# WHITEPAPER

## Ultrasonic-assisted drilling and deep hole drilling of aluminum alloys with VibroCut *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 ultrasonic movements 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 VibroCut *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 VibroCut *ultrasonic* system as shown in Figure 1. An ultrasonic movement is generated in the rotating tool holder and the kinematics of the machining process are deliberately superimposed onto it. The amplitude is set in the NC program using M commands and over a wide range. The ultrasonic frequency is set automatically by the system and controlled during the drilling process.

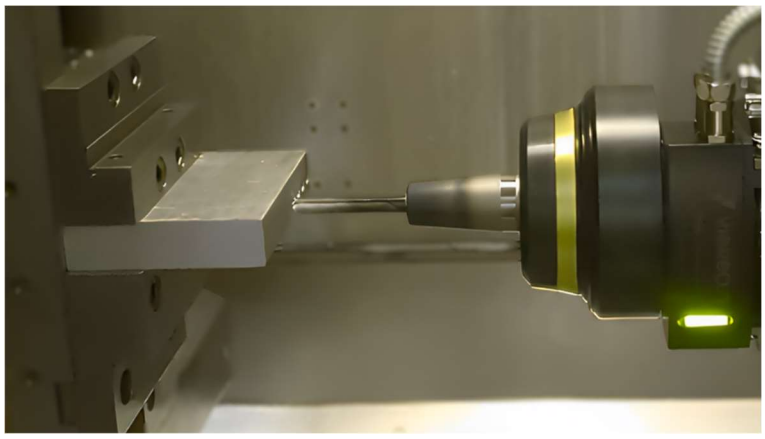

*Figure 1: Test setup*

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



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*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 |
| Ultrasonic frequency | ≈ 27 kHz | ≈ 20 kHz |
| Amplitude $\hat{A}_{pp}$ | 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 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 an amplitude of 12 µm leads to a significant reduction in feed forces for all feeds. If the 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. 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

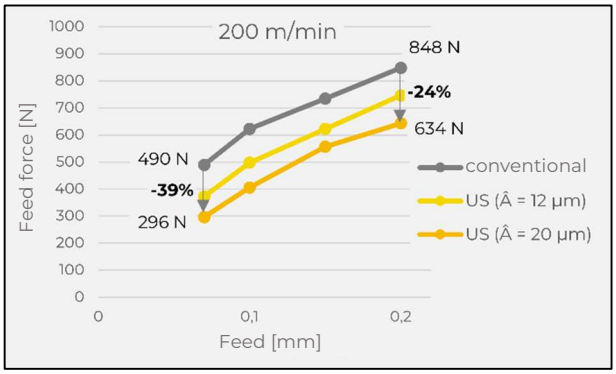


*Figure 2: Diagram of the feed forces (EN AW-7075)*



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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 amplitude. The reduction in force at a low feed rate of 0.1 mm and an amplitude of 25 µm 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 an amplitude of 15 µm, 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 an amplitude of 25 µm, 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%.

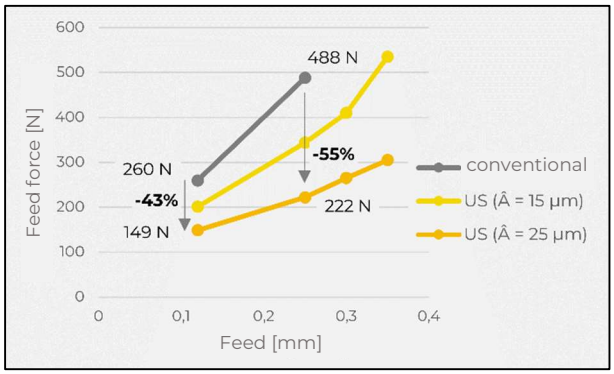


*Figure 3: Diagram of the feed forces (EN AC-42000)*

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.



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

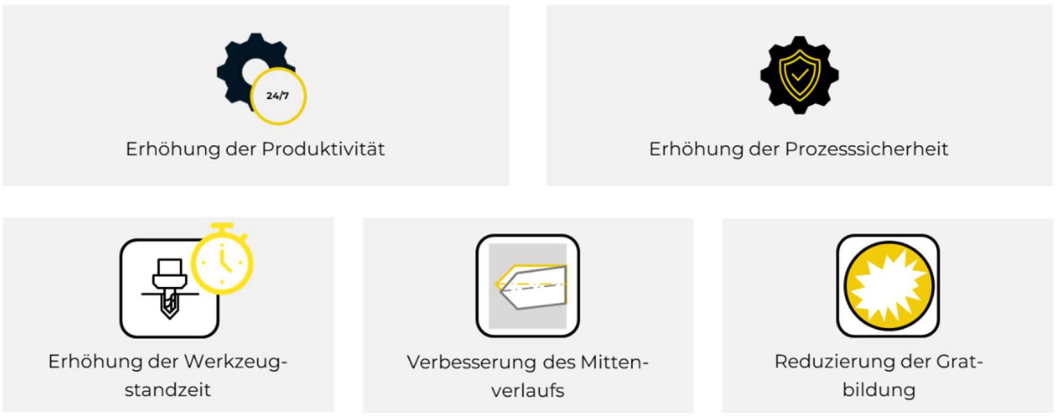


*Figure 4: Advantages of ultrasonic-assisted drilling and deep hole drilling*

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.
Especially in series production and with a high degree of automation, process reliability is

## Cost savings with VibroCut *ultrasonic*

**Calculation example cutting parameter increase**

- Machine hour rate: 75 €/h
- Planned occupancy time: 6000 h/year (750 shifts/year)
- Increase in cutting parameters: 25...100 percent

| Increase in cutting parameters | Increase in productivity | Savings per machine and year |
|---|---|---|
| 25 % | 9,0 % | 40,500 €/year |
| 50 % | 15,0 % | 67,500 €/ year |
| 100 % | 22,5 % | 101,250 €/ year |

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

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.



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## Further information

VibroCut *ultrasonic* is a patented system developed by VibroCut GmbH and sets new standards in hybrid machining. As a product and technology provider and integration partner, we enable the efficient use of ultrasonic technology in your production. Our ultrasonic systems are available as tool holders for retrofitting to new and existing machines, supplemented by comprehensive services.

The VibroCut *ultrasonic* system offers maximum flexibility with different performance classes and dimensions, suitable for all common spindle interfaces such as HSK, SK or BT. A unique selling point is the precise amplitude and frequency control, which ensures the optimum movement status even during tool engagement. Depending on the machining requirements, four performance classes are available - from the Precision Line for delicate tools with speeds of up to 30,000 rpm to the High Performance Line for high-mass special applications. With a maximum power of 1,000 W, VibroCut *ultrasonic* even enables the


*Figure 4: Ultrasonic tool holder VibroCut ultrasonic*

reliable use of deep drilling tools with a length of over 2,000 mm. Thanks to the Precision-Line (100 W), Standard-Line (250 W) and Performance-Line (500 W) optimized for machining centers, seamless integration into machines with automatic tool change is possible.

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

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