (ISF) at Dortmund Technical University (TU) has spent more than four decades researching and teaching in the field of machining covering all relevant machining processes and related technical subjects. A team of research associates are currently working in the Collaborative Research Center (CRC) Transregio 73. As part of sub projects B2 and B3, research is being conducted into the manufacture and modification of forming machines on which very hard tool steels (> 60 HRC) have to be machined with micro tools. Kistler provided the ISF with the new MicroDyn 9109AA cutting force dynamometer for the project. Thanks to its very high natural frequency, the world's smallest dynamometer unlocks completely new possibilities for the institute in the development of its micromachining processes — with astounding results.

The ISF currently numbers more than 80 research associates, technical and student supporting staff, who are engaged in three research departments: machining, grinding technology and simulation and process development. The departments are equipped with modern machine tools and machining centers to achieve machining processes of the highest standard. The scientists also have access to comprehensive measurement technology and a computer infrastructure with well-developed basic equipment. Suitable premises and laboratories enable tests to be performed in the right framework conditions and the results precisely evaluated.

New manufacturing technology to master economical and ecological challenges

As part of the Collaborative Research Center (CRC) Transregio 73, the TU Dortmund is working with the Leibnitz University Hanover and Friedrich-Alexander University Erlangen-Nürnberg. Funded by the German Research Foundation (DFG), the Collaborative Research Center was initiated to develop a new manufacturing technology called sheet-bulk metal forming (SBMF). This technology is designed to unite the advantages of sheet and bulk metal forming processes and extend possibilities with regard to component complexity. Besides the development of forming processes, the manufacture of innovative forming tools with specific characteristics represents a major step towards technology transfer into practical industrial implementation. Micromachining offers significant benefits in respect to the required form, dimensional accuracy and surface integrity, while enhancing the efficient and economical manufacture of forming tools and prolonging tool life.



Twin-blade micromachining tool (diameter d = 0.2 mm) for machining hardened high speed steel (> 60 HRC)

“Scientists would be fumbling in the dark if it wasn’t for measurement technology”

Eugen Krebs has been a research associate at the ISF for several years and is responsible for the sub project B2 along with Alexander Meijer in the CRC Transregio. The two colleagues’ work at the institute focuses on micromachining. Their duties include process and tool development for the respective machining tasks for which they need the right measurement technology. “Micromachining demands the highest standards from measuring equipment on account of the very fine dimensions. Machining involves mechanical processes in which highly dynamic forces can occur over a very wide measurement range. Reliable measurement and analysis of these forces is crucial for our process evaluation. Without measurement technology, we scientists would be left to fumble in the dark,” explains Krebs.

Along with 22 other research associates, he has been doing research in the Transregio CRC since 2010. “The Collaborative Research Center Transregio 73 plays a significant role in the necessary development of forming technology, and thus also in the mastering of current economical and ecological challenges,” adds Krebs. “This project creates the scientific fundamentals that will enable us to satisfy growing demand for customized, flexible systems of increasing functional density.” The results achieved will improve the economic and resource efficiency of forming processes.

Daunting process requirements

Forming tools in sheet-bulk metal forming consist of very fine, complex forming elements, which at the same time have to withstand high stresses. “We had to discount a lot of materials for the forming tools in the project because they simply didn’t match up to our requirements,” continues Krebs. In the end, they opted for a powder metallurgical high speed steel with high resistance to wear and tear and dimensional stability with case hardening of up to 65 HRC. “At the beginning of the Transregio, we doubted that materials of this nature could be reliably machined at all with micro tools (less than d = 1 mm in diameter). Sub project B2 focused on tackling this challenge.”

