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The application study of micro and meso mechanical manufacturing

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ABSTRACT

The present study is based on application of machinery manufacture, for machinery manufacturing based on micron and middle scale is an important object of today's science and technology research. It is a dual-use technology which has both civilian and military applications, and it has a great influence. This paper mainly introduces the current situation of its development at home and abroad, analyzing the relationship between itself and the micro electronics technology, summarizing the present situation of its development, studying the three challenges which it faces with on the part of the basic theory, the engineering and technical and commercial, analyzing five aspects of its enabling technology, main problems arising in the development as well as the corresponding countermeasures. It is expected that the paper can be little referential to the related areas of research in China. Based on parallel but different technologies of micro processing equipment, miniaturization equipment, micro manufacturing system, and Micro compatible characteristics in micro manufacturing, we believe that agreement between study of the Micro-manufacturing equipment and systems and the strategic policy of M4 components and products production, will make carrying M4 satellite competition very promising. These devices are similar to most computers used in current days, which you can play once it is plugged, meanwhile it can work independently and can be integrated into the system easily.

KEYWORDS

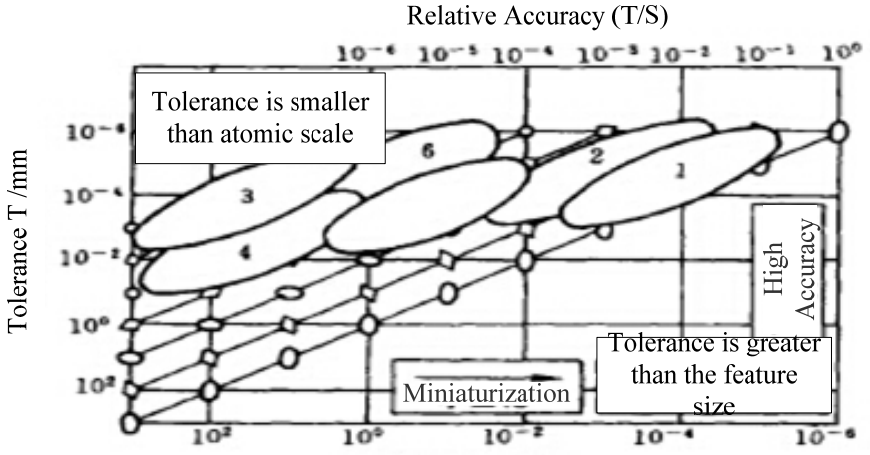
Micro-scale; Meso-scale; Machinery manufacture; Application study.

INTRODUCTION

The technique of micro-miniaturization is a dual-use technology in21st century which has both civilian and military applications, and it has a profound impact on civil and national defense science and technology as well as other technologies and has been a leader in science and technology research. Its basic technology is micro machining which broadly refers to all the small size manufacturing process technology. In micro miniaturization technology, however, the current main generated from micro-electronic mechanical system (MEMS) technology, and micro processing technology grows from the eliminated methods in the mainstream in the semiconductor manufacturing process. The significant advantage of these techniques is that it can be used for mass production, but in shape processing for any small 3d materials; it has been restricted for a certain degree.

THE RELATIONSHIP BETWEEN THE TECHNOLOGIES OF MICRO/MESO MECHANICAL MANUFACTURING AND MEMS

In the application of the micro-miniaturization techniques, according to the dimensions of the micro-mechanical features, 0.001 mm can be divided into 0.001 microns nanomachines. In this small micro mechanical and mechanical field of 1-100mm, according to the corresponding part of the special size, three scales can be divided namely, the nanoscale (0.1-100 nm), micron scale (0.1-100 - um) and middle scale between macro and micro (0.1-100 - mm). Nanotechnology is usually specific to the design materials, measurement, manufacturing, control and products, and other aspects of the nanometer scale. In most areas, precision machinery manufacturing technology in the traditional feature sizes has reached to millimeter and it is constantly pursuing preciser processing. However, micro processing technology develops on the one hand, the processing of three complex shapes, on the other hand, pushes toward a higher precision and size limit.



