World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

A study of micro-mechanical cutting

Xin Zhong [a], Shuai Wang [b], Fuwei Lv [c], and Qiyu Liu[d]

College of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, 266590, China.

[a]zhongxinlulu@163.com, [b]2430310604@qq.com, [c]673716592@qq.com,

[d]1076926733@qq.com

Abstract: The use of micro-machined parts in terms of speed, economy, capability, and expanded material range makes micro-manufacturing (also known as precision engineering) an important choice. One of the main components of micromechanical machining is micromechanical cutting, which focuses on micromechanical cutting process to produce chips. That is, micro - turning, micro - milling and micro - drilling. The research progress and prospect of micro-machining cutting process and industrial application are summarized, and the application of micro-mechanical cutting process is further developed [1].
Keywords: Keywords: micro-manufacturing, micro-mechanical cutting, micro-milling, micro-turning, micro-drilling, precision engineering.

---

1. INTRODUCTION

The miniaturized regions have begun new approaches, particularly in the field of electronics and biomedical devices. The development trend of micro manufacturing industry makes the manufacturing industry create and adopt new processes on the micro scale of mechanical design and machinery manufacturing process.

Literally, the micro manufacturing is just a small-scale production process, because of the parts and products are manufactured on a micro scale, also can be called a precision manufacturing or processing with high precision requirement [2].Technically, micro cutting can be described according to the ratio between the edge radius unit and the size of the tool. This shows that the edge radius of tool is the key factor of cutting material granularity in micro machining.

The market for micro-manufacturing technology is expanding, which has inspired many different companies to continuously develop new technology projects in order to meet these requirements [3].

Since 2000, the annual growth rate of twenty percent, micro manufacturing as emerging technologies include laser micro machining and ultrasonic cutting, in the future is expected to increase at a higher speed and have further development [4].

The scale of micro-manufacturing is the key to most of the problems associated with production components. In particular, due to the processing in precision machining, high precision, to produce a product features and actual measurement precision are challenging, makes higher request for the whole process, in fact, as the product is more and more small, processing costs will increase exponentially the dotted box in Fig.1 highlights in the production of chips micro -machining process, and we can find that micro process more efficient than others[5].

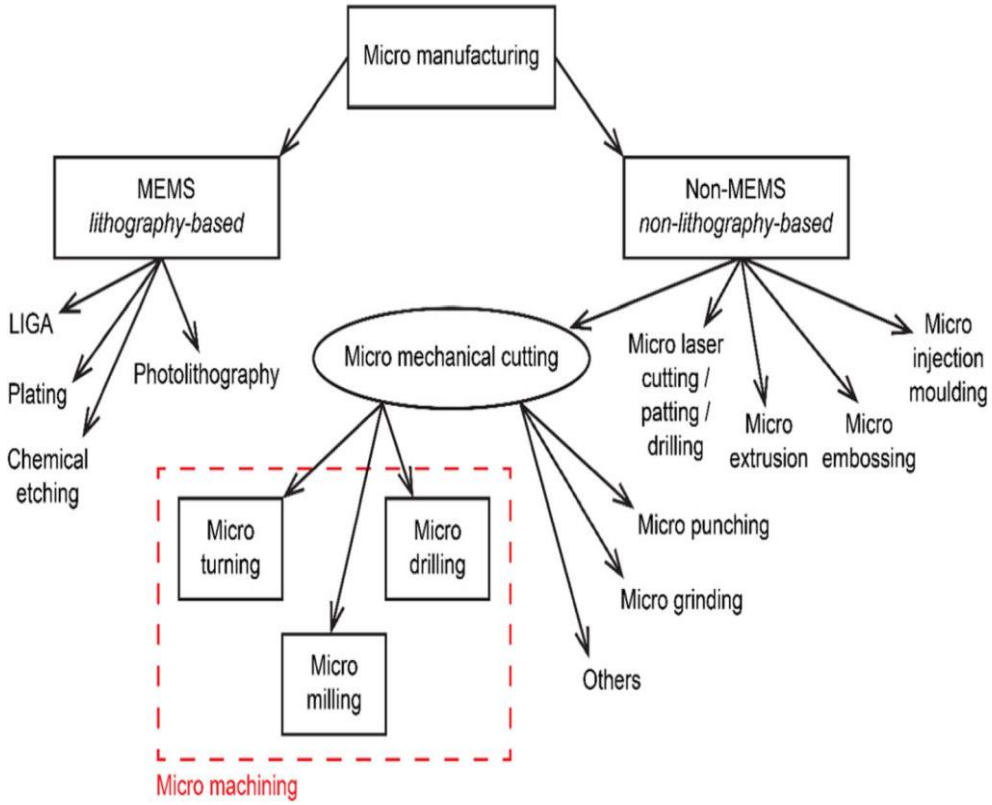

Fig 1 Chip-generating micro-process with the scope of this review [6].

1.1 Micro-manufacturing

Fig. 2 shows the during 1990 to 2016 in Scopus lookup to tiny turning/milling and drilling file, which is the only consideration to improve the engineering application of micro cutting files [7]. Although the microprocessing technology is relatively new, there are still some questions in the future development direction of the industry and the continuous vigorous development of the technological process.