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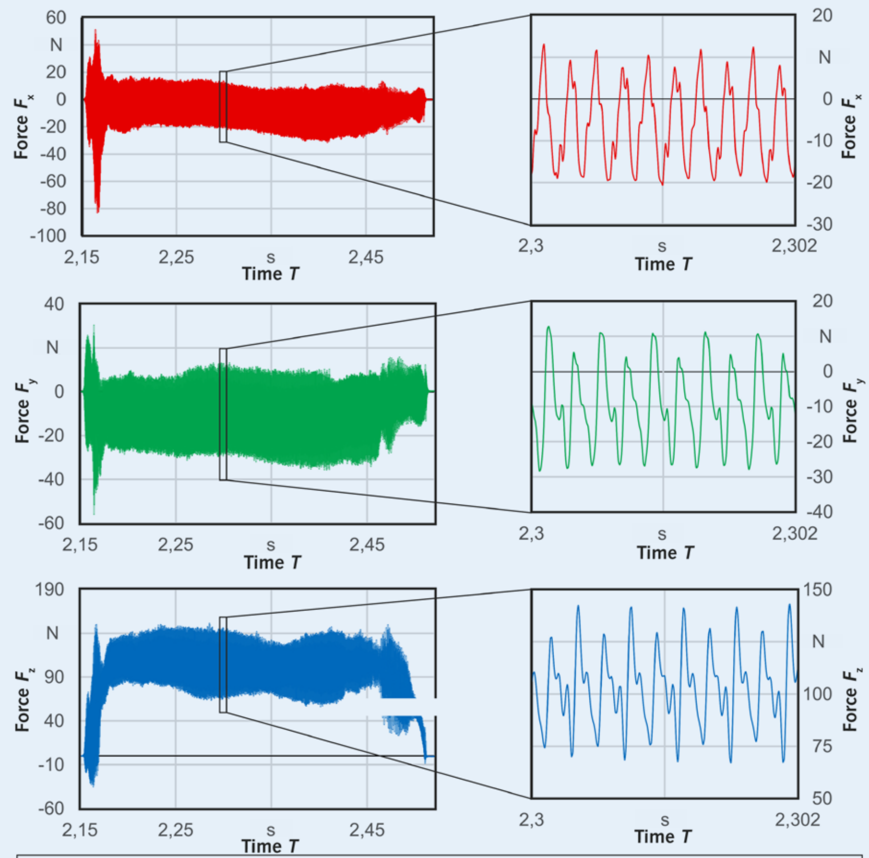
Alexander Meijer (on left) and Eugen Krebs (on right) are research assistants at the ISF engaged on the “Transregio 73” research project



Tool		Cutting parameters		
Micro end mill	d = 1 mm	Cutting speed	v_c	= 480 m/min
Cutting	z_n = 2	Axial depth of cut	a_p	= 25 µm
		Radial depth of cut	a_e	= 1,0 mm
Material	ASP®2023 (63 HRC)	Feed per tooth	f_z	= 25 µm

An unfiltered force signal on the X, Y and Z axis from research into the micromachining of hardened high-speed steel. Despite the high spindle speed of n = 152,800 rpm and a tooth passing frequency of ft = 5,093 Hz, the individual tooth engagements can be detected without significant overshooting

The solution: Rugged measurement technology with high natural frequency

Developing micromachining processes for high-strength materials with tool diameters ranging from 0.2 to 1 millimeter involved in-depth machining tests in which both suitable process parameters were to be identified and tool concepts optimized. Reliable measurement technology was required for the job, capable of both responding very sensitively and clearly while precisely mapping forces of less than 1 N to more than 200 N in a single process run. Another key criterion required by the ISF of measurement technology was high natural frequency. “If the natural frequency range of the force measurement system is less than 4,000 Hz, the force measurement platform will be excessively excited during the micromachining process, so we might end up measuring platform vibration instead of cutting force signals,” admits Krebs. Rugged qualities were also important for measurement technology to ensure that external influences like temperature or cooling lubricant did not compromise the process. And finally, repeatability and measurement accuracy were prioritized by the research team. “We frequently repeat measurements up to five to ten times. So of course it is crucial to obtain comparable, reliable results for the same tests,” concludes Krebs.

Thanks to the high natural frequency of the MicroDyn, the TU Dortmund can measure highly dynamic forces at spindle speeds of up to 160,000 rpm

Exploring the impossible with Kistler
The MicroDyn 9109AA cutting force dynamometer fulfills all the above ISF requirements, and also offers many other benefits. "The TU Dortmund and the Kistler Group can look back on a long, intensive partnership. In the past, we have frequently conducted research with different Kistler dynamometers, and so far we have been very happy with them all. When we were given the opportunity to test the prototypes of the new MicroDyn 9109AA dynamometer to assess our analyses of tool modifications, we jumped at the chance," Krebs remarks.

The ISF has been using the dynamometer since February 2018. What has changed since? Krebs: "Before using the new Kistler dynamometer, our problem was that the micromachining force measurements were always compromised by the measurement instrument's natural frequencies. We no longer have to contend with this obstacle. Thanks to the high natural frequency of 15 kHz on all three axes (x, y, z), we can measure highly dynamic forces at spindle speeds of up to 160 000 rpm. This increases dynamic properties by a factor 2.5 compared to the predecessor product." The device is also suitably dimensioned for a measurement range of up to 500 N. "We have never achieved the likes of this with our measurement technology. The MicroDyn has played an important role in extending the bounds of the possible. Now we are able to analyze processes with cutting speeds of vc > 500 m/min using small tool diameters," remarks Krebs. "This measurement technology development provides new insights into micromachining, which used to be beyond our reach due to technological limitations."

Although the Transregio 73 research program will finish at the end of 2020, Krebs and Meijer firmly intend to continue using the Kistler dynamometer. "We would like to explore further tool modifications and stretch the process limits of micromachining even further. So we look forward to the continued support of Kistler's measurement technology experts in the development of our processes."

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