Good Vibrations for Die-Sinking EDM

Piezo Actuators Accelerate Microstructuring

Actuators based on the piezo effect move heavy loads with resolutions in the sub-nanometer range and response times below one millisecond, enabling dynamic operation at high scanning frequencies. Moreover, since they have no moving parts in the conventional sense, piezo actuators are not only very reliable, but also are maintenance-free. Diverse applications, ranging from medical and metering technology, to photonics, semiconductor technology, automation and production technology benefit from these characteristics. In all these applications, piezoceramic actuators contribute to advances in technology. For example, when die-sinking EDM is used to produce precision components, piezo actuators help to drastically shorten the production times.

Fig. 1 Sonodrive 300 vibratory spindle (Figure: ICT-IMM)

The increasing complexity of products and processes requires the production processes to constantly increase throughput, precision, geometric diversity and accurate repeatability. At the same time, the trend in automation is toward miniaturization.

So it is hardly surprising that also in the field of die-sinking EDM, microstructured precision components are now manufactured, often in large piece quantities. Examples include the manufacture of filter elements or injection nozzles for the automotive industry. This in turn drives the need for economizing production processes associated with microstructuring: Cost and resource efficiency play important roles in this context.

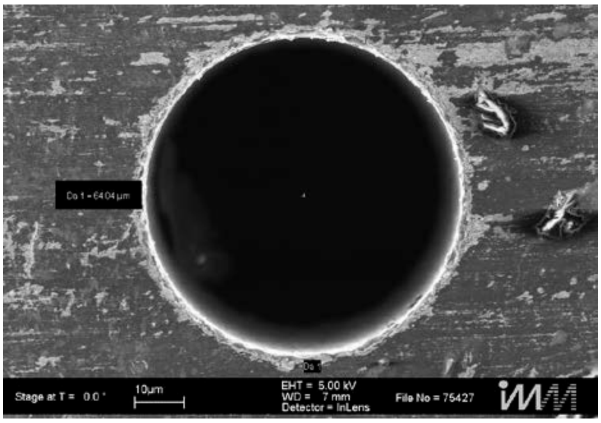

Fig. 2 A hole 64 µm in diameter produced with a die-sinking EDM machine equipped with a vibratory drilling spindle. The deviation from concentricity and cylindricity of the hole is in each case only 1 µm (Figure: ICT-IMM)

Faster Die-Sinking EDM Operations with a Vibratory Spindle

This topic has been taken up by the Institute for Microtechnology in Mainz (ICT-IMM), which has become part of the Fraunhofer Gesellschaft in 2014. The Sonodrive 300 (Fig. 1) is a serial-production vibratory spindle, which, in high-precision microdrilling operations, can cut machining times by up to 60 %, compared with standard equipment, employing a patented process (Fig. 2).

The spindle rotates and vibrates simultaneously, preventing the particles produced in EDM from being deposited in the hole, thereby eliminating the need to machine them again. In conventional methods, this is unavoidable, because the small electrode distances do not allow any flushing in the micrometer range. Depending on the material to be machined and the job at hand, the vibration path can be set and adjusted at any time during the process.

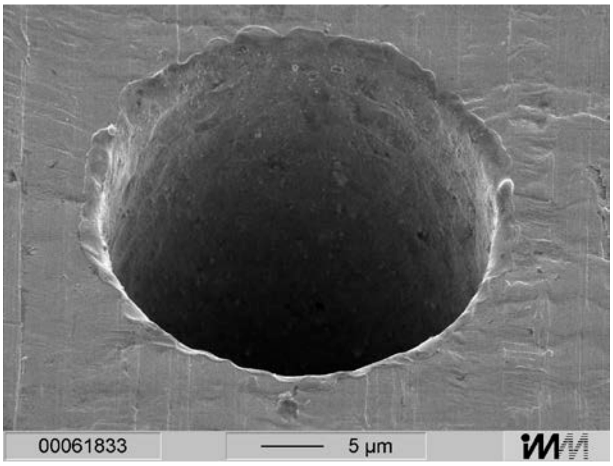

Fig. 3 A hole only 20 µm in diameter produced with a die-sinking EDM machine equipped with a vibratory drilling spindle (Figure: ICT-IMM)

Compared with conventional methods, this delivers substantial speed benefits, accelerating the entire production process (Fig. 3). With a 0.2 mm diameter blind hole in a 1.0 mm thick VA material, the machining time in a test on a EA12 die-sinking EDM machine from Mitsubishi Electric was reduced from 200 to slightly below 80 seconds. On an Agie Compact die-sinking EDM machine, the 0.2 mm diameter through-hole in a 0.4 mm thick VA material was also obtained 60 % faster through the use of a vibratory spindle (Fig. 4).