1.Nanotechnology 2.MEMS 3.Ultra Precision Processing 4. Traditional Exquisite Processing 5 Traditional Middle Scale Processing 6.Ultra-precision Middle Scale Processing

Figure 1 : The Relative Accuracy of Different Technologies

The primary difference between M4 and MEMS technology lies in the usage of materials and manufacture processing methods. M4 technology dedicated to the development of metal-mechanical manufacturing process, and the tool it uses can form a geometric surface which can accommodate various types of materials, while MEMS technology is a processing method for the exploit and manufacture of semiconductors and related materials. M4 technology is suitable for a single object, while MEMS technology is more suitable for mass production. M4 technology is uesd for three-dimensional micro movable parts, equipment and organization, and MEMS technology is more inclined to the plane of micro-mechanical components of MEMS devices.

THE PRESENT SITUATION OF MICRO/MESO MECHANICAL MANUFACTURING

As for micro machining technology, there are micro cutting (by milling, cutting and drilling), fine grinding, EDM, electronic counter work and laser, micro ultrasonic machining and focused ion beam machining method for removing material, laser welding, electrical micro stamping and other binding or attachment to deformation, and the stereo lithography techniques. In addition to the silicon micro mechanical processing method based on plane, in the process of the establishment of T.M asuzawa system, basic concept and main contour line in micro machining technology are provided, the basic characteristics of different types of processing technology are discussed, and more promising fine transfer method, suitable

using places as well as its development status are introduced in detail. The development of these techniques in the practical application of concrete examples is at the laboratory research stage now.

Material removal processing has the function of adding material shape, so it requires more flexible and more precision machining parts and materials. Since the component and shape are processed, so the current M4 technology study mainly concentrated in the process for removing material. In order to meet the needs of such reserves and weapons, the National Laboratories of United States in Sandia have developed medium-sized processing technology. By selecting the fibrinogen, and using fine milling, turning, other excited states of femtosecond laser and micro EDM to process engineering materials such as metal, ceramic and graphite. It can produce tiny three-dimensional parts with conical ball cavity characteristics, such as the shape of the trough and tilt, thus achieves the goal of weapon components miniaturization.

Different processing technology has its own characteristics, scope of application and processing performance. At present, most believe that the potential micro processing technologies which suitable for the M4 include:

(1) Laser micro machining. This technology has been carried out in a lot of work. However, there is still a large number of basic questions remained for further research and application in micro/meso mechanical manufacture which makes full use of this technology.

(2) Ultrasonic micro machining. The technology aims for vulnerable brittle removing materials, such as glass, silicon, graphite and ceramic. Using ultrasonic energy, the micro processing of small parts which have the honeycomb structure characteristics can be completed, but further exploration is still needed for the depth of understanding the and breadth of its application

(3) The abrasive flow micro processing. This technology uses the liquid medium. Abrasives, for example, under certain pressure, flows through the surface of the processed object to accomplish the removing material processing, and it is for the removal of burrs and polishing sharp edges.

(4) Micro EDM. This technology is relatively mature, already forming an application system which is suitable for micro EMD, but it still lacks of research on incentive machining and simulation technology for further optimization and better application.

(5) Micro ECM. ECM has advantages such as processing surface of good quality, tools with no loss, a wide range of forming, etc., but it still needs further research, especially the application study which can adapt themselves to the M4.

(6) Micro cutting processing. It is characterized by high efficiency, wide scope and relatively mature technology research, and it is indispensable in many micro small as well as medium-sized products manufacturing. Micro drilling is widely used in the manufacture of electronic printed circuit boards. At the present stage, micro drill diameter has reaches the M4 durable limit, and the key to its technology research is to broaden the limit in processing and develop its simulation ability. But the actual situation of micro milling and turning processing is that it is still using conventional ultra precision machine tool, thus makes it difficult to meet the mass production requirements for its high cost and low efficiency.

(7) Slurry polished micro grinding, Micro-extrusion and Micro-stamping. They belong to the new processing methods in the study of the M4, and their basic knowledge need to be further studied.

(8) Particle impact. It is a potential new method in the application of the M4, especially in the surface processing and the characteristics revising of base materials..

(9) Micro SL. It can accurately and quickly create three-dimensional micro mechanical parts which can be made of metal, resin or powder and has complex contour and no draft angle. But further research is still needed in the practical exploitation.

(10) Fluid Jet Micro Processing. There are for example, the more traditional water jet grinding method, and micro machining method, which can reduce the proportion to develop new fluid jet. But its potential needs a further study.

