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APPLICATION OF THE MICRO WATER ABRASIVE INJECTOR FINE JET FOR PRECISION MACHINING

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Abstract: *This paper presents some basics of the innovative developed reliable 2D-precision processing by the abrasive injector waterjet with a reduced jet diameter of 0.3 mm and below. Particularly the challenging drilling and cutting of brittle materials, such as silicon and glass, with this fine jet is explained. Furthermore the use of this novel precision machining technology for the 3D-5axis precision processing is discussed.*
Key words: *abrasive waterjet cutting, precision machining*

1. INTRODUCTION

The conventional abrasive injector waterjet cutting is proved to be usable for versatile machining tasks since a long time. But it is very limited in its precision and its applicability for precision machining (Loeser et al., 2009b; Miller, 2004; Liu, 2010). This served as a starting point for the research activities carried out in a cooperation between the Chemnitz University of Technology and the ATECH GmbH. Beside the unsatisfactoring kinematic capabilities/accuracy of the leading machines the standard abrasive injector waterjet cutting uses an abrasive waterjet diameter/kerf width of only 1.0 to 0.8 mm. The fine abrasive injector waterjet cutting reaches a kerf width of about 0.5 mm. When the now state of the art kerf width is 0.3 mm (Miller, 2004) or below (Vollrath, 2008), it is called micro abrasive waterjet cutting (Loeser et al., 2010b). Machinable tolerances, attributes or bridges in contours are much smaller than the jet diameter. Table 1 explains this classification for the abrasive injector waterjet in more detail.

Miller (Miller 2004) shows trials of a micromachining with abrasive suspension jets with a strongly reduced suspension jet diameter including the possibilities for an appropriate suspension valve. Among other things Liu (Liu, 2010) explains tests with a preproduction nozzle. Here the potential minimum jet diameter / kerf size is expected to be about 200 µm (the same as in: Moriarty, 2009; Loeser, 2010a&b; Vollrath, 2008). At this size the industrial practicability ends (Loeser et al., 2010b). Liu further presents the tentative use of "stencil-aided waterjet stage" for a further reduction of the jet diameter. Under the conditions of a reduced injector jet diameter, the drilling of brittle materials is very challenging, as explained later on. A smaller jet diameter results in a smaller kerf and also reaches new spheres for the accuracy of inner corners and inner outlines. So the micro abrasive injector waterjet cutting achieves a significantly higher precision of the cutted contours. The finer grained abrasive material (commonly used: garnet sand of different groups of sizes between 63 µm and max. 125 µm) improves the quality of the cut surface. The micro water abrasive injector fine jet is also better suited for the drilling and cutting of coated, sensible or multilayered materials (Loeser et al., 2010b). The precision machining with the abrasive injector waterjet is far more than only a reduction of the jet diameter. As explained in (Loeser et al., 2010b) e.g. the industrial practicability, a new technology and a stabilization of the cutting process are essential. This is especially important for a precision machining of brittle materials as glass and silicon. It was necessary to develope a new cutting head, different leading machines and the technology (Loeser et al. 2009a).

	Standard abrasive injector waterjet cutting	**Fine-abrasive injector waterjet cutting**	**Micro-abrasive injector waterjet cutting**
Kerf width	ca. 0.8 mm	ca. 0.5 mm	ca. 0.3 mm or below
Accuracy of contours	± 0.1…0.5 mm	± 0.05…0.2 mm	± 0.02…0.1 mm or less
Gauge of materials	1…100 mm	0.2…50 mm	0.1…20 mm
For items	measuring the minimum size of ca. 30 mm or above	measuring the minimum size of ca. 10 mm or above	measuring the minimum size of ca. 3 mm or above
Notes	State of the art in the last 20 years	State of the art in the last few years	Reliably implemented by ATECH in 2009

Tab. 1. Division of the abrasive injector waterjet cutting (cf. Seim, 2009; Loeser et al., 2010b)

2. PRECISION DRILLING AND CUTTING OF GLASS AND SILICON

Compared to other materials the cutting and especially drilling of brittle materials like glass and silicon is much more challenging. The drilling is nessecary for the manufacturing of inner contours and done with lower water pressure to reduce the risk of damaging these brittle materials. A special technology and newly developed facilities are required in addition to the equipment (cutting head, leading machine) and technology already used for the developed micro abrasive injector waterjet fine cutting - in particular to stabilize the drilling process under these conditions (Loeser et al. 2010b; Loeser et al. 2009a).

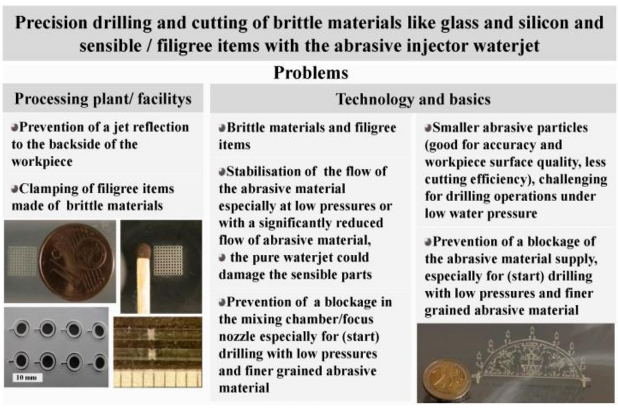

Fig. 1. Tasks and samples of parts for a precision machining of brittle materials like silicon and glass

So figure 1 shows main problems, samples of parts and tasks for the realisation of this special application of precision machining with an abrasive injector waterjet in more detail. A lost flow of abrasive material for example could lead to a destruction of the sensitive materials through the kinetic energy of the pure waterjet. As pictured, different work had to be done in the spheres of the processing plant and supplementary facilities as well as in the development of the technological conditions. The next figure (figure 2) presents summarised the important results and parameters of this work at a glance.

