한국공작기계학회 2001년도 춘계학술대회 논문집 pp.287~293

Manufacturing Process of Micro-drill

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Abstract

Resently, reduction of industrial products in size and weight has increased by the application of micro-drill for gadgets of high precision and gave rise to a great interest in a micro-drilling. Due to the lack of tool stiffness and the chip packing, micro-drilling requires not only the robust tool structure which has not affected by the vibration, but also the effective drilling methods designed to prevent tool fracture from cutting troubles.

Firstly, this paper presents a new manufacturing process of micro-drill for improving the product rate and an optimum shape of micro-drill for lengthening the tool life, and secondly suggests between tool life and drilling torque acquired in the inprocess monitoring system.

Key words : Microdrill(마이크로 드릴), Manufacturing Process of Microdrill(마이크로 드릴의 제조공법), Tool life(공구수명), Machinability(가공성), Mass Production(대량생산)

I. Preface

Drilling operation is one of the most basi manufacturing methods among the machine tool manufacturing and it is getting more important for improving the productivities associated wit micro-drill manufacturing. In order to keep up with the trend of high performance, miniaturization of electronic products, an increas need for high precision drilling works are required Particularly the need of nano-micrometer detailed drilling works are rising. Due to the rapi development of high-technology medical equipments and new micro-element particles. Therefore there should be new studies and developments of micro-scaled drills and their new elements.

In Korea to be sure, the importance of micro-machining technology is rising due to hole-miniaturization, new material developments, high density of circuits, multi-layers circuits high integration for improvement of VLSI integration on high-technology medical equipments and computer circuits[1]. In advanced industrialize countries such as U.S.A and Japan, micro drill machine equipped with high-frequency air spindle, has been already practiced for the use of micro manufacturing and reported to make possibly hole drilling work. These manufacturing process can not be seen with naked eyes, so drilling process monitoring has been automated through torque detection or acoustic emission sensor.

Nowadays, we see empowered-endurance drills by making corpuscle with cast sintered allo but producing problems with high speed cutters. Developments of multi-purpose drilling tools with consideration on heat-resistant adding TiC, TaC are on the way. In addition, there has been drill developments such as cast sintered alloy multi-purpose drills with adding diamond to the top of the drills and microscopic drills addi diamond to the top of them. When using diamonds, the degree of hardness, thermal conductivity and abrasion resistance are to b improved by ten times up to hundreds times of tool life expectancy and high precision abili However the major problem is that it is extremely hard to manufacture such drilling tools. Therefor optimum design of micro-drill shape and manufacturing process technology are urgently required.

This study therefore focuses on the technology on material selection of micro-drill to manufacturing method for mass production and also a large quantity production for scale of 30μm or under micro-drill developments, and evaluation of micro-drilling operations.

II. Purpose and Study Background of Micro-Drills Development

2.1 Purpose and Study Background of Micro-Drills Development

Micro-drill manufacturing technology wil be the frontier engineering in 21st century so tha advanced nations are taking this important and funding into this with passion. By having this advanced and high value-added technology, we can produce high-technology products. Only 4 countries have this micro-drill manufacturing technology (0.04mm: 40/1,000mm, compared to human hair size of 100/1,000mm), importantly the 4 countries are hesitating to transfer this technology to oth countries because this technology is a futur coming gold technology. Due to a diameter of te n~hundreds micrometer, this micro-drill for use o drilling needs high speed spindle to gain consisten cutting speed.

In Korea, there has been a big interest in miniature drilling driven by increased demand in printing company, IC purpose mikes from 1970th. High-tech drilling development started to minimize burring sound from mikes in the late 80th. From the late 80th, miniature drills(under 3mm) development started to cope with the large quantity production of printer circuit mould, sin then automatic drilling works started with introduction of CNC machines. The more microscopic the micro-drilling, the more preciou manufacturing and design of the drill needed. Today it is possible to manufacture the drill scaled of 0.3~1mm.

Today within the domestic industries, micro-machining is getting important to cope with the trend of high density of circuit board, ne material developments that needed for high-tech medical equipments and computer circuit board. This situation has produced an urgent need of credible data collection for micro-drilling manufacturing ability.

