

# WHITEPAPER

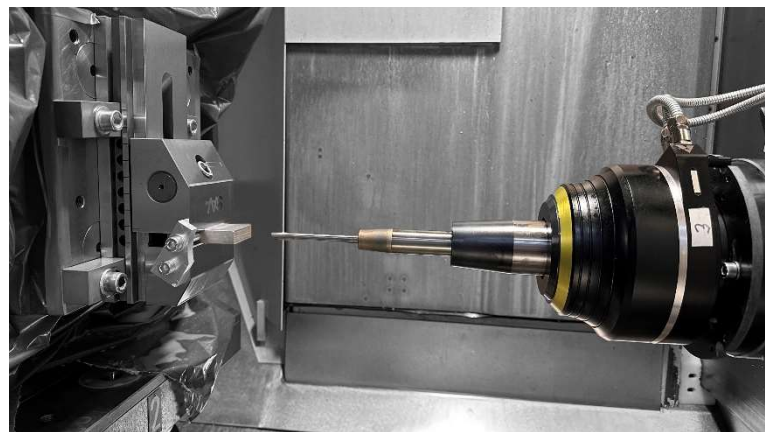
## **Ultrasonic-assisted drilling and deep hole drilling of aluminium alloys with VIBROdrill ultrasonic**

Components made of aluminum alloys are used as wrought or die cast alloys in almost all industries. Due to their favorable material properties, low costs and good machinability, aluminum alloys are used for components produced in large quantities and manufactured as part of series production processes. The focus here is on optimizing productivity, quality and process reliability in order to continuously increase efficiency and cost-effectiveness. Ultrasonic assistance for drilling and deep hole drilling processes can make a significant contribution here. The high-frequency vibrations modify the material behavior during chip formation in favor of low cutting forces and minimize friction, which significantly increases the performance of drilling and deep hole drilling processes in aluminum alloys.

### **Investigation into the use of ultrasonic support with VIBROdrill ultrasonic**

As an example for the group of aluminum alloys, the ultrasonic assistance for drilling is examined using the example of a reference part made of a wrought alloy EN AW-7075 (AlZn5.5MgCu) and a cast alloy EN AC-42000 (AlSi7Mg).

To implement ultrasonic assistance, a machine tool was equipped with the VIBROdrill ultrasonic system as shown in Figure 1. An ultrasonic vibration is generated in the rotating tool holder and the kinematics of the machining process are deliberately superimposed onto it. The vibration amplitude is set in the NC program using M commands and can be changed over a wide range. The



*Figure 1: Test setup*

vibration frequency is set automatically by the system and controlled during the drilling process.

The test parameters were varied depending on which material was to be machined and are summarized in Table 1.



Table 1: Parameters of the machining investigations

	EN AW-7075 (AlZn5,5MgCu)	EN AC-42000 (AlSi7Mg)
Tool	VHM – straight fluted	VHM with PCD cutting edge – straight fluted
Bore diameter	Ø8 mm	Ø8 mm
Drill depth	20 mm	67 mm
Cutting speed $v_c$	200 m/min	138 m/min
Feed rate $f$	0,07 ... 0,2 mm/U	0,12 ... 0,35 mm/U
Vibration frequency	≈ 27 kHz	≈ 20 kHz
Vibration amplitude	12 µm / 20 µm	15 µm / 25 µm

In order to evaluate the effects of ultrasonic assistance, the feed forces of the drilling process were determined using a force measurement platform and compared for conventional and ultrasonic-assisted drilling.

### Technological effects and mechanisms

With reference to the tests in EN AW-7075, Figure 2 shows the progression of the feed forces for the various feed rates as well as the conventional and ultrasonic-assisted drilling process with increasing vibration amplitude. According to the basic machining theory, it is first apparent that the feed forces increase with higher feed rates and that the forces of conventional drilling are max. 848 N. The cutting forces and the removal of chips often define the limits of productivity and process reliability in drilling processes. Ultrasonic assistance with a vibration amplitude of 12 µm leads to a significant reduction in feed forces for all feeds. If the vibration amplitude is increased to 20 µm, the feed forces are further reduced. The result is a reduction in feed force of 194 N or 39% at a feed rate of 0.07 mm.