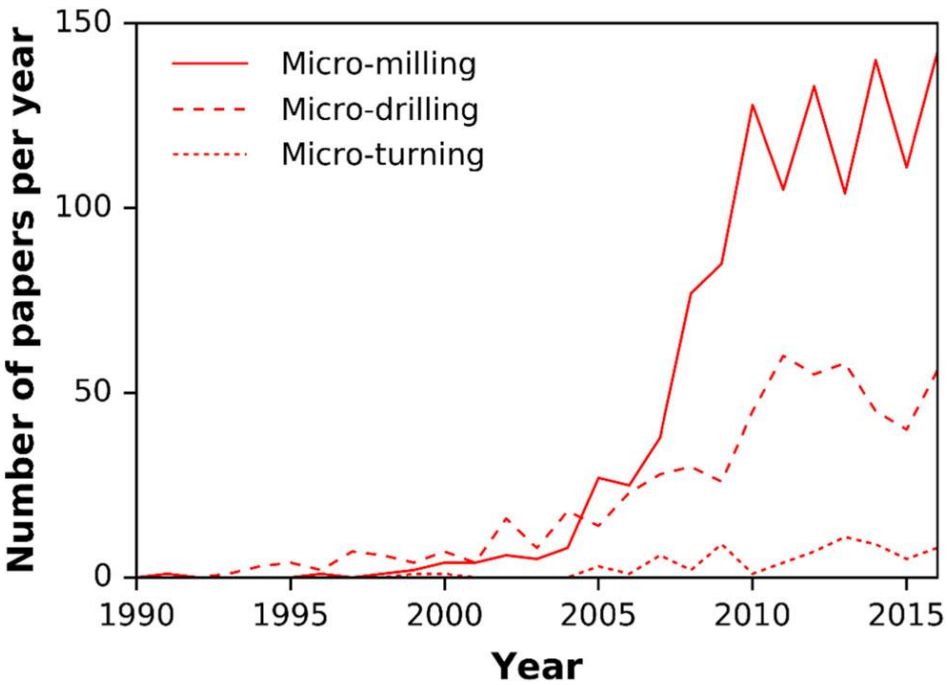

Fig 2 Number of papers per year of “micro-milling”, “micro-drillng”, “micro-turning” [7]

2. MICRO-CUTTING CONFIGURATION

Compared with other unconventional technologies, it has the advantages of fast speed and low cost. The traditional micro-machining process is to complete the process with the same original cutting characteristics in the process [8].The material is cut or ground to produce the desired size. But microfabrication tools and processes must be changed and improved rather than reduced to size.

2.1 Micro-turning

The micro-turning is very similar to the traditional turning. However, it requires a very balanced machine and needs to be very sophisticated. Accuracy (often referred to as "ultra-precision machining").This is a physical process, and because of the constant use of diamond cutting tools, almost any material can be processed, thus providing a very good surface finish. Due to the fact that the tool is often under pressure during micro turning, heat is obtained from friction during cutting. The biggest problem with micro turning is that the tool is broken. This may be caused by many different factors, the most common being chatter. This is usually due to improper machine rigidity and material not having consistent properties [9].

In general, micro-lathes are constructed in a manner that is similar to a traditional lathe, but with smaller and more precise components. But there are some fundamental differences, for example, a tool dynamometer is incorporated into the measurement of the cutting force exerted on the micro-tool, to help reduce damage.

2.2 Micro-milling

Micro-milling is very similar to traditional milling, except that the spindle speed used is faster than traditional. Extreme accuracy is also necessary, and even very small errors will lead to serious problems. Micromilling is used in a wide range of applications [10]. Due to its potential,

it is being actively studied because it may replace micro-EDM. Micromilling has been proven to have better accuracy, while still five times the material removal rate of the micro-EDM machine tool.

Micromilling is a kind of technology with many advantages and quickly becomes the first choice of micro-machining process. In general, micro-milling is defined as the mechanical properties of a milling process on a micro scale, or 1 μ m will affect the design accuracy[11].

2.3 Micro-drilling

Micro drills are processes that use microtools to produce holes that are less than 50 microns in diameter. The research of micro-drilling does not have much research results compared to other techniques for producing micro-holes because micro-drilling tools require complex shapes and geometries[12].Compared to other drilling techniques, micro drills are very effective and can produce deeper holes, although they cannot be drilled into a flat bottom.

The biggest problem with micro-drilling is damage during micro-drilling, and micro-drills that need to increase the thrust of the forcing sensor are used to solve this problem. Vibration is the main cause of tool wear and excessive wear and fracturing of the external angle of the drill. Because rotational drilling speeds are significantly faster than traditional processes, acoustic sensors are used to avoid breakage problems.

3. MODELING

Models are often used to predict forces and whether the tool can be used without any problems [13].By using analysis methods and complex algorithms to model the micromilling process and gain support, more research was conducted to increase the reliability of the results [14].

