

EVALUATION OF MICROMACHINING PROCESSES FOR FABRICATION OF MICRO-CHANNELS

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Abstract - Micromachining is the most diverse category of manufacturing processes available for fabricating parts which are less than 1 mm in size. Micromachining covers any technique in which tools are used to cut, bond, form, deform, or remove material for the purpose of creation of the channels or heat exchanger assembly. This paper provides a summary of the three types of manufacturing processes currently being used in the fabrication of micro channels. The three micromachining techniques compared in this research are wire-cut EDM, micro-slotting and micro- milling.

I. INTRODUCTION

Micromachining is not only a simple miniaturization of processes using macroscopic tools. As a matter of fact, a lot of specific concerns have to be met for successful fabrication of microstructures. Micromachining techniques can be divided into two main categories: Processes working with undefined cutting edges e.g. grinding, honing, lapping, and processes are using defined cutting edges like drilling, milling and slotting. Especially grinding works at high cutting rates. Most of the cutting energy is transferred into heat and absorbed by the work piece. The properties of the work piece can be altered or decreased by surface cracks and internal stress due to external forces as well as by micro-structural changes due to excessive heat.[4]

Electrical Discharge Machining (EDM) is a non-contact machining process for conductive materials that has been applied for more than 40 years. It has been proved particularly useful such as in mold making, tool making industry micro-structures including micro-shaft, micro-holes, specially shaped micro-holes, and micro-slots. Due to its high accuracy and the good surface quality that it can be produced, EDM is potentially very suitable for micro-fabrication. The EDM process utilizes the thermo-electric energy released between a work-piece and a highly charged electrode. A pulsed electrical discharge across the small gap (known as the “spark” gap) between the work-piece and the electrode removes material from the work-piece through melting and evaporation [5]

The end-milling process is one of the most widely used material removal processes in industry. Micro-end-milling refers to a basic end milling process using tools down to 10 μm in diameter. Because the geometries that can be produced by micro-end-milling are more flexible than those produced by lithography, this process is potentially useful as a companion to lithography based MEMS processing techniques. Furthermore, a larger range of materials can be processed using this process. This process is also important for the production of meso-scale parts (parts on the order of 1mm to 1cm) which are too large for lithography techniques, but too small for many other traditional

processing techniques. Micro-end-milling is essentially the same process as end-milling on the macro scale. However, there are a few important differences. As the tool diameter becomes smaller, the rotational speed theoretically required to achieve the recommended cutting speed is far above the technical limit of the available spindles. Another concern with micro-milling is that run-out can become comparable to the diameter of tools. The run-out to tool diameter ratio becomes much larger for micro-end-milling than for traditional milling.[6]

Micro slotting tools are much more stable than micro end mills because they are not rotationally symmetric and much more rigid. By micro slotting, minimum sizes of trenches can be reduced to about 15 μm in width at an aspect ratio of about ten. Such dimensions cannot be achieved by micro milling.

In the present work, Different channels of 600 μm , 500 μm and 300 μm are fabricated using above mentioned techniques. The channel fabricated is compared on the basis for surface finish, time taken for fabrication, etc.

II. FABRICATION OF THE TEST PIECE

In order to study the micromachining process, a standard aluminum test piece was manufactured. In the first process, three test pieces consists of micro-channels in parallel having individual width of 600 μm , 500 μm and 300 μm under constant depth of 2.0 mm. The rectangular micro-channels were fabricated using a high-accuracy CNC wire-cut electrical discharge machine (EDM). Wire-Cut EDM from Sodick Technologies India Private Limited, Model: AG600L was used

In the second process, similar geometrical dimensions of the test piece are selected, but the a slotting saw of 0.5, 0.4 and 0.3 mm width and 50 mm diameter was used on the Universal Milling Machine. In the present work slotting saw operation was done on JP-M2 Universal Milling Machine.

The micro milling was done using Long Reach Mini 2 Flute Micro Mills Z72010 and Z72020, and has said dimensions of the micro-channels. The micro end mill cutter was operated on MTAB, XL Mill CNC milling trainer.

III. RESULTS

In order to compare the micromachining processes, same dimensions of the part were selected for studied three cases. The surface roughness value range for all the three studied micro machining processes are compared and reproduced in Table 1.1. It was observed that the surface roughness value even vary from channel to channel, as the tool/wire will wear as the machining time increases, that is the reason of putting the RMS value range for a particular process and not absolute value. The surface roughness values of individual channel are shown in Figure 1-3 for all the studied processes.

Table 1.1 Surface Roughness (RMS value)

Process	RMS Value
Wire cut EDM	1.20-6.90 μm
Slotting Saw	12.8-20.80 μm
Micro milling	4.12-10.20 μm

