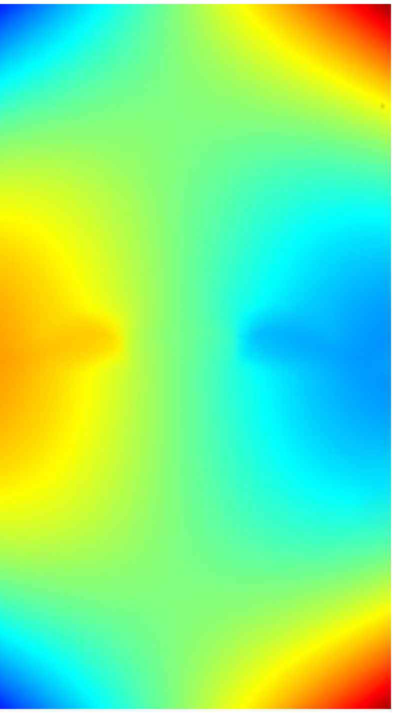


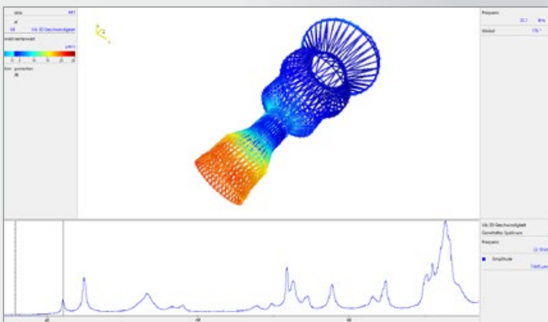
Optimizing grinding parameters

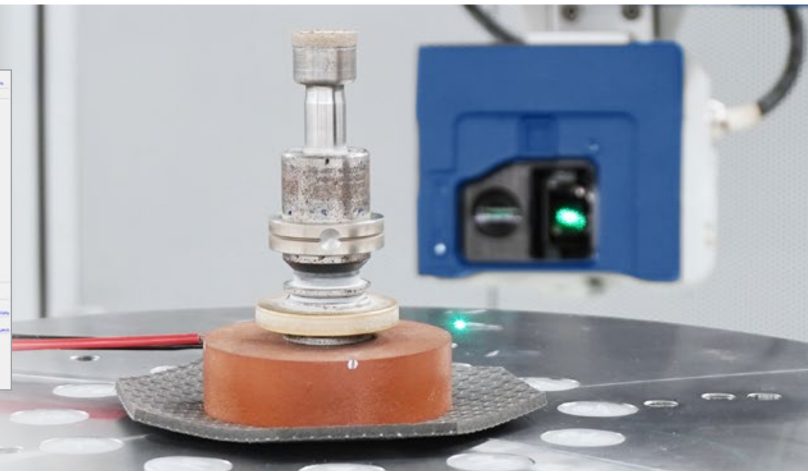
Combined vibration and topography measurement

Application note

Optical freeform surfaces simplify complex lens systems and enable specific modes of operation. The manufacturing process is usually complex, long and expensive. Typically produced in small batches in multiple loops using CNC machined grinding, the Ernst Abbe University of Applied Sciences Jena (EAH) started an AI-supported approach analyzing the resonance frequency and vibration measurement data combined with 3D topography measurements in order to optimize the grinding process.

Measurement of resonant frequencies and 3D deflection shapes of a grinding tool with broadband excitation in the RoboVib Test Center from Polytec





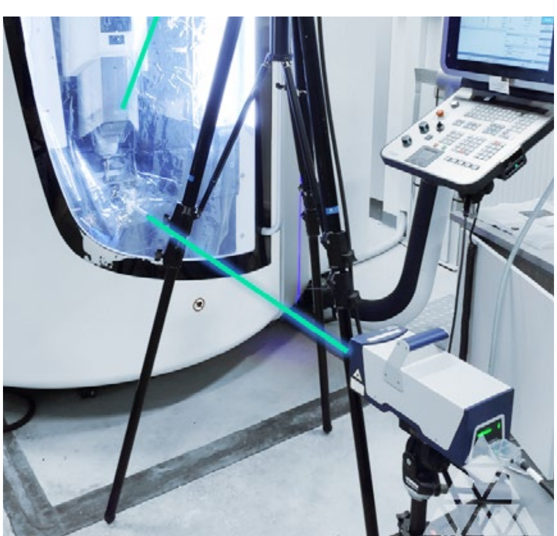
Ground optical freeform surfaces are challenging in terms of accuracy of its shape, vibration-induced medium-frequency surface defects (must be removable by final polishing steps) and roughness (in nm range). The process chain from coarse to fine to ultra-fine grinding is subject to numerous influencing variables.