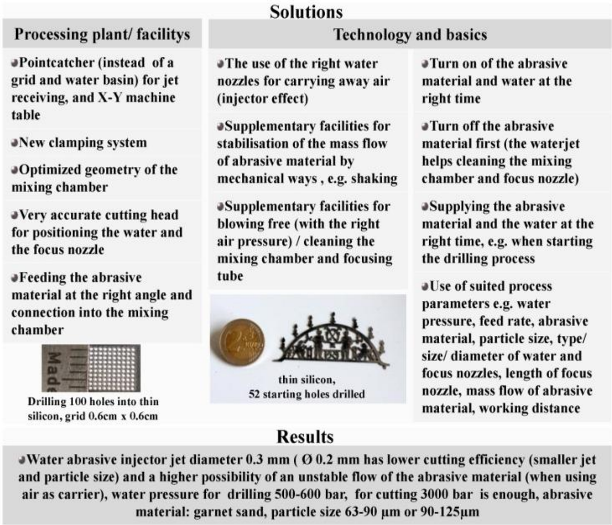

Fig.2: Solutions for the drilling and cutting of brittle materials

3. ACTUAL RESEARCH WORKS

Within a further research project in a partnership between the Chemnitz University of Technology and the ATECH GmbH and based on the experiences of the 2D-precision machining with an abrasive injector waterjet, this technology is used for a new 3D-5axis precision manufacturing with the abrasive injector waterjet. Main aspects for this task field are presented in the next figure (figure 3). Apart from fundamental basic explorations, including the occupational safety, the suitable kinematic concept for the leading machine was specified. Furthermore in connection with the development of necessary machine parts, tests for the 3D-precision machining, especially the determination of the cutting parameters had been successfully executed. The CAM-based modelling of the real micro water abrasive injector fine jet form, including the compensation of deviations, is currently under way.

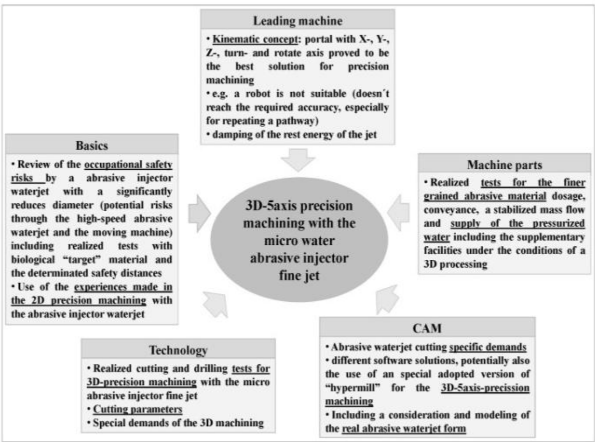

Fig. 3: Realisation of the 3D-5axis precision machining with an abrasive injector waterjet

4. CONCLUSION

The successfully implemented drilling and cutting of glass and silicon and the ongoing research works for the 3D-machining had been the key aspects of this article. After the favourable realisation of a 2D-precision machining with the micro water abrasive injector fine jet also the more special application of drilling and cutting of brittle materials as silicon and glass was realized in a reliable and stable manner. Especially the implementation of the challenging drilling (e.g. start holes) with an reduced water pressure and a reduced but nevertheless secure and stable mass flow of the finer grained abrasive material was eminent important. When drilling brittle materials also a circling movement of the jet can be beneficial. As claimed in the result of the presented research works new applications for the abrasive waterjet cutting were opened up. Now the next step is the utilisation of the micro water abrasive injector fine jet for a 3D-5axis precision machining.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Liu, H.-T. (2010): Waterjet technology for machining fine features pertaining to micromachining, In: *Journal of Manufacturing Processes 12*, p.8-18, www.elsevier.com/locate/manpro

Löser, C.; Seim, T.; Pilz, R. & Dürr, H. (2009a): Präzisionsbearbeitung mit dem Wasserabrasivinjektorstrahl, In: *Zeitschrift für wirtschaftlichen Fabrikbetrieb (ZWF)* Jahrg. 104 (2009) 7-8, p. 632-636

Löser, C.; Pilz. R.; Seim. T. & Dürr, H. (2009b): Wasserabrasivstrahlfeinschneiden, In: *Scientific Reports, Journal of the University of Applied Sciences Mittweida*, Prozessentwicklung für Teilefertigung und Montage, Nr. 3, 2009, p.37-40

Löser, C.; Thehos, K. (2010a): Schneiden- auf den Hundertstelmillimeter genau, Professur Fertigungslehre und ATECH GmbH erhöhen Präzision des Wasserabrasivstrahlschneidens, In: *TU-Spektrum, Das Magazin der Technischen Universität Chemnitz*, 1/2010, ISSN 0946-1817, p.31

Löser, C.; Pilz, R.; Seim, T. & Dürr, H. (2010b): “Abrasive waterjet fine cutting based on the injector principle – Technology and processing plant for the precision cutting with the abrasive injector waterjet”, In: *Proceedings of the 20th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM 2010*, California State University East Bay, USA, 12.-14. 07.2010, p. 635-642

Miller, D. S. (2004): Micromachining with abrasive waterjets, In: *Journal of Materials Processing Technology 149 (2004)*, www.elsevier.com/locate/jmatprotec, p. 37-42

Moriarty, T. (2009): World premier showing of new kind of machining centre, www.waterjet.se, *Accessed* 12.11.2009

Seim, T. (2009): *brochure ATECH GmbH Chemnitz*, June 2009

Vollrath, K. (2008): Wasserstrahl schneidet gut ab in der Mikroproduktion, *VDInachrichten*, Nr. 28, 11.07.2008