WHITEPAPER

Ultrasonic-assisted drilling and deep hole drilling of copper and copper alloys with VIBRO*drill ultrasonic*

Parts made of copper and copper alloys are found in essential components in various industries such as the electrical or energy industry. In many cases, they are manufactured using machining processes, whereby various processes such as drilling and deep hole drilling are used. Despite their comparatively low strength, copper-based materials in particular, as well as low-alloy copper alloys, are considered difficult to machine. The reason is the tough material behavior with high forming capacity. The result is poor chip forming behavior and high machining forces, which pose a challenge for industrial processes in terms of productivity, process reliability and quality.

Investigation of ultrasonic assistance with VIBRO*drill ultrasonic*

As an example for the group of copper-based materials and low-alloy copper alloys, an investigation of ultrasonic assistance during drilling is carried out using a reference component made of CuCr1Zr (2.1293). For the implementation of ultrasonic assistance, a machine tool was equipped with the VIBRO*drill ultrasonic* system according to Figure 1. Here, an ultrasonic vibration is generated in the tool holder and superimposed on the process kinematics.

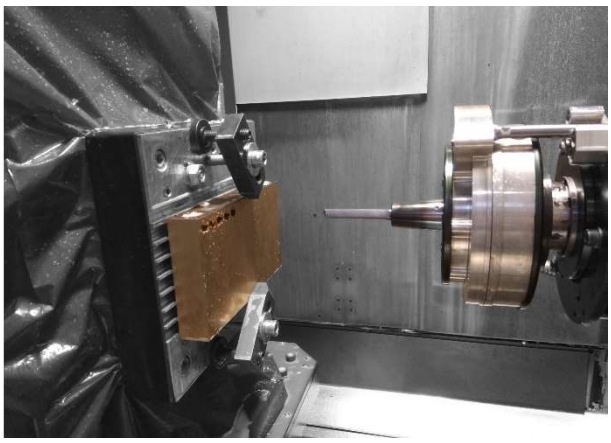

Figure 1: Test setup

The tool used was a straight fluted solid carbide drill with Ø12 mm. The drilling depth was 40 mm. In order to evaluate the effects of ultrasonic assistance, the feed forces of the drilling process were recorded with the help of a force measurement device and compared for conventional and ultrasonic-assisted drilling. Within the test series, different feed rates from 0.05 mm to 0.25 mm were investigated for the cutting speed of 90 m/min. For the ultrasonic-assisted process, the vibration frequency of the tool was approx. 17,000 Hz and the vibration amplitude was 12 µm and 20 µm respectively.

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Technological effects and mechanisms

Figure 2 shows the course of the feed forces for the different feeds as well as the conventional and ultrasonic-assisted drilling process with increasing vibration amplitude. In accordance with the basic machining theory, it first becomes apparent that the feed forces increase with higher feed rates and that the forces of conventional drilling are very high at a maximum of 5,743 N. In practical applications, these lead to limitations in productivity and problems regarding process reliability. The ultrasonic assistance with a vibration amplitude of 12 µm leads to a significant reduction in feed forces for all values of feed. If the vibration amplitude is increased to 20 µm, the feed forces decrease further, especially for the higher feed rates. The result is a reduction of the feed force from 5,743 N to 2,739 N at a feed rate of 0.25 mm. The drastic force reduction of 3,004 N corresponds to 52 %. This is due to the influence of ultrasonic assistance on chip formation, which is clearly visible in the chips at a feed rate of 0.05 mm (Figure 3). While chips produced by the conventional drilling process are very thick due to the build-up on the rake feace, ultrasonic assistance produces significantly thinner chips. The improved chip flow and the changed material behaviour due to ultrasonic assistance have a direct effect on the cutting forces. The reason for this is that ultrasound influences the material properties, changes the process kinematics and greatly reduces the friction between the chip and the tool, especially the rake face, allowing the copper chip to be slide off more easily. The reduced process forces have a favourable effect on the drilling process and its properties and enable further potential for improvement. In this context, the quality of the holes is significantly improved with regard to the hole straightness deviation, which is a critical factor in deep hole drilling in particular. Furthermore, the formation of burr at the exit of the hole as well as tool wear are reduced. Another decisive factor is the potential to further increase the cutting values, especially the feed rate, thereby significantly increasing productivity.

