# HYBRID-MACHINING OF BRITTLE-HARD MATERIALS

**Friedrich Bleicher, Johannes Bernreiter**
**Institute of Production Engineering and Laser Technology**
**Vienna University of Technology**

**Overview**
*Development of an ultrasonic workpiece table for the machining of brittle-hard materials like glass, ceramics and carbide. Thereby the workpiece is moved with a frequency of about 20kHz and amplitudes of up to 15 microns. These vibrations support the main cutting process and enhance the supply of the coolant lubrication. With the implementation of the vibration measurement a closed-loop control was built.*

## I. Introduction

Brittle-hard materials like glass materials and ceramics are used in the design of parts, which should resist high mechanical stresses or mechanical and chemical abrasion. The following figure presents some specific material properties.

Due to brittle hard materials properties the preferably used technology in machining is NC-grinding. Tools are available starting from small diameters, like mounted points or end mill shaped cutters, up to larger dimensions like cup wheel cutters. The grain size comprises dimensions from less than 10 microns up to more than 200 microns.

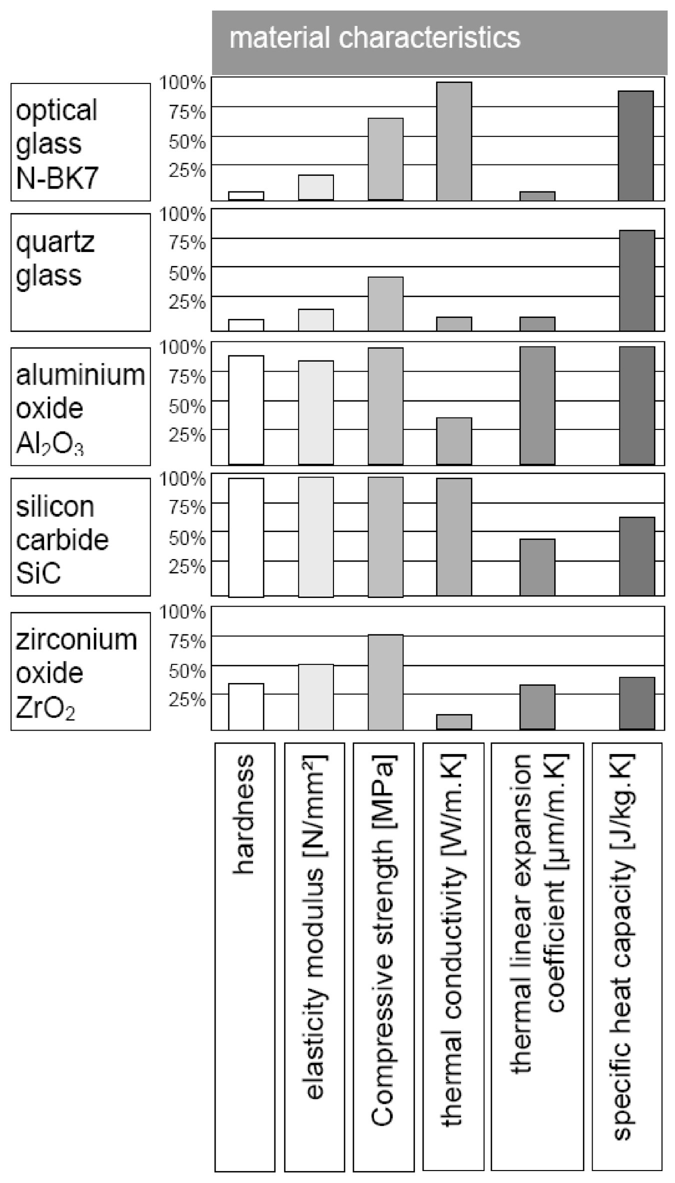



**Fig. 1:** Mechanical properties of brittle-hard materials

## II. Ultrasonic-Assitsted Grinding

In the grinding operation the tool is to be rotated by the main spindle and effects the main cutting motion. The material removal is done like in a standard grinding process. Additionally a subsidiary motion can be performed to the main cutting motion. In order to achieve this subsidiary motion the tool is stimulated in the direction of the axis of rotation with high frequency and low amplitude vibrations (hybrid machining). For ultrasonic supported machining a rotating tool is used similar to the process of jig grinding as discussed in [1], [2]. The following figure shows a mounted point with the tool holder.