The grinding tool and its alignment towards the surface as well as process parameters such as speed, feed rate, infeed depth and, in case of ultrasonic grinding, the frequency. A functional and high-precision optical surface can only be achieved with a sophisticated combination of these parameters.

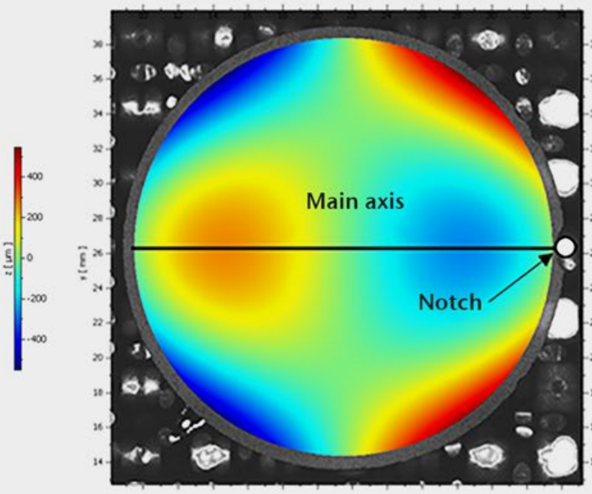
The optimization of the grinding process is the subject of current research at the Ernst Abbe University (EAH) in Jena. This requires identifying and quantifying the decisive factors in the process chain - using optical, non-contact metrology from Polytec for an analysis of the vibration behavior and surface texture.

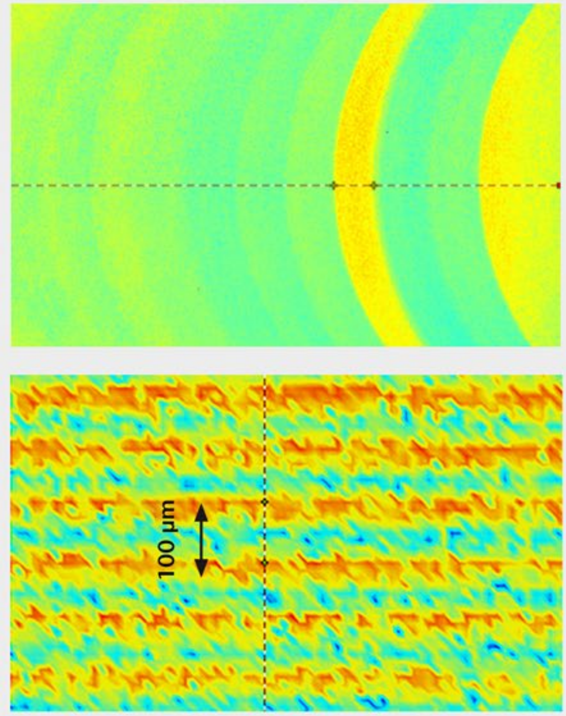
For a deeper understanding of the kinematics of the machine tool and the influence of different process parameters on the resulting surface, the EAH university used 3D measurement technology from Polytec for vibration analysis and topography:

Measurement of machine movement and workpiece vibration during the sanding process with VibroFlex QTec.



- Broadband measurement of machine vibration and visualization of the relevant vibration shapes using the 3D Scanning Vibrometer QTec
- Local vibration measurement on the workpiece during grinding using VibroFlex QTec
- Large-area measurement of form deviation and medium- to short-frequency surface defects with the white-light interferometer TopMap Pro.Surf
- Lateral high-resolution measurement of surface texture & roughness using the optical profiler TopMap Micro.View



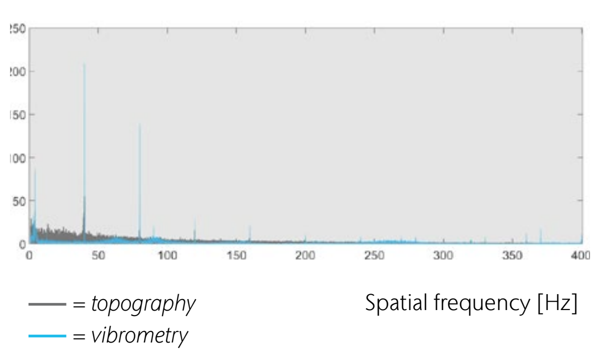


Form accuracy of Alvarez lens (optical freeform surface) inspected with large FOV profilometer Pro.Surf; detection of mid-frequency disturbances by microscope profiler Micro.View.

The dynamics of the 5-axis CNC machine for ultrasonic grinding are examined by analyzing the resonance frequency and deflection shape - both in standstill mode and with the machine components being excited by a modal hammer. This identified those tool speeds and ultrasonic frequencies that lead to the excitation of the machine's resonance frequency and thus to undesirable vibrations during the manufacturing process. Further investigations with the machine being activated and during machining revealed effects that had remained undetected during machine standstill conditions. For example, the integrated temperature compensation of the CNC machine led to steps of around 1 µm on the surface at intervals of one second. The width of the steps was linked to the feed rate of the tool due to the automatic activation and deactivation of the temperature compensation. The temperature compensation of the CNC machine was therefore deactivated to improve quality.