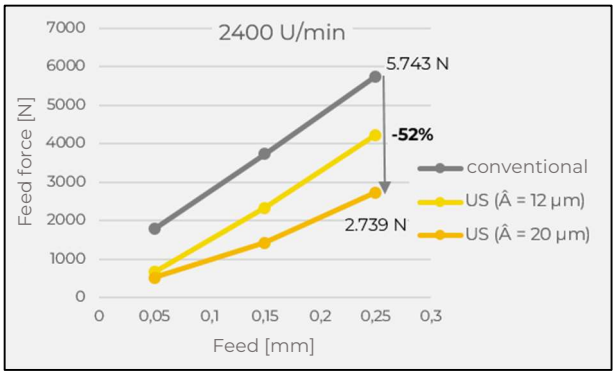

Figure 2: Diagram of the feed forces

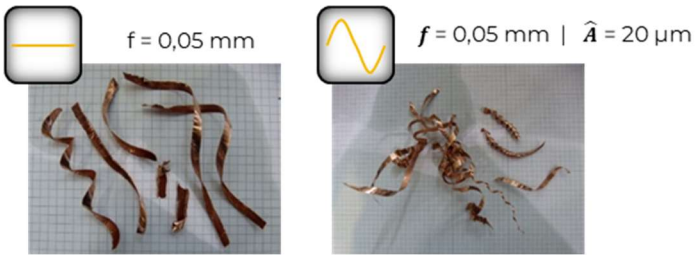

Figure 3: Chip formation in comparison

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Customer benefits

The drastically reduced cutting forces have a positive effect on the limits of the drilling process in terms of productivity, process reliability and quality. Figure 4 summarises the advantages of ultrasonic assistance when drilling copper and copper alloys.

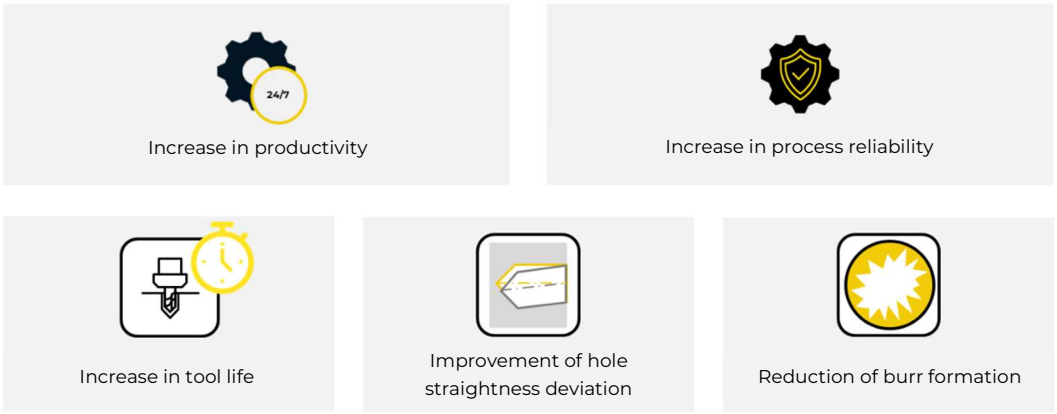

Figure 4: Advantages of ultrasonic-assisted drilling and deep hole drilling

In particular, the hole straightness deviation when drilling and deep hole drilling is significantly improved by the ultrasonic force reduction, which is a decisive factor in many industrial applications. Furthermore, the drilling process is safer, especially near its performance limits. For example, the reduced cutting force reduces the probability of spontaneous tool breakage. Especially in series production and with a high degree of automation, process reliability is a decisive factor for cost-effective production. When