For this purpose a piezo-electrical actuated resonator is used, which is typically implemented in the tool holder (cf. [3]). The resonance frequency, determined by both the geometric shape of the tool and the tool mass, can be located at approximately 20 kHz. Due to the resonance effects the amplitude is built up to values of about 1.0 microns to 3.5 microns. The resulting process interaction helps to perform machining applications on new materials.

**Fig. 2:** Ultrasonic tool with measurement device

## III. Workpiece Seated Actuator

The aim of the work at the Institute for Production Engineering and Laser Technology of the Vienna University of Technology was to develop a device for ultrasonic-supported machining which seeks to meet the following requirements:

- mounting of the vibrating device on conventional machine tools as a mechatronic clamping device
- direct mounting of workpieces on the vibrating device
- uniaxial excitation of the workpiece in a closed-loop system to control frequency and amplitude

To achieve these goals the following device was developed (see fig. 3). The vibrating device consists of a double array of piezoelectric actuators. These are preloaded by a single screw nut. The actuator is connected via a cylindrical body with the workpiece holder. Due to the extension of the piezoelectric ceramics by the supply of electric current the mechanical structure implemented in the housing lengthens in axial direction. Through the induced oscillation, the sonotrode construction is brought to resonance.

The vibrating system is connected to the housing by a membrane located at the height of the vibration node. For processing in a closed-loop system strain gages are applied.
For the excitation of the sonotrode two piezo-ceramic rings (38x20x8mm Ag, measured capacity 1nF per ring) were implemented. On the microprocessor-based sine wave generator with a serial interface to a master PC both the frequency and the amplitude of the output signal can be adjusted. The set parameters are sent to an amplifier, which is supplying the piezoelectric rings with up to 1000$V_{ss}$ (peak-to-peak value).

