Micro Materials
Excellence in Nanomechanics

User case study

GFE Schmalkalden e.V. (Germany)

Overview

To improve the machining process of thin, susceptible structural components made of the difficult-to-cut alloy Inconel 718, the milling process for trochoidal roughing and finishing was analyzed [1]. Newly developed PVD hard coatings were used to modify heat distribution during the cutting process and to improve tool life. In addition to validating cutting materials, tool micro-geometry, and coolant supply, new PVD hard coatings, including their post-processing methods, were developed.
During machining tests (Fig.1), the most suitable PVD coatings were also identified. A TiSiN-based coating demonstrated the best results for rough milling due to its longer tool life. For finish milling processes, boron-containing coatings led to reduced tool wear and the lowest surface roughness of the machined structural parts.
To reduce machining efforts in further investigations, micro-impact tests and vibrational wear tests at higher temperatures were used in coating development to identify trends in the fatigue behavior of the coatings and their affinity for built-up edges.

Fig. 1. Trochoide rough milling of undulated grooves in Inconel 718.

GFE NanoTest platform configuration

- NanoTest Vantage alpha platform
- Spherical diamond indenter, 25 µm radius.
- MicroTest load head.
- Impact load range: 300 mN – 7 N.
- NanoTest Pendulum Impulse Test Module.
- Tests at room temperature.
- Optical microscope.
- The investment in the NanoTest platform was funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Micro Impact Test Experiments

The NanoTest Vantage Alpha platform was used to perform micro-impact tests on PVD-coated carbide samples with the following parameters:

- Applied loads ranging from 750 mN to 2000 mN.
- Calibrated spheroconical diamond probe with a 25 µm end radius and a 90° cone angle.
- Impacts at 90° to the surface.
- Accelerating distance: 40 µm above the initial coating surface.

As shown in Fig. 2, there is a strong correlation between the final impact depth and the flank wear of the milling tools during trochoidal rough milling of Inconel 718. The greater the final impact depth, the higher the wear on the tools. In the analyses carried out, the AlCrTiN4 coating, which is particularly characterized by a nanolayer structure as well as high hardness and elasticity, exhibited a lower impact depth, indicating high resistance to crack formation and propagation. This coating also demonstrated the lowest tool wear during trochoidal roughing.

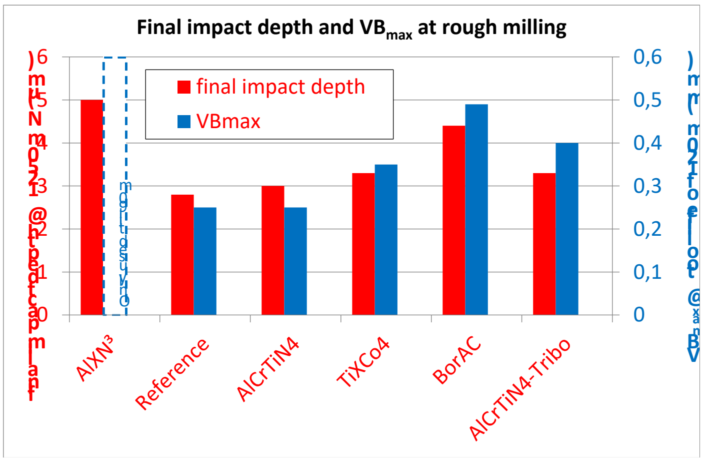

Fig. 2. Correlation between the wear mark width VB_{max} in trochoide rough milling of Inconel 718 after a milling path of 120 m and the final impact depth with an impact force of 1250 mN.

Similarly, a strong correlation was found between both the initial and final impact depths and the tool wear during finish milling of Inconel 718 [2].

User Profile

The Society for Manufacturing Technology and Development Schmalkalden e.V. (GFE Schmalkalden e.V.) is an industry-oriented research facility that offers its customers and partners comprehensive solutions for all aspects of tools. GFE conducts application-oriented basic research, applied research, contract research, and technology-oriented consulting in the field of precision tools.

In collaboration with partners and customers, GFE develops product and technology solutions that are critical for business success. GFE is known for being sophisticated, visionary, and innovative in solving development tasks, while also being practical and needs-oriented in implementation. This makes GFE the ideal partner not only for medium-sized companies but for any organization needing precision tool solutions. GFE covers the entire process chain from design, simulation, production, coating, to testing of precision tools, enabling application-oriented development of new precision tools, hard coatings, and cutting technologies.

GFE's core competencies include manufacturing technology, tool technology, machining technologies, coating technology, measurement technology, and quality assurance. Their services encompass preliminary research, applied and contract research, technology-oriented consulting, services, prototypes, small series production, and certification.

One of GFE's key strengths is the development and application of new PVD coating systems for various applications. Among other innovations, wear-resistant coatings are developed for application on cutting tools used in machining difficult-to-machine alloys.

For more information, visit www.gfe-net.de.

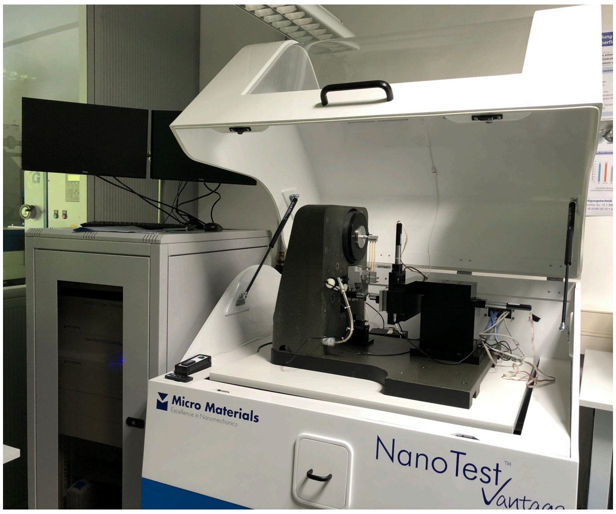

Fig.3. GFE NanoTest platform.

Highlights from the user

- Quick and simple indenter mounting.
- Intuitive software.
- Micro-impact testing can be used for rapid screening of new coating systems.
- Impact tests provide insight into coating adhesion and residual stresses.

Quote from the user

"With the Micro Impact Test, it is possible under closely controlled conditions to simulate the machining process and thus save valuable resources for complex machining tests."

References

[1] H. Frank, M. Schiffler, F. Welzel, T. Maul, T. Cselle and A. Lümkemann, "Machining technology and PVD coatings for milling thin structural parts of Inconel 718," *20th Machining Innovations Conference for Aerospace Industry 2020 (MIC 2020) - MIC Procedia (2020),* pp. 055-063, 2nd December 2020.

[2] H. Frank, H. Joost and M. Schiffler, "Analysis of the micromechanical behaviour of PVD coatings to predict machining and cutting behaviour," *20th Plansee Seminar,* pp. HM 15/1-HM15/12, 2022.

Micro Materials Ltd

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