4. MICRO-CUTTING PROCESS

4.1 Chip formation

Cutting thickness is very important in micromilling because it affects surface finish and workpiece quality. The minimum cutting thickness depends on the tool's sharpness and machining materials [1].The surface finish of different materials requires different minimum cutting strength.The formation of cuttings is the key to understanding the removal of micro-machining metals.

4.2 Surface finish

Surface finish is very important in microprocessing, because it has a great influence on the strength and precision of the workpiece, and often determines the quality of the workpiece [1].The main reason for the surface finish of micro-milling is spindle speed, material removal rate and cutting depth. Most surface quality in micromilling is controlled by cutting thickness and shape. If the chip thickness is less than the cutting edge radius, it will result in poor surface roughness. Spindle speed and feed speed have been shown to control chip formation and surface finish.

5. INDUSTRIAL APPLICATIONS

As with micro-milling operations, special tools can be used to remove material during micro-milling milling. This is when the tool has a gravel coating on the back surface of the cutting edge, which allows the grinding process to be completed after the conventional milling process is completed. This is usually to improve the surface quality of parts used in micro-products such as drones. Although this is a relatively new application and process, it has great potential. Fig. 4 shows an example of a micro-machined part/workpiece.

Typical micro-machined applications

Part/workpiece	Geometry feature	Micro-process	Material
Micro-cups	Less than 1 mm in diameter, various thicknesses	Micro-machining Micro-deep drawing Micro-stamping Micro-spinning	Molybdenum Copper Aluminium Steel
Micro-gears	Diameters less than 1 mm, features less than 10s of microns	Micro-machining Micro-forging Micro-extrusion Micro-casting EDM	Metals Polymers
Shafts	Less than 1 mm in diameter	Micro-machining Micro-extrusion	Steel and alloys
Micro-screws Micro-cans	Diameters of 0.1 to 0.5 mm	Micro-machining Micro-forging Micro-extrusion	Various metals
Micro-gear shafts	Features of 30 to 40 μm	Micro-machining Micro-forging Micro-extrusion EDM	Metals
Micro-moulds, dies and punches Tool tips	Die-bore or inner pockets in less than 1 mm; punch diameter from 0.05 to 1 mm	Micro-machining Sintering EDM Laser cutting	Tool steel Tungsten Stainless steel Glass Ceramics

Fig.4 Typical micro-machined applications [1].

6. CONCLUSION

As the world's demand for micro parts increases, the micro-manufacturing industry has tremendous growth potential and expansion potential. This demand has encouraged new research and development in many cutting processes. The range of materials that can be processed is as follows [1]:

- Steel, aluminum, brass
- Ceramic, glass
- Plastics, polymers

REFERENCES

[1] Brian Boswell, M. N. Islam, Ian J. Davies (2017) A review of micro-mechanical cutting.

Int J Adv Manuf Technol DOI 10.1007/s00170-017-0912-y.

[2] Mian AJ, Driver N, Mativenga PT (2011) Chip formation in microscale milling and correlation with acoustic emission signal. Int J Adv Manuf Technol 56(1):63 – 78.

[3] Waurzyniak P (2013) Micro manufacturing keeps shrinking the envelope. Manuf Eng 150:65 – 73.

[4] Uhlmann E, Piltz S, Doll U (2005) Machining of micro/miniature dies and moulds by electrical discharge machining—recent development. J Mater Process Technol 167:488 – 493.

[5] Liu X (2012) In situ metrology system for micro-milling machine. J Manuf Syst 31:15 – 21.

[6] Piljek P, Keran Z, Math M (2014) Micromachining—review of literature from 1980 to 2010. Interdiscip Description Complex Syst 12:1 – 27.

[7] Document search results for “micro-milling”, “micro-drilling” and “micro-turning”, Scopus (www.scopus.com), Elsevier B.V., Amsterdam, The Netherlands (accessed March 17th 2017).

[8] KocM (2011) Micro-manufacturing: design and manufacturing of micro-products. Wiley, Hoboken.

[9] Mandal S, Kumar A, Nagahanumaiah A (2012) Assessment of micro turning machine stiffness response and material characteristics by fuzzy rule based pattern matching of cutting force plots. JManuf Syst.

[10] Xie J, Li YH, Yang LF (2015) Study on 5-axial milling on microstructured freeform surface using the macro-ball cutter patterned with micro-cutting-edge array. CIRP Ann Manuf Technol64:101 – 104.

[11] McKeown PA (1987) the role of precision engineering in manufacturing of the future. CIRP Ann Manuf Technol 36:495 – 501.

[12] Cheng K (2013) Micro-cutting: fundamentals and applications. Wiley, Hoboken

[13] Altintas Y, Jin X (2011) Mechanics of micro-milling with round edge tools. CIRP Ann Manuf Technol 60:77 – 80.

[14] Zhou L, Peng FY, Yana R, Yao PF, Yang CC, Li B (2015)Analytical modeling and experimental validation of micro endmilling cutting forces considering edge radius and material strengthening effects. Int J Mach Tool Manu 97:29 – 41.