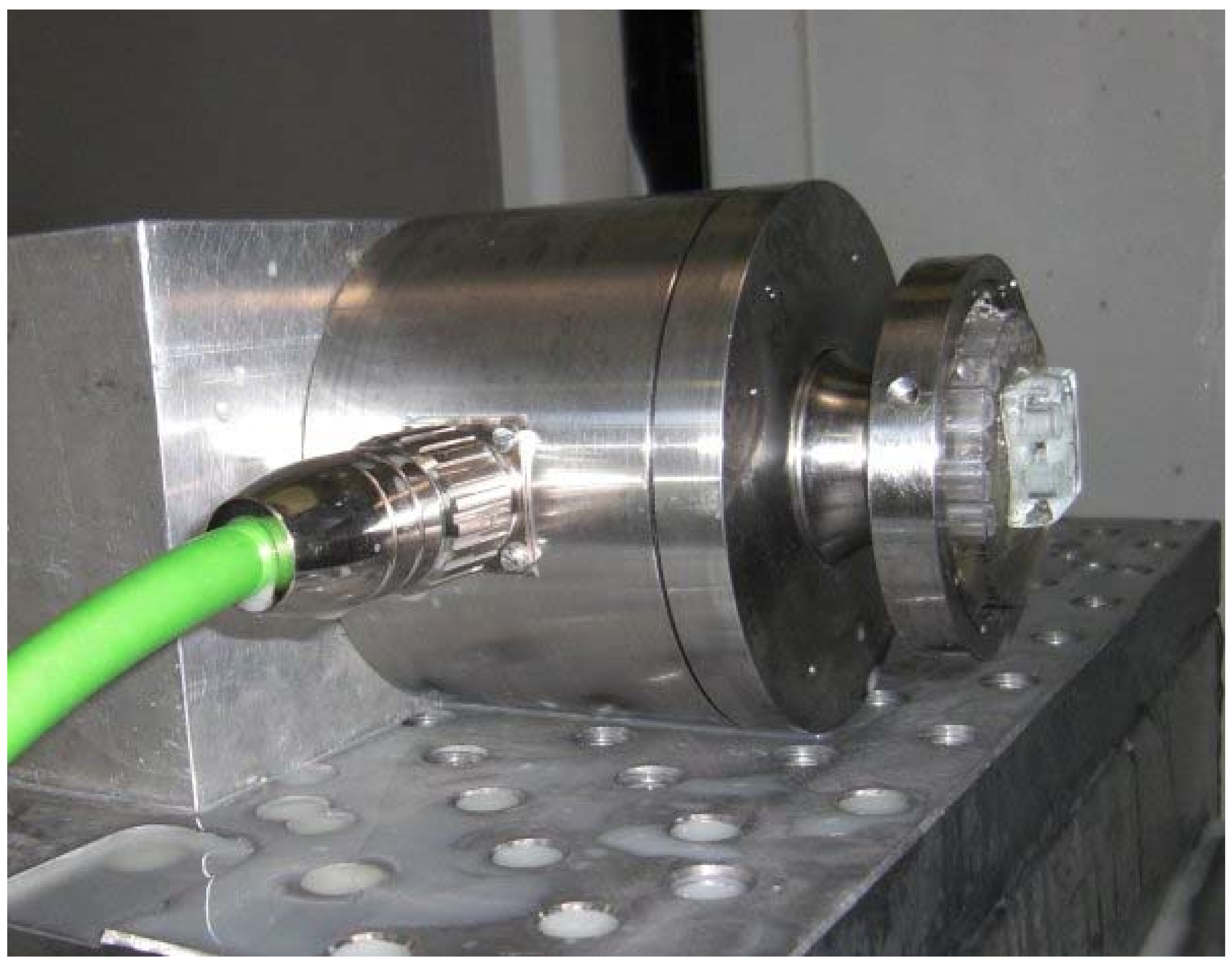
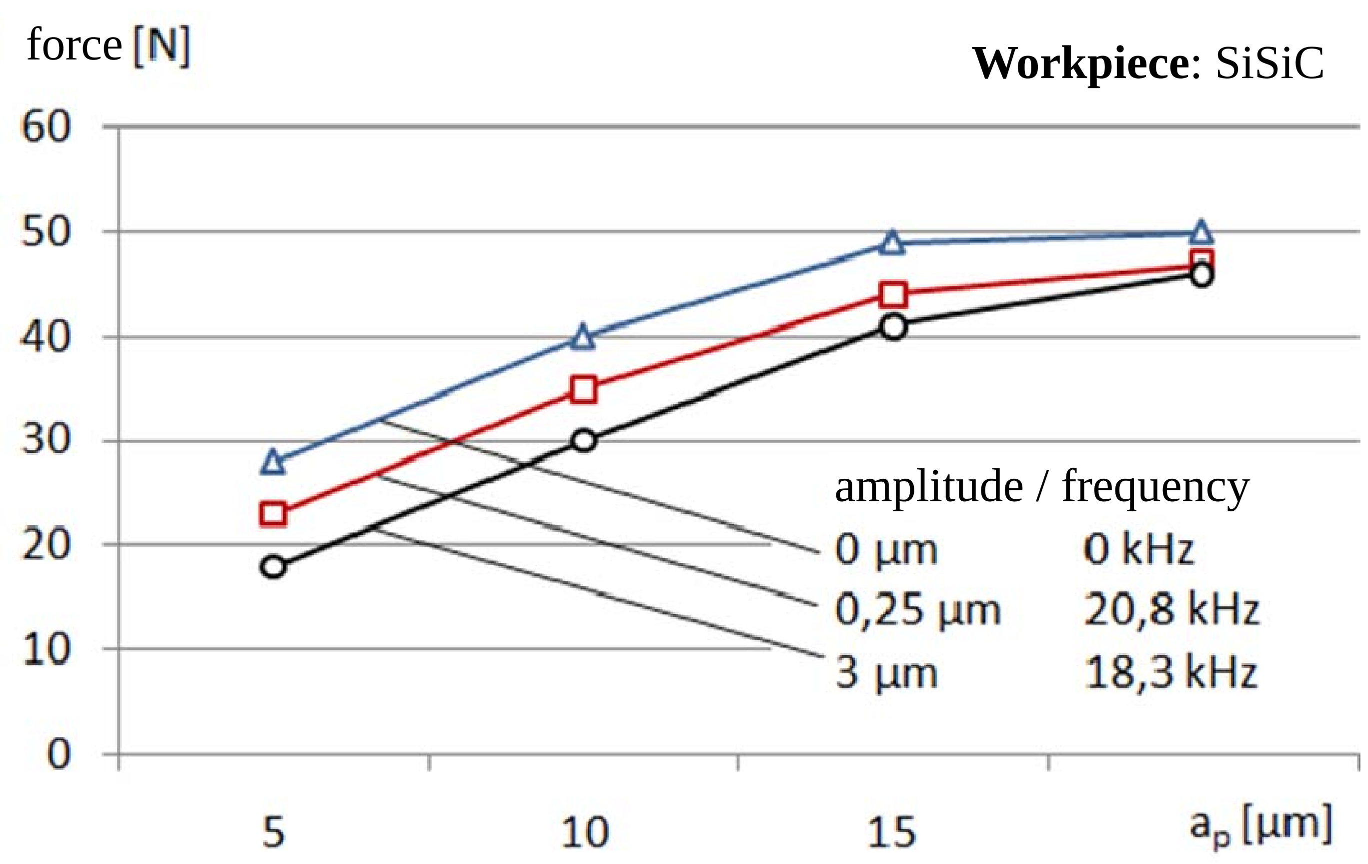