(11) FIB processing. Sandia National Lab of United States has successfully used this method to carry out the processing of micro parts and tools. Its resolution reaches up to nano-scale, and it is very promising.

THE CHALLENGES WHICH MICRO/MESO MECHANICAL MANUFACURING

The challenges on basic theory

Scaling.

When the size is reduced to the demanding range of micro/meso scale, whether mechanical processing method that can accurately realize, and what the advantages and limitations are.

The effect of processing methods towards micro-structure.

The full understanding of this challenge is very necessary. To produce the needed parts, any micro-structure changes led by different processing methods should be understood and under strictly control.

The effect of micro-structure towards processing methods.

Because under the micrometer particle micro-structure, processing materials removed by intermediate mechanical and the size of the processing unit are different in size and sequence, the material is difficult to be regarded as uniform. Compared with traditional machining, micro mechanical processing needs more energy that will increase the unit of middle

scale, making it influence the comparison with the corresponding processing methods. Therefore, we must consider the influences of the restrictions and directions as well as that in removing processing.

The superficial chemical effects.

Compared with the macro scale, in parts removal process within micron and middle scale, because he proportion between the surface area and volume of the chip and the components will increase, so attention should be paid to effects of superficial chemical reaction in process, or part of the superficial chemical reaction.

Mechanical properties of micro and meso scale materials.

Differences between the mechanical properties of macro scale materials and that of micro scale materials are great. However, the data related to the properties of micro and meso scale materials are lack of. So it should be studied vigorously on the mechanical properties of micro and meso scale materials.

The challenges in processing methods

The relative stiffness.

Compared with the conventional processing, in micron scale, processing power used for large milling and drilling makes rigidity of the relative moving parts influence relatively low machining precision. Thus it should be known how to control this influence.

Controlling of the motion.

With the required speed, and technology of precision parts processing, measuring, and using tools to control have developed, the ability of the relative motion has been restricted in M4. At present, there are no measuring sensor parts and tools specified for M4.

Beating.

In Sub-micron precision parts processing which is in 10 UN -- 10 mm, you need to have the micro level artifacts (turnery) or tools (milling machine, drilling machine, processing) for the rotary motion at high speed. It needs further study to improve the accuracy of achieving this goal.

TABLE 1 : Experimental Parameters List of Straight Flute Micro Milling

Parameters	Values
Cutter diameter (ball end) /mm	0.2
spindle speed ($10^4 r \bullet \min^{-1}$)	4.2
feed speed ($mm \bullet \min^{-1}$)	10
Z direction engagement / μm	10

Controlling of the process.

To effectively use the M4 method in the field of production, it is necessary to control the process in order to obtain sufficient reliability and repeat-ability. Many of the current work is still at the experimental stage, and we have not yet fully understand the long-term stability of the M4 method. The controlling of M4 process needs some appropriate performance measurement sensors, to measure temperature, vibration and micro power consumption, and so on.

The ability of processing.

Little is known about the capability of the uncertain M4 methods used in mass production and many experiments have not been carried out yet. Obviously, this problem is deeply related to the *controlling of process*.

Challenges in Commercialization

Production.

To win the economic competition, the M4 method requires a lot of energy, and should also produce parts in the short time. In response to this challenge, it is should be possible that many M4 devices used at the same time, in order to ensure fast promotion of parallel production or continuous production.

The cost.

Cost is a clear obstacles that must be addressed.Economy is prerequisite of production capacity in the micro and meso scale,affecting the smooth development of M4 motorway.

Time.

The timely development of products is also important. How to pass the verification of the product, make a quick market design, satisfy demand of the high benefit products as well as manufacture of them will be crucial problems.

Support.
The making of the laws about M4 manufacturing technology and design needs time cost and more support. On the contrary, the laws can help the development of the advanced M4 technology and the existing CAD/CAM/CAE software.

Economic assembly.
The ability of assembling M4 technical operations with a single small parts is regarded as a big obstacle. It still needs a long time and a high cost in the current days.

AIN TECHNOLOGIES

Processing Technology

What mentioned above are the current processing technologies, and have been recognized as suitable ones for the development of M4 processing technology. The basic processing mode provided by the expensive simulation software I-type pipe cutting will be of great help to the research in this area and it has become a major technology.

