

Honing and internal circular lapping of drill-holes in the 0.015 to 4 mm diameter range

Through-holes of high quality and precision

In the field of micro-engineering, the machining of small diameter holes presents a particular challenge which is made even harder with the processing of hard, brittle materials. Micro bore sizing is suggested here as an economical alternative.

BY PATRIC MIKHAIL

→ The miniaturization of products is gaining ground not only in electronics, analytical systems, the automotive industry, telecommunications and medical technology, but also in machine manufacture. The market is developing as dynamically as the national economic importance of micro-engineering itself and will grow to a significant extent in the coming years. This can be observed at every level of added value within this particular field [1].

In order to miniaturize successfully, more is often required than merely making everything smaller. Thus, even the choice of materials must be reassessed, given that the machining of ductile materials is particularly critical in the micro-engineering field. For most applications, even the slightest formation of burrs or plastic deformations is unacceptable [2]. For these reasons, the use of cemented carbide, ceramics, silicon

and polycrystalline diamonds (PCD) is gaining ground. Moreover, since conventional processing methods cannot be arbitrarily scaled down, it is often necessary for the entire system of the related tools and machines to be changed.

Conventional methods limited to a diameter of 1.2 mm

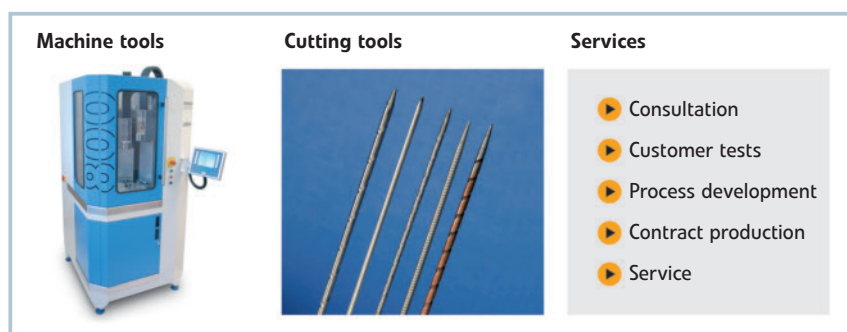
Brittle materials are predominantly ground and polished with the aid of diamonds as the cutting material. In micro-engineering, the processing of a drill-hole presents a particular challenge. Above all, problems lie in the difficulty of access to the machined surface and, not infrequently, the high aspect ratios involved (depth relative to diameter of the hole).

Conventional drilling, using machining tools or lasers, or by punching, eroding or shaping a core (powder injection molding, PIM) are economical methods which have succeeded in qualifying for micro-engineering applications. Thus, there is no

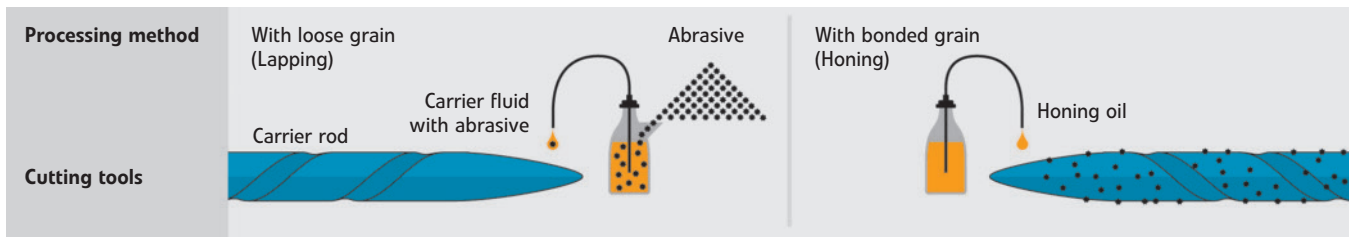
difficulty in making micro-holes efficiently, provided they are not subject to exacting demands for precision (shape, dimensional accuracy et cetera), quality of finish and consistency. While drill-holes with diameters greater than 2 mm can still be ground or conventionally honed, these techniques come up against their limits with diameters below 1.2 mm at the very latest.