**Fig. 3:** Ultrasonic actuated workpiece table

To determine the oscillation frequency and amplitude a strain-gauge bridge-amplifier with adjustable phase angle of the output signal was implemented. A software-tool based on LabView handles the entire control of the system. The limitation in the use of this mechatronic workpiece fixture derives from the weight limitation of the workpiece and comes along with the frequencies, which have to be selected to obtain a resonance vibration.

## IV. Experimental Results

The activated tool modifies the cutting process through the subsidiary motion. For the metrological control of the resulting vibration and the calibration of the strain gages, an eddy-current measuring device for contactless measurement was used.
The metrological analysis of the vibrating device demonstrated that in the respective resonance frequencies amplitudes of up to 15 microns can be achieved. It could be shown, that this effect leads to a reduction of cutting- and feed forces of about 10% up to 25% for the machining of different brittle-hard materials




**Tool:** Hollow-Drill

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| grit size (blocky) | diamond D 107 | diameter | $d_S$ = 5,5 mm |
| concentration | C 200 | length of shaft | L = 45 mm |
| revolution speed | $n_S$ = 8.000 rpm | coating thickness | x = 1,5 mm |
| feed rate | $v_W$ = 360 mm/min | | |

REFERENCES

[1] Spur, G.; Sathyanarayanan, G., „Ultrasonic Assisted Grinding of Structural Ceramics“. 1st International Machining and Grinding Conference, Dearborn, USA, 1995

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[3] Schinhaerl, M., Pitschke, E., Rascher, R., Sperber, L. et al., “Temporal Stability and performance of MR polishing fluid”, Proc. International, Symposium on Optical Science and Technology, SPIE 49th An. Meeting, Denver, 2004