Measuring

In order to achieve the M4 technology application, it is necessary to hold the technology of measuring the size and surface quality of the M4 parts. (1) Optical interferometer. Interference measuring method is a relatively mature technology, which can effectively apply to the measurements of extremely precise movement, size and surface topography.(2) Scanning probe microscope (SPM). Various kinds of SPM technologies such as scanning tunneling, atomic force and approach of optical and scanning electron microscope have been successfully applied in a lot of ultra-precision measurement fields such as nanotechnology and the measurement of the surface microscopic morphology and size.(3) Electron beam focusing comparator. It belongs to the traditional technologies. According to the survey, this technology has been applied to the base.

In micro-technology applications, the main measurement methods are as the followings:(1) Micro force measurement. Draping, such as torque, become measurable. Through the feedback in the process of implementation, it is understood that the original deviation of the controlling, monitoring, forecasting tools and the key structures such as accessories should be paid more attention.(2) The internal strain gauge measurement. It can directly measure the force, and can be used as an alternative. But innovate design of internal strain sensing method is needed.(3) Tje measurement of tiny deformation. In the application of the M4, various types of deformation is difficult to avoid. Therefore, we need to be able to carry out built-in measurement in this micro and meso scale. And all of those measurements should paid attention to the function of real-time sensing and measurement. The trajectory characteristic curve of surface roughness in planar micro milling is shown as Figure 2.

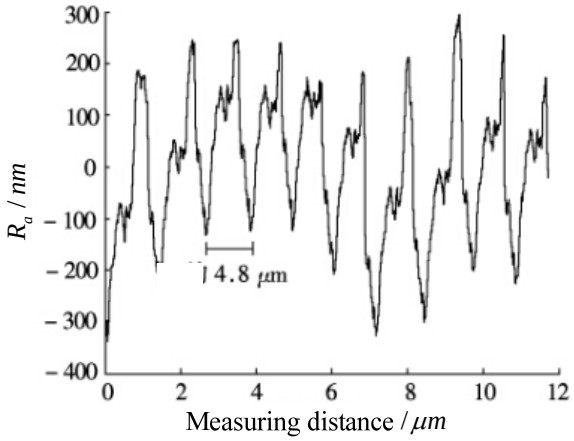


Figure 2 : The trajectory characteristic curve of surface roughness in planar micro milling

The clamping and operating parts

Most of the regular clamping and operation can be accomplished in the micro and meso— scale, but the transportation and assembly, the most common machining operations, are not suitable in this scale. Positioning and clamping in the machine parts, the parts need to be moved from a device to middle places between the collecting device and different parts of another device which connected the itself to the collecting one. Setting up and operation of each part, therefore, is a crucial indispensable condition. This operations should be reduced as far as possible.

Surface polishing

In the M4 application, the parts need to be finished as high as possible, and it's surface roughness should reach a low degree. Whether use a conventional burring technology or surface polishing technology, depends on the degree of damage caused by different polishing technologies on sub-surface of micro/meso scale parts which needs a further study.