Overall concept for processing minimal diameters

The firm of Microcut has recognized this situation and, with micro bore sizing (MBS) now offers an economical solution to the problem of machining holes down to a minimum diameter of 15 µm – particularly for use with hard materials [3, 4]. Easy to use processing systems permit shapes (diameter, roundness, parallelism, straightness, cylindricity) to be machined to comply with stringent tolerances and degrees of surface roughness to be specifically improved. To this end, micro bore sizing was conceived as an integrated system comprising machine, tool and backup services (Fig. 1). With the MBS, machining is performed with precision tools under controlled force. Given that processing takes place cold, no structurally related weakening of the material occurs in the marginal zones. With the ›Unibore 800‹ machine, two processing methods are available for the diameter range from 0.4 to 4 mm (Fig. 2). The choice of method is determined, first and foremost, by the material to be processed.



1 Microcut's micro bore sizing (MBS) is designed as an integrated system comprising machine tools, cutting tools and services



2 The two processing methods offered by the MBS system are lapping with a loose abrasive (left) and honing with galvanically bonded grain

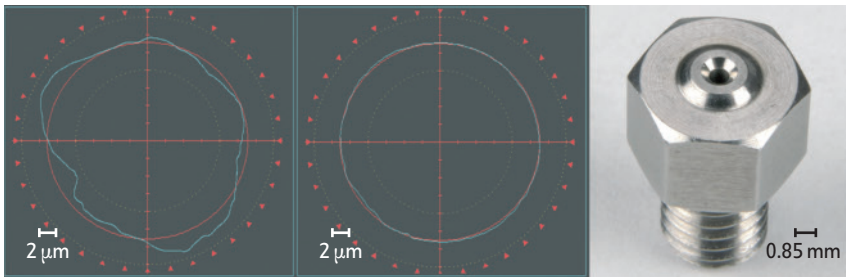
With the first method (lapping), hard, brittle materials such as ceramics, sapphire and cemented carbide with a loose grain are preferred if it is necessary to meet exacting standards of surface quality. A tool consists of a carrier rod or wire, a carrier fluid and an abrasive (typically, micro-diamond). During processing, the carrier rod is wetted with the grinding agent and introduced into the hole (Fig. 2). The conical element then enlarges the basic hole, while the cylindrical section ensures a consistent final diameter, even when high unit quantities are involved. Thanks to the precision of the carrier rod and consistent

processing conditions, the user is spared the need for tedious probing to check the desired diameters and shapes.

Second method is used for softer materials

Honing is available as the second method in micro bore sizing. The term ›honing‹ applies when processing is carried out with a tool containing a galvanically bonded grain (Fig. 2). This method, in particular, is used for softer materials, such as steel. The shape of the carrier rod is the same as for the first method but the diamond grain is securely bonded to the carrier. The range of MBS

machines comprises specific, application related models and universal, modular versions. Criteria for the choice of machine are the diameter and shape of the hole, the size and symmetry of the workpiece, the material and the amount to be removed, and the relevant batch size. An important element of the MBS system is the processing tools, in that their accuracy determines the accuracy of the diameter. With the choice of tool, moreover, surface roughness and abrading performance can be controlled. The one-piece tools feature conical and cylindrical parts and are made to the required degree of accuracy, either >>>



3 Measurement of the hole in a nozzle shows that the secondary processing of the diameter (0.85 mm) using MBS ensures a roundness of 0.2 µm



4 A hole is made in the ›hammer‹ (left) to a final diameter of 1.296 mm, accurate to within 2 µm. The hammer forms part of the ›Pellaton‹ watch winding mechanism (right)

» as standard tools or for specific, application related purposes. Important criteria for the tool are its shape, the chip groove, the size of the diamond grain and a coating which primarily depends on the material to be processed. With certain production machines, the carrier wire is fed to the machine from a reel, so that the worn tool is continuously replaced. The MBS system is rounded off by a range of services comprising advice, process formulation, customer trials, contract work and machine servicing.