2.2 Domestic and the World Trend of Studies on Micro-drills

U.S.A and Japan are now successfully utilizing drilling machines that attached with a spindle used for microscopic drilling works. Tha means the drills can conduct hole drilling works scaled 50μm up to tens of micrometer. These works can not be detected effectively by naked eyes so that torque detection or sound detectio are being used to have effective monitoring systems for drilling works.

2.3 Utility Fields of Micro-drills

Micro-drilling are mainly used to produce cameras, audio machines, video players, computers, high-tech medical equipments and monitoring systems. Importantly, micro-drills ar being utilized to perform works of hole-drilli scaled diameter 0.1mm~0.5mm on multi-layers circuit board of printers. And the numbers of the holes are thousands up to ten thousands on each board. Because fuel injection, nozzle holes, opti fibers, microscopic nozzles, space engineerin medical equipments and measurement gauges are getting microscopic, there are many studies are on the way to manufacture micro scaled drills to keep up with the new needs of complicate and compounded shape and moulds of the above the products.

A study shows, the shape and the material of micro-drills have a big influence on th effectiveness of drilling and the final products t manufactured by the drills. Drills that equipped with durability, heat-resistant and economy are urgently required to be created. The materials used to make micro-drills are high-speed steels and sintered cemented-carbide alloys, while the former is weak by durability and the latter is weak by abrasion. In order to minimize the weakness of the high-speed steels, a method of making sintered cemented-carbide alloys by corpuscles but this still has problems wit high-speed cuttings.

There are many tries to make drills, for examples, drills made of TaC compound materials to give heat-resistant, multi-purpose drills made ultra-light compound materials attached with diamond to the top and micro-drills coated with diamond to the top. A study shows, solidity, heat conduction can be improved and these can eventually improve cutting ability and abrasion proof. These all not create far more tool life expectancy up to hundreds times but also high precision works. However it is extremely hard to make such drills so far. Therefore optimum manufacturing processes and manufacturing plans are urgently required for micro-scaled drills making.

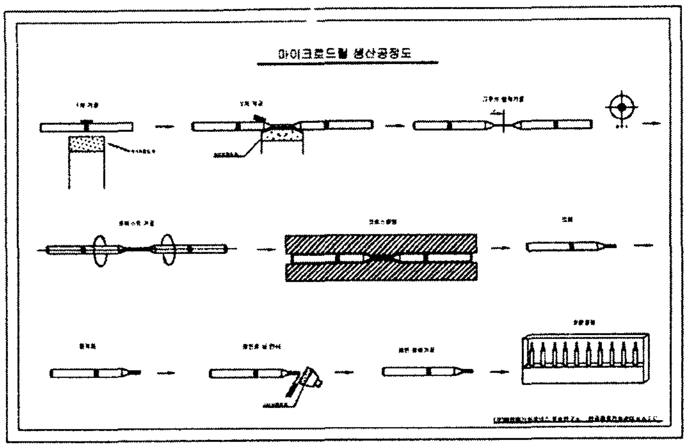


Fig.1 The manufacturing processes for the material of high-speed steel

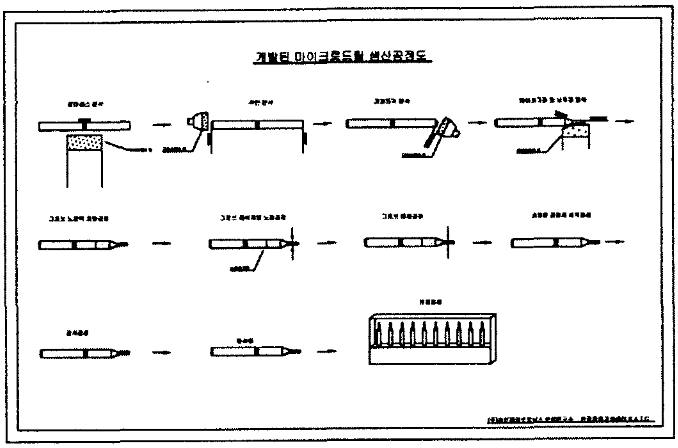


Fig.2 The manufacturing processes for the Material of sintered cemented-carbide alloys

Korea today imports 100% of micro-drills and their parts and the import is seen as dramatic increase in the future. The current domestic market value of micro-drills is KRW 120 billions while their parts and materials consist KRW 1.6 trillions and the world market value is estimated about $90~100 billions.