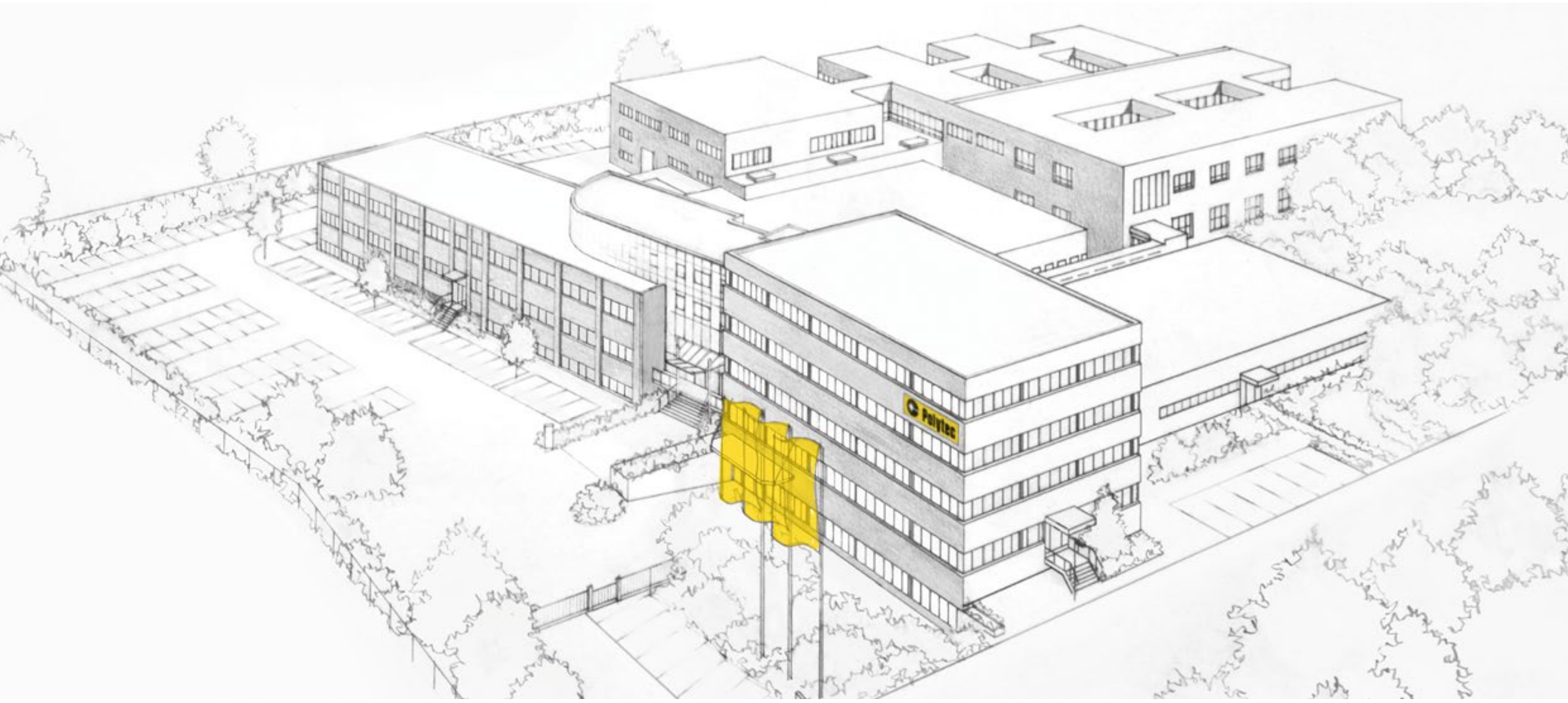
The active workpiece machining requires a permanent cooling of the workpiece and tool by a cooling lubricant. Using a test setup with beam deflection, the laser vibrometer was able to measure the underside of the workpiece in order to investigate the machine vibration during operation, including its effects on surface roughness. The surface structure indicated a direct correlation between the distance or spatial frequency of machining marks on the resulting component surface and the grinding process parameters of speed and feed rate. The combination of the surface measurement and the vibration measurement data by frequency showed a high degree of agreement between the machine dynamics and the resulting surface structures.

By combining optical vibration measurement and optical surface measurement, it was possible to gain an understanding of the factors influencing the grinding process parameters on the quality of the resulting surface. Future investigations aim to be able to predict the quality of the product based on the vibration monitoring of the manufacturing process.



Superimposition of topography and vibration measurement data showed machine vibrations as the origin.

Polytec



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