The new spindle principle combines high concentricity tolerance of 1 to 2 µm absolute at a revolution of up to 3,500 min-1 with a high-frequency vibration of max. 300 Hz and a stroke of up to 15 µm. The spindle fits in with all commercially available die-sinking EDM machines as "Plug & Play" solution. The matching miniaturized wire pay-off device likewise developed by ICT-IMM can also be easily integrated. This allows the concentricity tolerance to be reduced to 1 µm absolute.

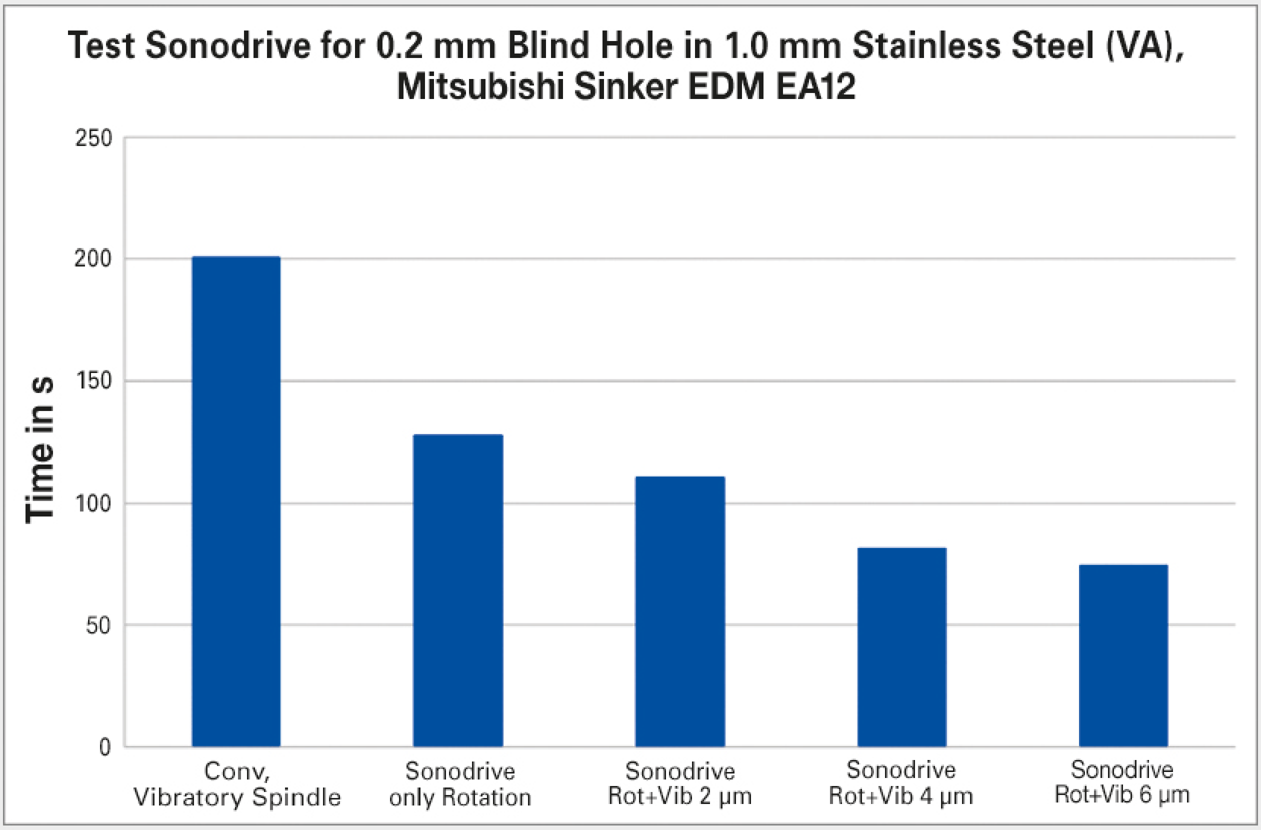

Fig. 4 With a 0.2 mm diameter blind hole in a 1.0 mm thick VA material, the machining time in a test on a EA12 die-sinking EDM machine from Mitsubishi Electric was reduced from 200 to slightly below 80 seconds (Figure: ICT-IMM)