III. Micro-drill Shape Designing

This study aims at making micro-drills scaled below 100 μm. The same scaled drills on the current market are being sold at about KRW 15,000 and they are all imported from Japan. The average life expectancy is from 3 to 6 holes pe tool and manufacturing costs are very high.

The manufacturing processes recommended by this study is different from others. As seen on Fig.1, it has total 9 steps consisting of grooving cutting, grooving, compression & beading, twisting, cutting, cross rolli heat treatment, cylinder grinding, edge grinding, measuring, and testing on the high-speed steel. The materials meeting the requirement for making such drills are high-speed steels and carbon steels.

And also Fig.2 indicates the manufacturing processes for the sintered cemented-carbide alloys, it ha total 10 steps consisting of centerle grinding, profile grinding, point ang grinding, taper grinding, grooved-coatin grooved-etching, cleansing, and testing o the sintered cemented-carbide alloys.

Such manufacturing mechanics will be able to produce massive products by using plasticity of metals, and thi will be successfully reducing costs manufactures and have competitive price against drills imported from Japan and other countries. However, the method of manufacturing drills requires credibl data by constant studies on the weaknesses of the method. Particularly the parts of shank, flute and the top require studies on heat treatment and efficiency of drilling works such as hardness, l expectancy and toughness. Importantly more effective heat treatment is needed to minimize the danger of brittle condition driven by difference heat treatment time.

3.1 Determination of Micro-drill Shape

Fig.3 shows each name of the top and part of the drill. With normal drill manufacturing works are highly influenced by chisel edge angle, shape of margin and shape of thinning, but with micro-drills processing it is not necessary to make the margin near the vertical hem and this will only encourage abrasion, a study shows. In case of micro-drills, it is designed X-type thinning shape. The reason of that is micro-drills need very small drill tips.

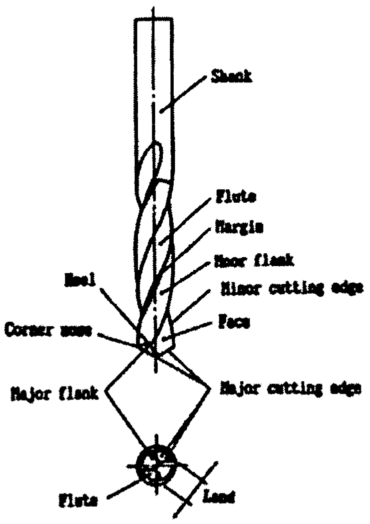


Fig.3 Shape of micro-drill

Therefore, S-type and N-type are not easy to make and W-type is weak by abrasion with less hardness. Fig. 4 shows the thinning shape which works on contact point between the process of drilling and structure when micro drilling work The shape of thinning on fleet of drill have an important effect on the tool life span and cuttin shape of structure. For the fleet part of drill, rake angle is set with α=12~15°, shear angle β =120~125°, twisting angle γ=30~35, which are wider than the angle of normal drill. The reason is to maintain a sufficient hardness on small flee and twisting angle γ=30~35° is to make the greatest maximum cutting abilities. Also, th length of twisting angle is set on less than 3. times of that of flute part.

3.2 Harness of High-speed Micro-drill

The shank and flute parts have an crucial effect on the tool life span of drill due to a sm drill angle. Therefore, in many cases the tool li span of micro drill depends on the cutting edge of shank and flute part, unlikely abrasion on the fleet of normal drill.

Table 1 shows the experiment of cutting

Test number	Drill diameter d=80μm	Drill diameter d=300μm
1	34sec	3min 42sec
2	1min 40sec	4min 40sec
3	28sec	5min 23sec
4	1min 25sec	3min 29sec
5	48sec	5min over
6	39sec	4min 32sec
7	53sec	4min 23sec
8	1min 3sec	3min 18sec
9	53sec	4min 33sec
10	46sec	3min 25sec

