›Micro Bore Sizing‹ of bores with a minimum diameter of 0.015 mm

Challenge accepted and implemented

Microcut Ltd. produces machines and tools for honing and internal cylindrical lapping of micro bores with diameters of between 0.015 and 4 mm. For small to medium-sized batches, the company also offers contract production.

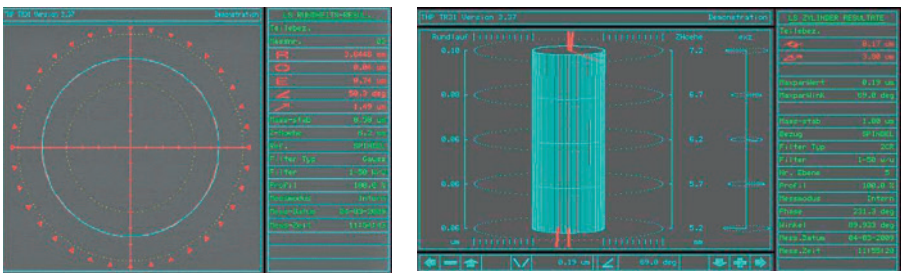
BY PATRIC MIKHAIL

→ In the field of micromechanics, machining boreholes presents a special challenge. This is due first and foremost to the difficulties inherent in machining surface accessibility, and the frequently high aspect ratios (bore length relative to bore diameter). Conventional boring using cutting tools, laser drilling, punching, erosion, ECM or powder injection moulding – to mention just a few – are economical processes which have all become established in the field of microtechnical applications. The efficient manufacture of micro bores is not in itself an inherent problem – provided no excessive demands are made in terms of precision and reproducibility. There are various reasons why an unfinished bore should be ultra-fine machined. These include surface and dimensional accuracy just as much as the shape, which in its unfinished condition can be out of round, wavy, conical or even banana-shaped. This is where ›Micro Bore Sizing‹ (MBS) developed by the company Microcut comes into its own.

Complete system comprising machine, tooling and service

Micro Bore Sizing is an economical solution for machining bores down to a minimum diameter of 15 µm, particularly for hard materials [1, 2]. The technology permits the geometry (diameter, concentricity, cylindricity) to be contained within close tolerance bands and the surface roughness to be selectively improved. Micro Bore Sizing is a user-friendly system comprising machines, tooling as well as services.

1 Application examples for the ›Micro Bore Sizing‹ process

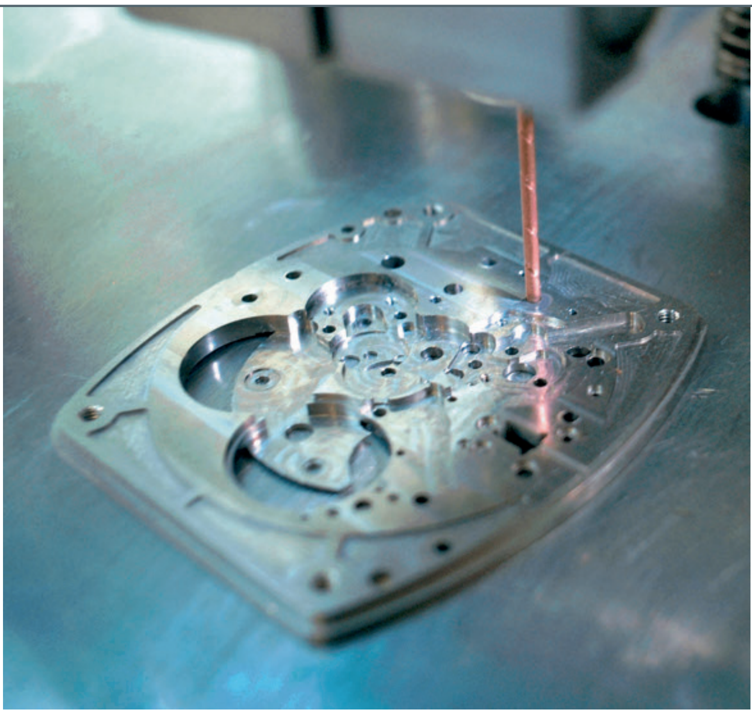


1 The 1.0 mm bore of a nozzle was machined using the ›MBS‹ process to a concentricity of 0.04 µm (left), a cylindricity of 0.17 µm (right) and a maximum parallelism of 0.19 µm