Typical applications reveal the potential of the MBS technique

The dimensions, shape and surface finish of a drill-hole are inextricably linked. If, for example, the specified tolerance for a diameter is 3 µm, a roundness of precisely 1 µm must be guaranteed. Surface roughness must also conform to a certain relationship with dimensional accuracy and the size and shape of the hole. With the MBS method, geometric truth is supplied by the tool and is then improved still further by superimposed movements (rotary and linear). Thus, the roundness of the hole typically proves to be more accurate than that of the tool. The hole in the nozzle in Fig.3 was drilled conventionally with a twist drill to a roundness of 5 µm. Sub-

sequent processing with MBS results in a roundness of 0.2 µm. Moreover, measurements made with a ›Taly Rond‹ measuring instrument registered a cylindricity of 0.37 µm and a maximum parallelism of 0.36 µm.

Fig. 4 depicts (on the left) a steel workpiece which is not rotationally symmetrical. The component, bearing the designation ›hammer‹, is used in the ›Pellaton‹ winding mechanisms of the watches made by IWC, based in Schaffhausen, Switzerland (Fig. 4, right). The Pellaton is widely regarded as one of the most efficient and reliable bi-directional systems for winding mechanical watches. The hammer features a hole with a final diameter of 1.296 mm, made by the micro bore sizing method. In this case, the seat for a bearing jewel must be machined to an accuracy of 2 µm. In this way, defects in the hammer and jewel are prevented and the optimum fit of the seat is assured. Thanks to the careful clamping and machining methods employed, the thin bridge between the hole and outer contour is unharmed and the position of the hole remains unchanged.

A standard was developed

At the Physikalisch-Technische Bundesanstalt (Federal Institute of Physics and Technology) in Braunschweig, Germany, work

is being done with the aim of reducing the uncertainty of measurements by means of opto-tactile probes, given that micro-holes with diameters of 0.2 mm are functionally decisive factors in many areas of industry. Examples include fuel injectors and the drawing plates used in the wire making and textile industries. Tolerances in the sub-micrometer range place exacting demands on the measurement of such holes. In order to calibrate the measuring instruments to the optimum extent, a standard for micro-holes with a high aspect ratio was developed in Braunschweig and made the subject of a patent application [5].

It proved impossible to achieve the requisite levels of finish and roundness laid down in the standard by means of erosion. With micro bore sizing, by contrast, the criteria were decisively improved upon. The upper part of Fig. 5 depicts a finely eroded surface, while the surface processed with MBS can be seen in the lower part. With the eroding of holes, degrees of roughness (R_z) of 10 µm (coarsely eroded) and 1.5 µm (finely eroded) can typically be achieved. With the MBS method, R_z values of 0.1 to 0.2 µm are obtained.

In precision engineering, most tools and guides call for extremely precise man-

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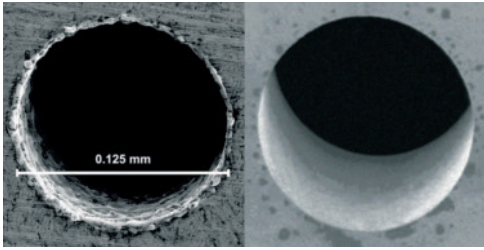
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5 In the formulation of a standard for micro-holes with a high aspect ratio, eroding (left) was followed by the MBS process (right) which enabled Rz values of 0.1 to 0.2 μm to be achieved

ufacturing tolerances. In particular, deep holes ($30\times D$ or deeper) of small diameters can only be made at considerable cost in respect of diametric and positional tolerances. With a Unibore 800 and a rotary table for 64 parts, by contrast, the firm of Make, Heimberg (Switzerland) can automatically calibrate holes from 0.4 mm in diameter to a high standard of quality. The part concerned is used both as a drilling and guide bush in a variety of industries.

Micro bore sizing is suitable for through-holes in the diameter range from 15 μm to 4 mm. Typical workpieces, such as nozzles, fine tubes and bushes, fall into this category. With the Unibore 800, holes can be made in non rotationally symmetrical workpieces of the type used, for example, in the manufacture of stamping and injection molding dies. It is preferable for hard materials, such as ceramics and cemented carbides, to be processed in this way. It is also possible, however, for the technique to be used to machine softer materials, such as steel, and non conductive materials, such as glass. The range of applications for micro bore sizing extends from the manufacture of fiber optics, medical products and semiconductors to the automotive and tool making industries. ■

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