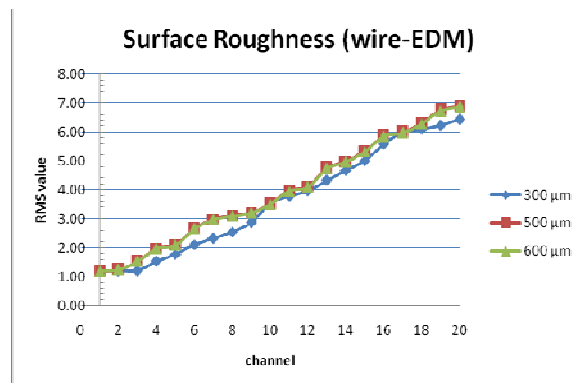


Fig.1: Surface roughness value of micro-channel fabricated by wire-cut EDM

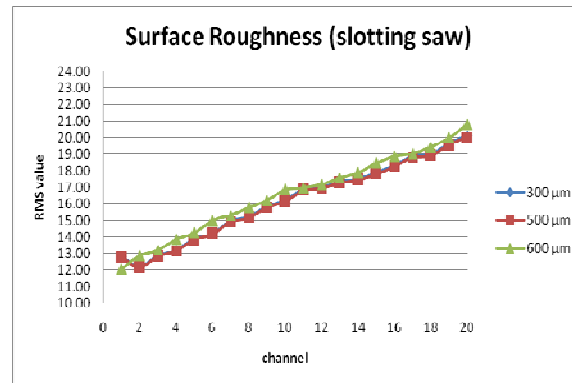


Fig.2: Surface roughness value of micro-channel fabricated by slotting saw

Table 1.2 shows the time taken to complete the machining process of a single test piece using studied three micro machining process. It was observed that maximum time was taken for the wire EDM processes, the reason may be attributed due to more fixation time taken for the wire. Second among the three processes was micro milling. The important point to look into micro milling was that the whole milling process was done at high rpm, at low rpm the milling tool break more often, leading to time consumption and more cost. The slotting saw fabrication method was easy to operate but the surface finish was much less than the studied two processes. Figure 4 shows the microscopic image of the fabricated micro channel made by EDM process.

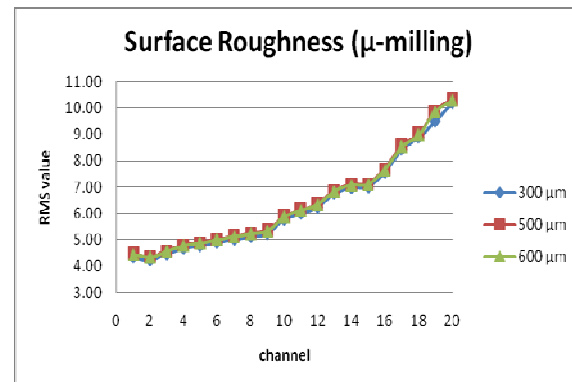


Fig.3: Surface roughness value of micro-channel fabricated by micro milling

Table 1.2 Time taken to complete machining process (including tooling)

Process/ Test piece	Wire cut EDM	Slotting Saw	Micro milling
Test piece-1 (micro-channel width = 600 μm)	141 minutes (stand alone)	89 minutes (stand alone)	101 minutes (stand alone)
Test piece-1 (micro-channel width = 500 μm)	147 minutes (stand alone)	90 minutes (stand alone)	102 minutes (stand alone)
Test piece-1 (micro-channel width = 300 μm)	152 minutes (stand alone)	98 minutes (stand alone)	112 minutes (stand alone)

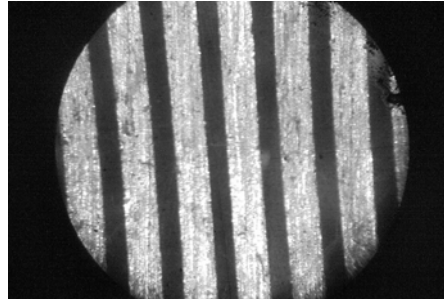


Fig.4: Microscopic image of micro-channel fabricated by wire-cut EDM

IV. CONCLUSIONS

- The surface finish of fabricated micro-channel in case of wire-cut EDM was observed to be superior than using micro end mill cutter, followed by those from slotting saw.
- The time taken to finish the job using wire-cut EDM was highest.
- The least time taken to finish the same job was using slotting saw.
- The micro machining operation using end mill cutter has intermediate surface finish but at lesser time.
- The cost of operating the wire-cut EDM was highest, followed by end mill cutter and slotting saw.

REFERENCES

- [1] Katz Z., Tibbles C.J., "Analysis of Micro-scale EDM process", International Journal of Advanced Manufacturing Technologies, 25 Vol. 5, No. 9-10, pp. 923-928, 2005.
- [2] Guanrong Hang, GuohuiCaol, Zaicheng Wang, Jing Tang, Zhenlong Wang and Wansheng Zhao, "Micro-EDM Milling of Micro Platinum Hemisphere", Proceedings of the 1st IEEE International Conference on Nano/Micro Engineered and Molecular Systems January 18 - 21, 2006, Zhuhai, China
- [3] Chris J. Morgan, R. Ryan Vallance, Eric R. Marsh, "Micro-machining and micro-grinding with tools fabricated by micro electro-discharge machining", Int. J. of Nanomanufacturing, Vol.1, No.2, pp. 242 – 258, 2006.
- [4] PR.Periyanan, U.Natarajan, S.H.Yang, "A study on the machining parameters optimization of micro-end milling process", International Journal of Engineering, Science and Technology, Vol. 3, No. 6, pp. 237-246, 2011.
- [5] Wang W., Kweon S.H., Yang. S.H. "A study on roughness of the micro end milled surface produced by a miniature machine tool", J. Mater. Process. Technol., Vol. 162-163, pp. 702-708. , 2005.
- [6] Yang K., Liang Y.C., Zhen K.N., Bai Q.S., Chen W.Q. , "Tool edge radius effect on cutting temperature in micro end milling process", Int J Adv Manuf Technol, Vol. 52, pp. 905–912, 2011.
- [7] D. Dornfeld, S. Min,Y. Takeuchi, "Recent Advances in Mechanical Micromachining", CIRP Annals - Manufacturing Technology, Vol. 55, Issue 2, pp. 745–768, 2006.