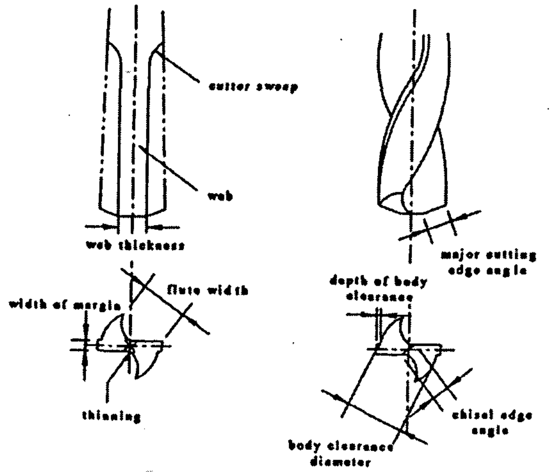


Fig.4 Characteristic of tinning shape

process with 80μm and 300μm micro-drill.
This result shows that the cutting on shank and flute part is affected by the cutting edge an angle between the fleet of drill and structure. the edge angle between the fleet of drill an structure is φ, normally the result should be φ =90°. But the angle from the result of this experiment shows 86°< $\varphi \leq$ 90° affecting by the sliding action.

Table 1 The life span of micro-drill with

Fig.5 Abrasion of micro-drill

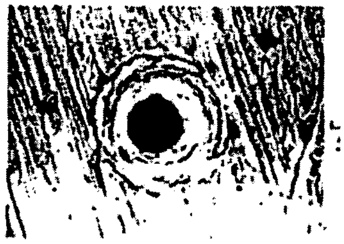
different size of diameter(φ=90°) Therefor Table 2 shows the relationship between micro-drill tool life and edge angle φ. Based on the result the larger contact angle will, the longer life sp will be maintained, the smaller contact angle, th tool life is shortened. So this shows the tool lif affected by not only the hardness of drill but als the contact angle φ between the drill fleet an the structure. Also, to reinforce the cutti abilities and preciseness, 34° taper at boundar between flute part and shank part will be very important to prevent the excessive stress in cas of rotating.

Table 2 A Tool life by edge angle φ

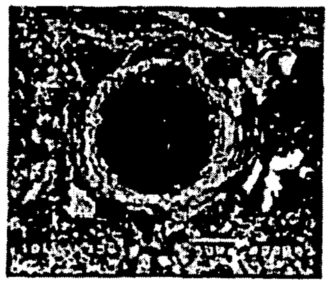
Contact Angle (°)	No. 1	No. 2
86°	19sec	23sec
88°	26sec	33sec
90°	1min 25sec	1min 6sec

3.3 The Tolerance Level against Abrasion of Micro-drill

The metal microscope, SEM or laser, can be used to measure tool life by affecting th different level of abrasion on the fleet part of dr Fig.5 shows the pictures of abrasion shape from laser microscope. But the most effective way of measuring the tool life of micro-drill level is predict the different type of signal after obtain machining load sensor in case of manufacturing, and finally this will be used to save the expense of high-priced drill. Currently based on the experiment results on Fig.8, the signal by cutting is extremely distinctive, however a



(a) Drill Diameter: 0.05 mm
(600rpm, 2 mm/min, Brass (t 0.3))



(b) Drill Diameter: 0.1 mm
(3000rpm, 4mm/min, Stainless (t 0.5))

Fig.6 Plow phenomenon with cutting signal

deeper experiment on drill abrasion will be required to measure an accurate boundary to predict the tool life as well as a study will needed to know the possibility to measure the tool life span of drill by abrasion.

3.4 The Shape of Crack and Direction on the Fleet of Drill

The shape of crack can be seen through laser microscope in case of micro drilling. Fro this study, the shape of crack on the fleet of dri was tried to analyze, it was difficult to distingu the precisive shape of crack due to lots of unclea parts appeared.