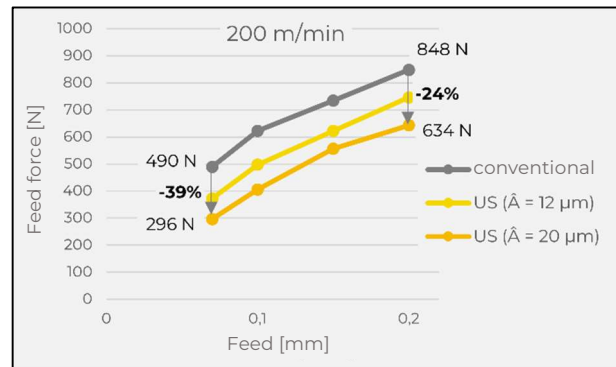


Figure 2: Diagram of the feed forces (EN AW-7075)

Correspondingly low feed rates are used for drilling cycles of deeper holes, for example. Here, ultrasound can ensure greater stability and accuracy or reduce the need to reduce the feed rate in order to achieve higher productivity. At the higher process feed rate of 0.2 mm, ultrasonic assistance with 20 µm reduces the feed force by 214 N or 24%. Furthermore, it was observed in the time curves of the feed force that ultrasonic assistance leads to a significant reduction in force fluctuations and the drilling process is stabilized due to the improved chip removal. This is due to the reduced friction between



the tool shank and the chips, which improves chip evacuation and reduces chip jamming. This is a decisive advantage, especially with long-chipping wrought aluminum alloys. Based on ultrasonic assistance, there is the potential to significantly increase the cutting values, especially the feed rate, when drilling aluminum, and thus to significantly increase productivity and cost-effectiveness.

Figure 3 shows the feed forces for conventional and ultrasonic-assisted drilling in the cast aluminum alloy EN AC-42000. Here too, the feed forces increase with higher feed rates and reach a maximum of 488 N for conventional drilling. The diagram shows that ultrasonic assistance also leads to a reduction in the feed force for all feed rates for cast alloys, with the effects increasing with a higher vibration amplitude.

The reduction in force at a low feed rate of 0.1 mm and a vibration amplitude of 25  $\mu\text{m}$  is 111 N or 43%. With a conventional process feed of 0.25 mm, the feed force is drastically reduced by 266 N or 55%. In the tests, the feed rate was increased on this basis. At a vibration amplitude of 15  $\mu\text{m}$ , the conventional feed force of 488 N is achieved at a feed rate of approx. 0.33 mm, which corresponds to an increase of 32%. At a vibration amplitude of 25  $\mu\text{m}$ , the feed forces are significantly lower than the conventional value, even at a feed rate of 0.35 mm. This results in a potential increase in feed rate of >50%.

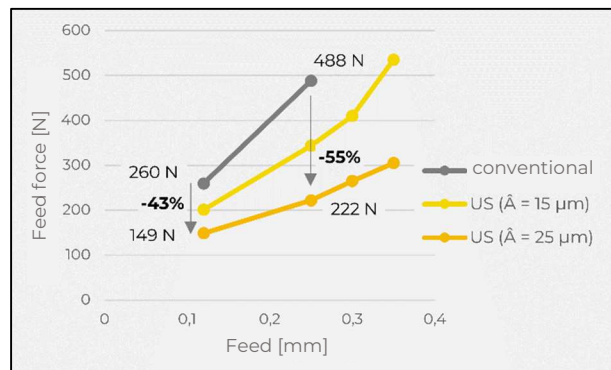


Figure 3: Diagram of the feed forces (EN AC-42000)

The reduced machining forces have a beneficial effect on the drilling process and its properties when machining wrought and cast aluminum alloys and open up further potential for improvement. In this context, for example, the quality of the holes with regard to the centerline, which is a critical factor in deep hole drilling in particular, is significantly improved. Furthermore, the formation of burrs at the hole exit and tool wear are reduced. Another decisive factor is the potential to further increase the cutting values, especially the feed rate, and thus significantly increase productivity.