It involves a precisely specified tool for each bore, using a chipping machine process and applying carefully controlled force. As the machining process used is cold, no material weakness occurs in the surface layers due to microstructural changes. As with conventional honing, instead it is possible to generate an increase in residual compressive stress levels. This benefits the components, lending them higher fatigue strength and a lower tendency to crack formation. The single-part MBS tools comprise a conical and a cylindrical section. The conical section is used to increase the size of the bore, which is then calibrated with the cylindrical section – in other words producing the same diameter in every workpiece.

Using the machine model ›UniBore 800‹, there are two different processes available in the bore diameter range 0.25 to 4 mm. Which process is selected depends primarily on the bore diameter, the material being machined and the required surface quality. As a rule, a tool with bonded abrasive is used. This process is suitable for practically all types of material. Conversely, loose abrasive is generally preferred to machine bores below 0.25 mm in diameter in brittle-hard materials such as ceramic, sapphire, and carbide. Known as lapping, this process addresses the most

Figures: Microcut



2 In a watch blank, the bearing surfaces for the jewels are produced to a diameter tolerance of 2 µm

stringent requirements in terms of surface quality. The benefits of the MBS process are:

- Minimal tool wear and consequently a long tool service life due to a diamond coating length of maximum 400 mm,
- No measurement control system is required for geometry and wear correction,
- A simple and consequently more trouble-free machine can be used,
- Process stability and extreme reproduction accuracy.

Table 1 provides a summary of values for the various quality characteristics typically achievable using Micro Bore Sizing. The dimension, shape and surface of a bore are known to be inseparably linked. Consequently if we look at the tolerance of a bore diameter, for instance, with a diameter of three micrometers, concentricity more accurate than a micrometer can be guaranteed. By the same token, the surface roughness is always inevitably in a defined ratio to dimensional accuracy and shape.

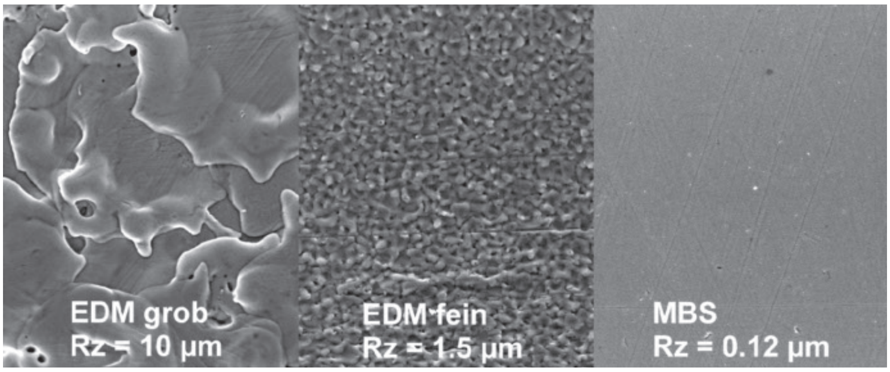
Excellent quality of MBS technique

The possibilities opened up by Micro Bore Sizing can be illustrated by using a few machining examples, with the emphasis »»

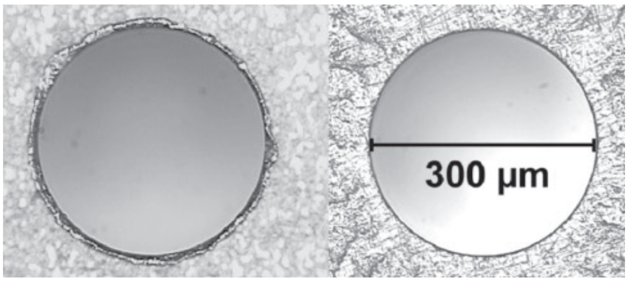
1 Quality characteristics of Micro Bore Sizing