But based on many cases and experiments, micro drill unlike normal drill, the bigger crack is not main factor to shorten tool life. The reason that normally the life span itself is shorter than

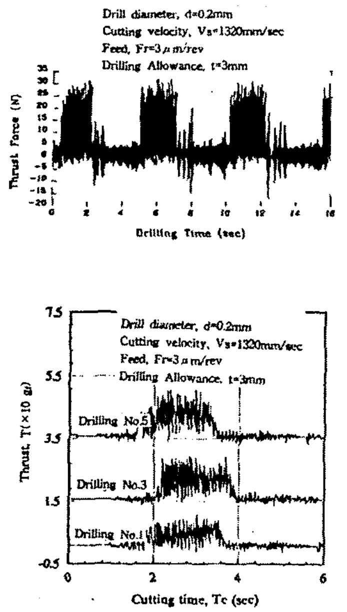


Fig.7 Measuring signal for evaluation of drilling

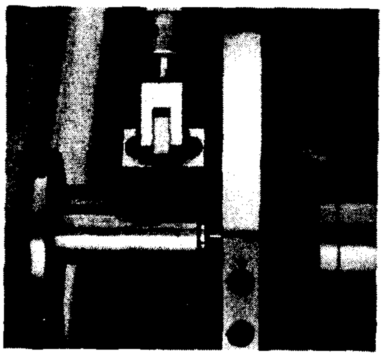


Fig.8 The manufacturing process for micro-drill on the body

the time to be spent on making bigger crack.

Therefore, it will be more practical to sho the relationship between the cutting abilities an abrasion rather than discovering the main factor affecting the tool life through examining the shap of crack and direction.

Fig.6 shows the surface of structure in cas manufacturing with 50μm and 100μm drill and both surfaces shows plow phenomenon with cutting signal. Also in case cutting, the signal is shown rapidly rising.

IV. Cutting Ability and Working Loads of Micro-drill

Cutting power when drilling is too small to signal, therefore it is very important to sel proper sensor to detect it. In order to monitor and

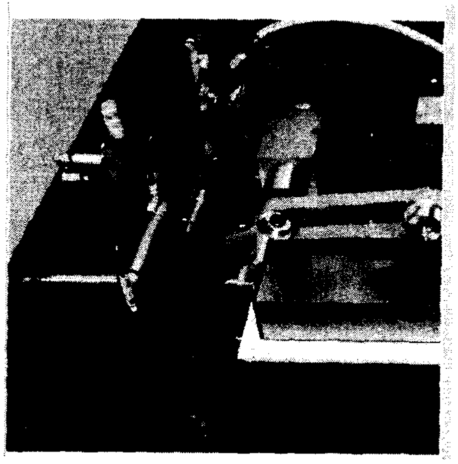


Fig.9 The manufacturing process for micro-drill on the body

detect the power signal, very sensitive sensor which are too expensive to be utilized, are needed Another reason is tool shank of pivot type is to small. By this study, it is possible to monitor t cutting power by attaching strain gauge(tool dynamo-meter) on the surface of the objective being drilled as seen on Fig.7. By transferring helped by Transducer and A/D Converter, the main power signal, which is signalized and connected to a computer, we can compare and analyse the signals from drilling. This stud proves that each different conditions of drill wor has their own waves and unique signals.

Also the interference of chips is one of the mai reason of reducing the tool life expectancy of dri when drilling.

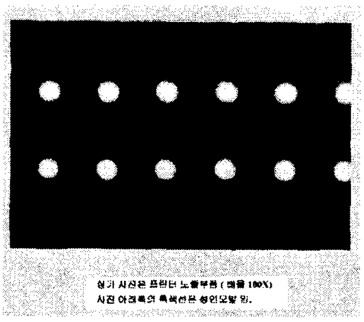


Fig.10 Manufacturing products

This study shows that cutting speed is the major factor effecting the tool life expectancy. In cases, the interference of chips can be eliminate if the depth of cut is not more than 300μm and nozzle for use of air installed.

Shown on Fig.8 and Fig.9 show new micro-drill scaled diameter of 40/1000 mm made by new process mechanics. And also Fig.10 indicates manufacturing products.

V. Conclusions

The conclusion of the study on development of micro-drill on the material of high-speed steel an sintered cemented-carbide alloys is as follows.

(1) Introducing a new method of manufacturing micro-drills which are high value-added and mass-production on the micro-drill.
(2) Determination and design of micro-drill shape for maximizing its life expectancy.
(3) Introduction of taper angle on shank part to improve the hardness of micro-drill.
(4) Proposal of drilling process to maximize th life expectancy of micro-drills..

Reference

(1) Peter Muller, "Flexible Usage of Microdrill European Production Engineering 16, pp.79~81, 1992