### 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 summarizes the advantages of ultrasonic assistance when drilling copper and copper alloys.

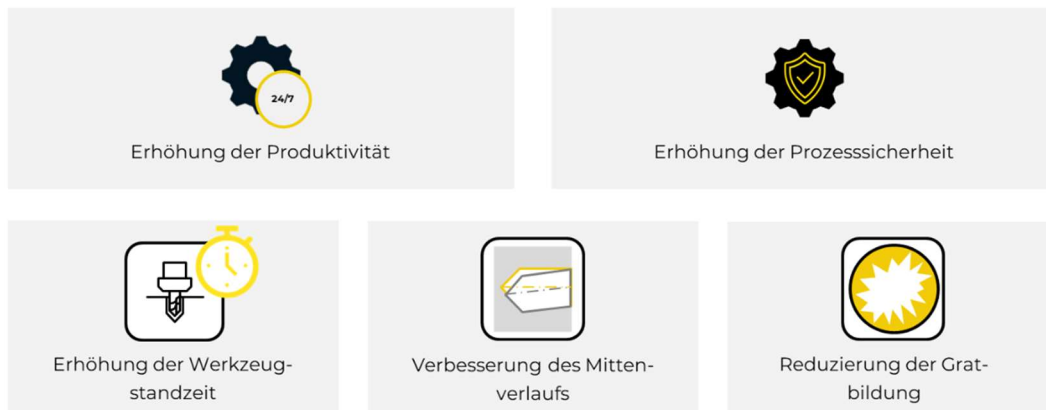


Figure 4: Advantages of ultrasonic-assisted drilling and deep hole drilling

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.

### Cost savings with VIBROdrill 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

Especially in series production and with a high degree of automation, process reliability is a decisive factor for cost-effective production. When 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.



## Further information

VIBROdrill *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 VIBROdrill *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

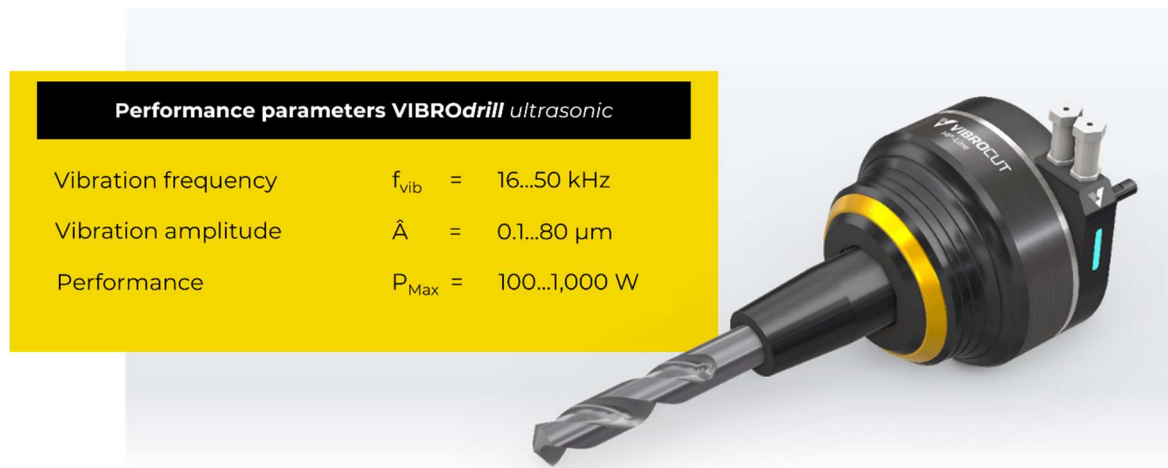


Abbildung 4: Ultraschall-Werkzeughalter VIBROdrill *ultrasonic*

speeds of up to 30,000 rpm to the High Performance-Line for special applications with 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:

**VibroCut GmbH**  
Annaberger Str. 240  
09125 Chemnitz  
[info@vibrocut.de](mailto:info@vibrocut.de)  
[www.vibrocut.de](http://www.vibrocut.de)

