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Micro press forming and assembling of micro parts in a progressive die

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Abstract

A micro press forming and in-process assembly technology were developed and applied to fabrication of metal parts and units. Technologies based on high-energy beams, such as ion and short pulse laser were developed for fabrication of features of dies in micro scale and finishing surface in nano scale. In addition, DLC coating on surface of the die was developed in order to improve wear-resistance and reduce friction. A micro gear with diameter of 0.2 mm was produced using sheet metals. Furthermore, a unit part with three components was fabricated in a precise progressive die using the micro press system. The results show that the micro metal forming could be a new technology for fabrication of micro devices, such as MEMS, bio-chips in low cost and with large quantities.

Keywords: Micro press forming; Automatic assembly; Progressive die; Micro metallic device

1. Introduction

MEMS (Micro Mechanical Electro system) and Biochips attract attention in this decade. These kinds of micro devices are mainly made of silicon or glass, and fabricated by using micro machining technique, which usually costs very high. Fabrication technology for providing the MEMS stably in lower cost is an important issue. Since the micro machining technique is based on photolithography that processes features in 2 dimensions or 2.5 dimensions, MEMS can only have restricted structures with fragile materials. On the contrary, metals have the properties of ductility, conductivity so that MEMS fabricated based on metal forming could have more freedom in structure with high strength and ductile materials. On the other hand, metal forming in sub-millimeter or micrometer scales also becomes a very important issue for the audio-video or information technological devices due to miniaturization of the structure parts [1,2].

The authors have been working on a novel micro metal forming technology in which micro parts or units are fabricated by micro press forming and automatic assembly processes in a progressive die [3]. Several kinds of sheet metals are supplied into the die by feeders and formed simultaneously in several steps and then, assembled together to a unit in the progressive die. We also introduced high-energy beams for the fabrication of micro die with feature of several micrometers and using DLC (Diamond Liked Carbon) coating technique to form film on the surface of the die for improving the wear-resistance [4].

In this study, we attempt to develop several kinds of die for punching and deep drawing, and utilize to press forming in a progressive die to produce some

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micro metallic parts and units.

2. Micro press forming for fabrication of mems

Press forming is one of most significant metal forming process for fabrication of complicated parts in a press machine. Most of parts used in Audio-Video (AV) and Information Technological (IT) devices are fabricated by the press forming. The feature of these parts became smaller and smaller these years. Furthermore, MEMS and Biochips consist of multi-parts constructing a system or a unit with complicated structure. Fabrication of parts/units with feature of sub-millimeters using press forming could be important in next few years. The issues for forming parts with sub-millimeters features are:

- Development of new method for fabrication and evaluation of die with feature of sub-millimeters,
- Surface treatment of die for protection from wear and breakage,
- Development and evaluation of metallic materials with fine grains,
- Handling and assembly of micro parts.

In this study, we proposed a micro fabrication system by using press forming to form micro parts in multi-steps and then, to assemble parts into a unit in a progressive die. Fig. 1 shows conception of the micro fabrication system. Several kinds of materials supplied into the progressive die by feeders, respectively, and formed simultaneously in the progressive die in several steps and then, assembled together in the same die. As the result, a unit part could be formed as an output of the press forming. In order to establish the micro fabrication system, accuracy of each element of dies in dimensions and of alignment is challengeable. The issues are shown as follows:

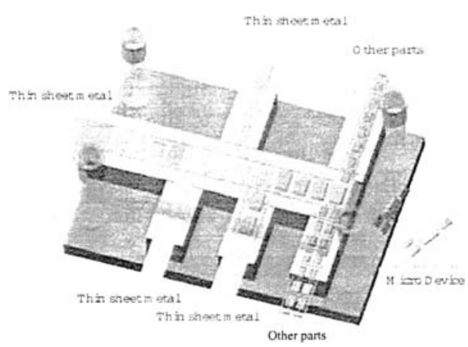


Fig. 1. Schematic configuration of press forming and in-process assembly in a progressive die.

- Establishing new methods for fabrication and evaluation of die features smaller than 20 μm,
- Keeping errors in dimension and allocation of the elements smaller than 1 μm,
- Treatment of die surface for protection from wearing and degradation and for processes without lubricant,
- Removing burrs larger than several micron before assembly process,
- Miniaturization and digitization of press machine for reducing errors in vertical and horizontal positions during the processes.

Methodologies on fabrication of micro die in size of several ten micrometers and design of the press forming process with the assembly system will be discussed in chapter 3 and 4, respectively.