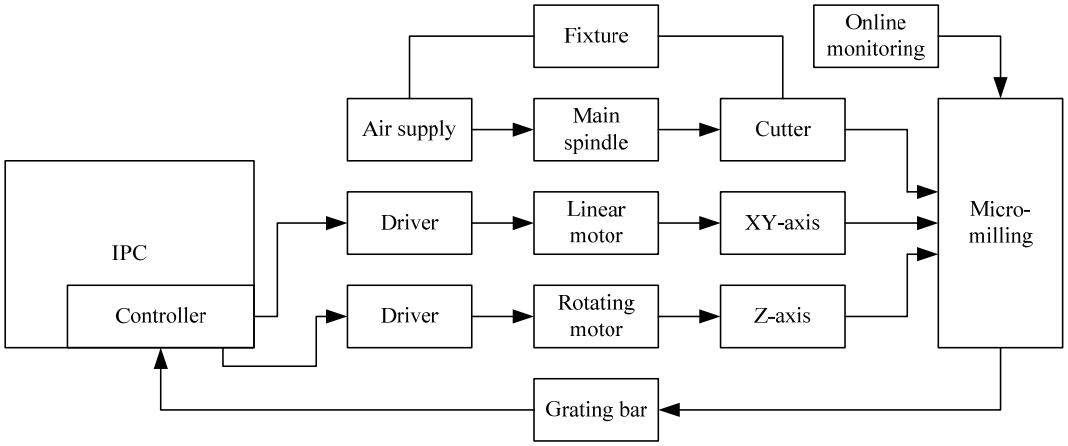


Figure 3 : Structure diagram of micro milling system

THE MAIN PROBLEMS IN RESEARCH AND DEVELOPMENT

At present, some scholars and academic institutions have been continuing to explore this new technology, and have gained fruitful research results. Japan, Taiwan, Germany, Switzerland and other European countries and regions have made plans in this respect. But miniaturization technology research in the United States, in terms of the traditional technology of mechanical manufacturing, has been ignored a lot. The National Science Foundation (NSF), held a "Micro - mechanical manufacturing (M4)" symposium in May 2000. The theme focuses on 3D precision machining method and geometric feature of small internal parts (0.01-10mm range) of the device. The range and the size of processing parts are discussed, and the result is that only by the combination of the traditional precision and ultra precision can precise three dimensional small parts meet the market demand. At the same time, there is also need an additional development and processing methods to suite for the miniaturization of related equipment, which will substantially reduce the cost. The technology can be applied to civil and national defense. If micro and small equipment and device are successfully implemented in special, pharmaceutical and other areas, then the social and economic benefits will be huge.

To meet all kinds of challenges, to establish and improve the technology needed, as well as to successfully implement and apply the M4 technology, works should be done from the following aspects:

(1) Determining the product application and processing technology. To successfully implement the M4 technology, several potential products would be compared to choose the most suitable one and then research about the equipment technology and manufacturing technology of such products will be carried out. In this way, the advantages of M4 technology can be shown clearly. And normally, the most suitable product is fuel injector.

(2)Understand the mechanical properties of the micro/meso materials. Micro/meso scale products has a wide application range, such as mechanical, optical, biological medicine, space, electronic, etc. So it micro-miniaturization will use a variety of materials. Understanding the mechanical properties of these materials can not only help to develop various kinds of technologies, but also has an important meaning for the prediction and optimization of meso-scale technology's inheritance system performance. Building a database about properties of various materials in sub-scale will play an important role in the effective development of M4 technology. Related researches mainly include: establishing a database, characterizing the properties of the materials, systems and devices, measuring and characterizing the residual stress before and after the processing.

(3) Meteorology. Evaluating and measuring quality and function of the parts and the product in micro/meso scale are a challenging work, which needs to carry out some research work on the following aspects: stress, parts of shape, size, location, surface integrity and subsurface damage.

(4) Designing of precision machinery. In order to ensure the precision and accuracy of micro/meso mechanical equipment of micro, researches on micro-dynamics, including micro structural dynamics, and processing stability when using micro devices; Choosing the accurate cutting tools and innovating the design of moving miniature brake; Designing spindles of small size, high precision, high speed; Study and using the corresponding micro sensor.

(5) The clamping and operating parts. Micro/meso mechanical manufacturing is a single processing, making parts should be accurately positioned and maintained. Research on the technology of clamping and operating individual parts must be done.

(6) Interface interaction. Studies of tribology, especially interface friction, and properties of contact interface and coating interface should be carried out.

(7) Assembling and packaging. M4 technology is a single processing. And if it lacks of effective assembling and packaging technology, it cannot work in practice. This technology is an important condition to ensure that the appropriate functions of the M4 technology be economically durable.

(8)The process controlling and planning. After determining a process method, problems such as the process planning, parameter selecting as well as the feedback and the control of the M4 technology must be studied. The first step is that based on the micro/meso mechanical machining characteristics, making process plannings, selecting parameters, and comparing the similarities and differences with traditional machining method. Then there should be a further study about the new or revised process planning and the selection technique of the parameters.

CONCLUSION

Above all, different technologies influence each other, and complement each other. The M4 concept originated in the miniaturization technology. It has now developed into the stage between technology research and application. M4 combined the silicon surface micro-machining technology, MEMS,LIGA, and traditional precision machining technology together, filling blank int domestic. Through functions of a wide range of materials and shapes, and the miniaturization of the device, the producibility and reliability can be improved. The study on the M4 technical feasibility focuses on the usage of a wide range of materials, quality of micro/meso scale 3d parts manufacturing, accuracy and production efficiency.

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