Criterion	Achievable values with MBS
Diameter range	from 0.015 mm with loose abrasive from 0.250 mm with bound abrasive
Diameter tolerance	± 0.5 µm
Aspect ratio	Up to 200 x D
Concentricity	< 0.2 µm
Cylindricity	< 0.4 µm
Parallelism	< 0.5 µm
Surface Quality	R_z < 0.2 µm
Cycle time	Dependent up on material, machining allowance, bore length
Part geometry	Rotationally and non-rotationally symmetrical
Material	Sapphire, ceramic, carbide, steel, various metal alloys, glass, various plastics

Excellent quality characteristic values can be achieved using the MBS process



3 Comparison of surface roughness: The start hole erosion (left), fine erosion (centre) and Micro Bore Sizing (right) processes are distinguished by approximately the shift of a decimal point



4 Bore following MBS machining before (left) and after (right) deburring

>>> on criteria which are capable of substantial improvement using the MBS technique.

Shape: Dimensional accuracy using the MBS technique is determined by the tool, and then further improved by superimposed movements (rotation and translation). This typically produces a degree of concentricity in the machined bore which is greater than that of the tool itself. Fig. 1 illustrates the measurement results achieved with a measurement device ›Taly Rond 31‹ gauging a nozzle bore. Following conventional boring with a twist drill, the bore has a concentricity of around 5 µm. Micro Bore Sizing then goes on to create a concentricity more accurate than 0.1 µm (Fig. 1, left. The measurement also indicates a cylindricity of 0.17 µm and a maximum parallelism value of 0.19 µm over a measurement length of 2 mm. See figure 1, right.

Roughness values of 0.1 to 0.2 µm can be achieved

Diameter and dimensional accuracy: Using the MBS process, a bore can be transformed from the starting to the desired final diameter, at the same time adhering to a narrow tolerance band. Fig. 2 illustrates a non-rotationally symmetrical watch blank made of steel. Here, the bearing surfaces for the jewels are machined using MBS to an accuracy of 2 µm, allowing optimum press fitting of the watch jewel to be guaranteed and effectively preventing defects in the watch jewel or bottom plate when the jewel is pressed into place. The gentle clamping and machining process used for MBS ensure that thin webs between the bore and other contours are not compromised. Another important requirement in the machining of bores is that the location of the bore should not change. MBS also addresses this key issue, as well as permitting strengthening of the bore surface, eliminating the need for a watch jewel and allowing the shaft to be mounted directly in the steel component. The surface roughness values and diameter accuracy can be brought down to the necessary tolerances with MBS.

Surface roughness: When using spark erosion as a boring method, typically roughness values R_z of 10 µm (rough eroding) or 1.5 µm (fine eroding) respectively are possible (Fig. 3). Using MBS, R_z values of 0.1 to 0.2 µm can be achieved.

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Machining and deburring linked with integrated brushing

When working with more ductile materials, even with extreme gentle machining action, burr formation as illustrated in Fig. 4, left, is inevitable. In the case of nozzles, tools and many other workpieces, the edge geometry plays a functionally decisive role, if we consider aspects such as the rate of flow and seal tightness, or inadmissibly loosening chips. A burr-free edge is consequently of particular importance. To achieve freedom from burr, it is now possible to integrate a brushing station into the bore machining process on the Uni-Bore 800. A typical sequence consequently consists of rough honing, finish honing and deburring. Fig. 4 right shows a bore after the deburring process.

Micro Bore Sizing was originally developed for microbores, but when applied on larger diameters also has a number of benefits to offer compared to conventional methods such as honing. It also provides system-related benefits when producing bores with transverse holes or recesses. On the Uni-Bore 800, small bores can be machined in non-rotationally symmetrical workpieces of the type used in inserts for the die making and injection moulding tool construction industry. In the ›MicroBore‹ machine model, the tool is automatically assembled in the machine from the coil. Examples include several million boreholes produced every month for the fibre optic industry on over 100 machines of this type. ∎

REFERENCES

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