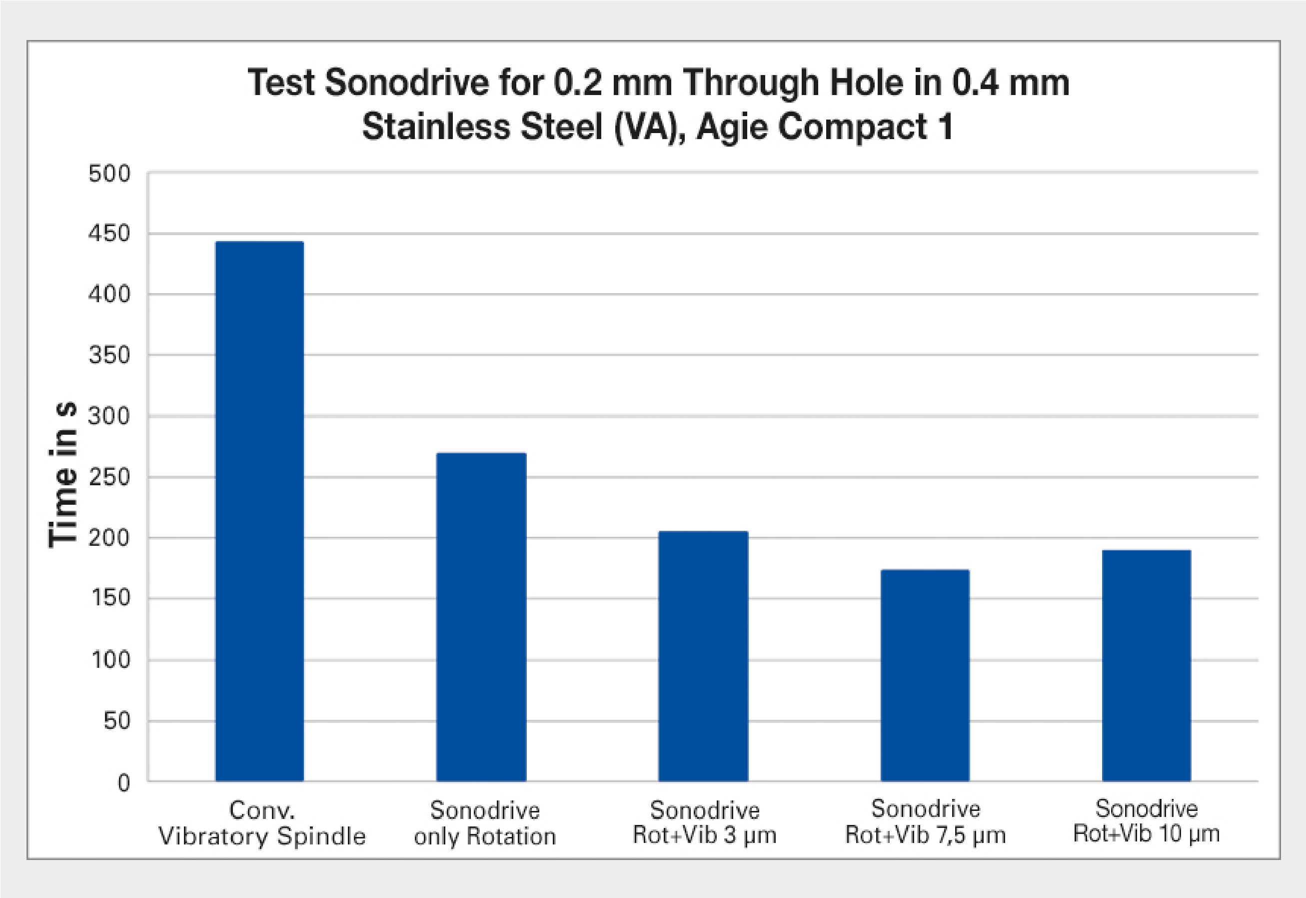

Fig. 5 On an Agie Compact die-sinking EDM machine, the 0.2 mm diameter through-hole in a 0.4 mm thick VA material was also obtained approx. 60 % faster through the use of a vibratory spindle (Figure: ICT-IMM)

Piezo Actuator Ensures Vibration

This technological leap for microstructuring has been achieved by combining just the right amount of know-how with components of high technical quality. A piezo actuator (Fig. 5) from the wide product range of Physik Instrumente (PI), headquartered in Karlsruhe, Germany, ensures vibration.

There are several good reasons why PI was chosen. The creation of vibrations virtually is a classic piezo application, because the piezo element starts to oscillate when an AC voltage is applied. This means that piezo actuators convert voltage directly into mechanical displacement. They achieve typical travel ranges of a few hundred micrometers and high dynamics with frequencies of up to several hundred hertz. The short response times of the piezos naturally also benefit the application as a vibration drive.