Cost savings with VIBRO*drill ultrasonic*

Calculation example cutting parameter increase

- Machine hour rate: 130,- €/h
- Planned occupancy time: 6000 h/year (750 shifts/year)
- Machining main time share drilling on cycle time: 35 %

Increase in cutting parameters	Increase in productivity	Savings per machine and year
20 %	7,1 %	45.000 €
40 %	10 %	78.000 €
100 %	17,5 %	136.000 €

Figure 5: Example calculation of the economic benefit of increasing the cutting value

comparing the feed forces, the potential of ultrasonic assistance to increase the cutting data, especially the feed rate, becomes clear. This significantly increases the productivity of the drilling processes and achieves high economic benefits according to the exemplary calculation in Figure 5.

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Further information

VIBRO*drill ultrasonic* is a patented system developed by VibroCut GmbH. We act as a product and technology provider as well as an integration partner for the use of vibration-assisted machining in your production. We sell our vibration systems as tool holders for equipping new and existing machines and offer related services.

The VIBRO*drill ultrasonic* system is available in various performance classes and dimensions to fit to your machine tool. We provide equipment for all common spindle interfaces such as HSK, SK or BT in various sizes. A unique feature is the innovative amplitude and frequency control, which ensures the optimum vibration state under process load. Depending on the requirements of the machining process, users can choose from four different performance classes - from the Precision-Line for delicate tools with speeds of up to 30,000 rpm to the High Performance-Line for special applications with

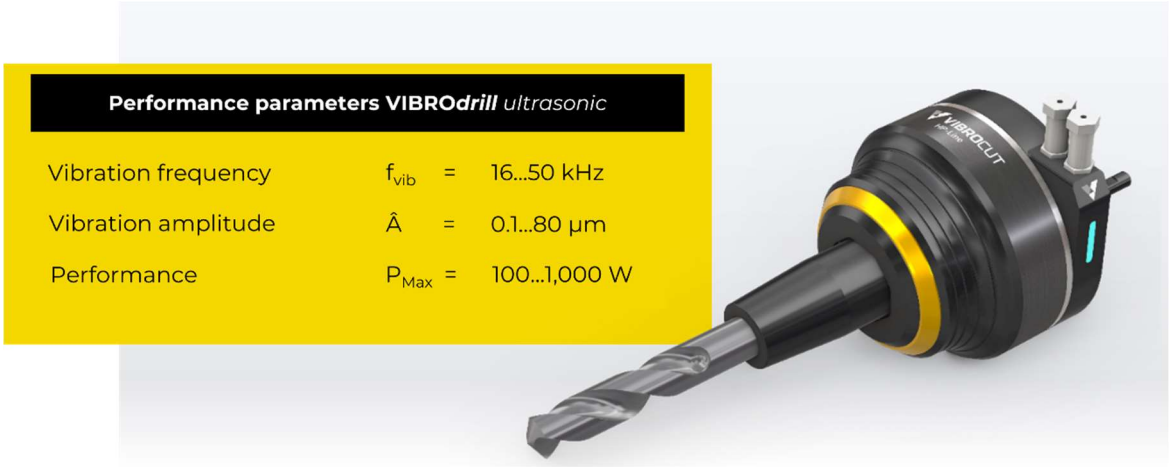

Figure 6: Ultrasonic tool holder VIBROdrill ultrasonic

large, high-mass tools. With a maximum power of 1,000 W, deep drilling tools with a length of over 2,000 mm, for example, can be set into ultrasonic vibration reliably and with sufficiently high amplitudes. The Precision-Line with an ultrasonic power of 100 W, Standard-Line with 250 W and Performance-Line with 500 W are designed for machining centers with automatic tool change.

Feel free to contact us directly or find more information on our website:

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