Fig. 6 Compact piezo actuator: The generation of vibrations is a classic piezo application (Figure: PI)

With its height of 25 mm at a diameter of 50 mm and its inner aperture of 25 mm, the selected actuator could also easily be integrated in the vibratory spindle (Fig. 7).

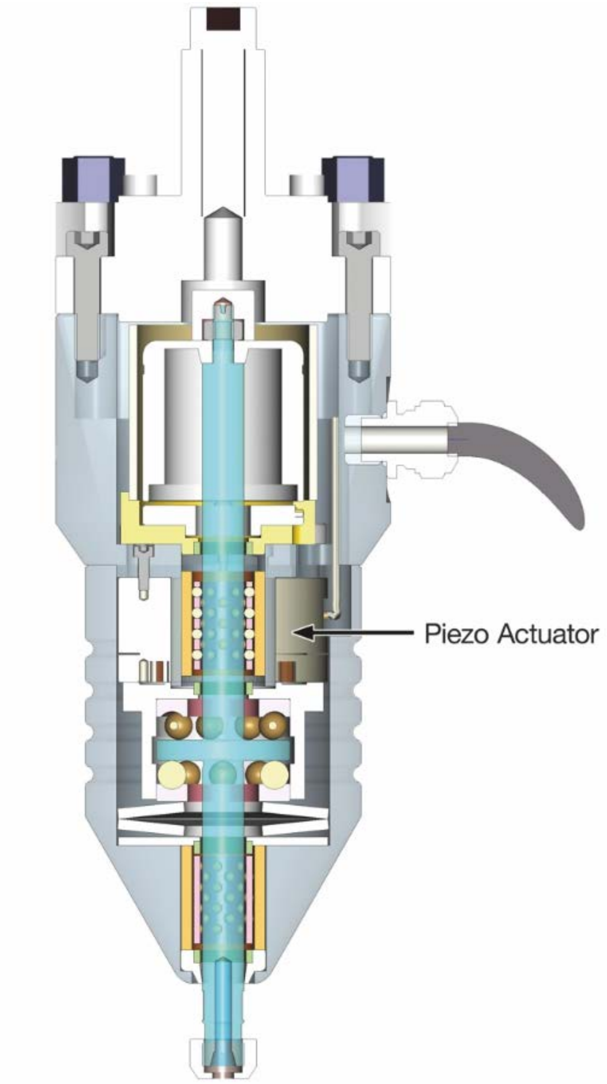

Fig. 7 The piezo actuator could be integrated into the vibratory spindle in a space-saving arrangement (Figure: ICT-IMM)

Since piezos are also suitable for large loads, the permanent motion of the spindle, whose weight varies between about 250 and 450 g, depending on the electrode, was no problem for the small drive. If need be, it can lift more than one kilogram. In contrast, electromechanical components for vibration generation were not an option for this application. Due to their structure and larger dimensions, it would not have been possible to integrate them into a useful unit for practical use.

There are still further arguments that speak for the use of piezos: Since the motion is based on crystalline solid-state effects, there is no danger of abrasion with this technology and there are no cogwheels, bearings or other mechanical parts subject to wear.

This makes the piezo actuator maintenance-free. This is an important characteristic, given that the piezo actuator operates throughout the entire machining operation. It has already proven its reliability, for example, in prototypes of the vibratory spindle, which has been operating at ICT-IMM for about four years now, where it has by now completed approximately 100 million operating cycles.

The piezo actuator is driven by an efficient, pulse-width-modulated high-power voltage amplifier, also from PI (Fig. 8). This amplifier is especially designed for the demands of low-voltage piezo actuators. At a peak output power of up to 280 W and an average output power of up to 100 W, it can supply and consume a peak current of up to 2,000 mA. This allows dynamic operation of piezo actuators of high capacity at a bandwidth up to the kilohertz range, more than is required for micro EDM.

Fig. 8 At a peak output power of up to 280 W and an average output power of up to 100 W, the amplifier especially designed for the demands of low-voltage piezo actuators can supply and consume a peak current of up to 2,000 m (Figure: PI)

A vibration-supported electrode chuck also saves time

Piezo actuators have also been tested and proven in a vibration-supported electrode chuck, which is also suitable as "Plug & Play" solution for all commercially available die-sinking EDM machines and clamping systems and has a very compact structure of 80 × 80 × 150 mm (Fig. 9).

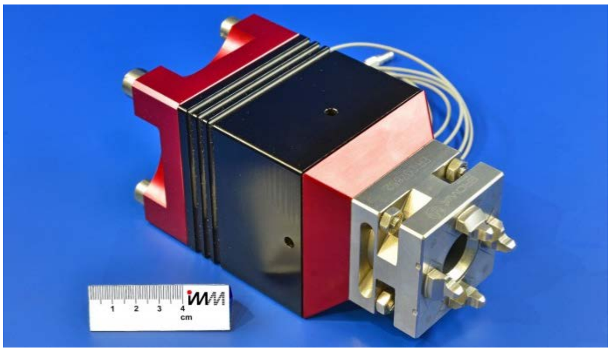

Fig. 9 Thanks to the piezo actuator likewise vibration-supported: The electrode chuck Microvibe 300 for micro EDM (Figure: ICT-IMM)

Here, too, the 300-Hz vibrations at an adjustable stroke of up to 15 µm accelerate the production process considerably: Thus, a long-term experiment with a hard-metal electrode (0.2 × 5 mm) and a sinking depth of 7 mm resulted in a time saving of 70 %. Production time was reduced from 17 hours and 20 minutes to 5 hours and 15 minutes. This can benefit many areas of application. Typical examples are micromachining, tool-making and mold-making and the manufacture of components for medical technology, metrology and machine technology. Piezo actuators used as vibration generators have thus made a substantial contribution to advancing the technology of die-sinking EDM to the lowest micrometer range.

About the Fraunhofer ICT-IMM in Mainz

Fraunhofer ICT-IMM is building a bridge between basic research and application, since the developments pass through the institute from the concept stage to basic and application-oriented research and onto their implementation in customer-specific solutions with product relevance. In doing so, they combine several thematic areas in which the replies to economically and socially relevant problems of the future are worked out.

Fraunhofer ICT-IMM conducts research and development in the core competences of Decentralized and Mobile Energy Technology, Continuous Chemical Process Engineering, Medical Sensors and Technical Sensors, Microfluidic Analysis Systems and Nanoparticle Technologies. The knowledge and developments gained from these fields are mainly applied in the business divisions of Energy and Environment, Chemistry, Process Engineering, Aerospace, Safety and Industrial Analytical Applications.

These product areas are supplemented on the technological side by know-how in mechanical precision machining processes, spark erosion, laser material machining and by a series of chemical and physical structuring methods for use in clean rooms.

About PI

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and fifteen sales and service offices abroad, the privately managed company operates globally.

Over 850 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

The required piezoceramic elements are manufactured by its subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications as well as parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.

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