3. Fabrication of micro dies

3.1 Fabrication of micro die by combining machining and high energy beams

High-energy beams including short-wavelength laser beam and ion beam was introduced to the fabrication of micro die with feature of several micrometers. The short-wavelength Laser and ion beams, which are widely applied in semiconductor process, have ability of removing materials with the features of several micro- and nano-meters, respectively, while the conventional machining generally processes shape with features as small as sub-millimeter order. Here, we proposed a combination of the machining and high energy beam processes for fabrication of micro die in such manner to process profile of the die roughly by the machining and the smaller features by laser process and then, the shape with sub-micrometer or finish surface in nano-order by ion beam [3].

Fig. 2 shows photo of a micro die for punching micro parts with gear shape fabricated by using the combination. The micro gear has a diameter of pitch circle of 200 μm and a module of 20. After machining the circle shape of punch, the micro gear with the feature of about 20 μm was fabricated by combination of short pulse laser and micro electrical discharge processes. Furthermore, the ion irradiation was applied to remove the traces on the sidewall and micro cracks on the leading edge. The detail conditions for the fabrication of the shape and finish of the surface were appeared in our previous works [3],

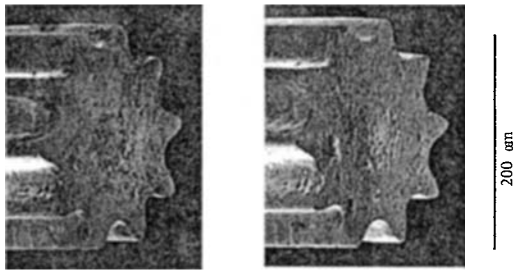


Fig. 2. Surface treatment for micro gear shaped punch by ion beam irradiation (800 V, 1.65 mA, 1 hr, incident angle 45 degree).

[4]. It seemed that the surface roughness of punch was improved after the irradiation. For micro-die, improvement of surface roughness and mechanical properties is important for protection from wear and breakage due to increase in stress concentration.

3.2 Die surface coating using ion DLC film

The authors also coated a DLC film on the die for reduction of friction and protection from wear [4]. In the case of metal forming in micro scale, the die bears larger stress on the shoulders or the leading edges than that in macro scale so that the DLC coating becomes easier to be damaged and the die becomes easier to be worn or broken. The authors evaluated the mechanical and adhesive properties of DLC coating due to the concentration of stress/strain by using a nano-indentation test, and tribological property depended on size by using a micro-bending test [4]. The results show that the DLC film coated with certain conditions could bear average stress as high as 10 GPa without delamination or breakage; the DLC film with larger hardness and elastic modulus show stronger wear-proof property but easier to delaminate; on the contrary, the DLC film with smaller hardness and elastic modulus show stronger adhesion strength with substrate but easier to wear. From the results of the wearing test, a DLC film with gradient properties by combining different coating conditions could be effective on both wear-proof and lower friction. In this study, a two-layered DLC film was coated on the substrate and the tribological property of the film was evaluated. Fig. 3 shows that the results for DLC film with gradient properties. It seemed that the significant damage was not observed after more than 50000 times for the die with radius of 600 µm. The results show that the DLC film with gradient properties is practical for real production.

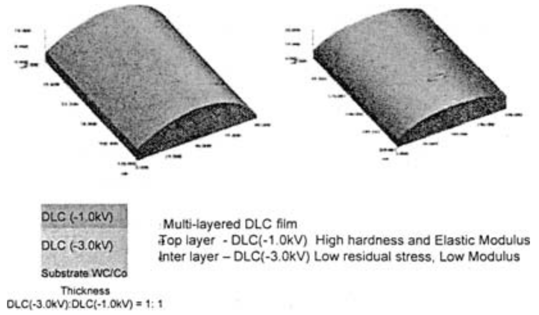
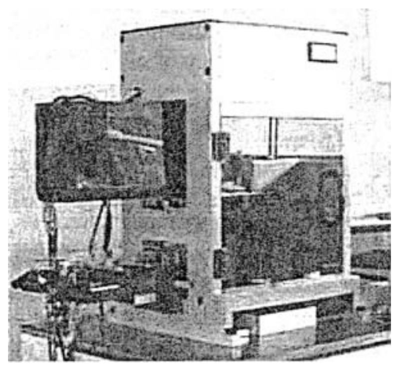


Fig. 3. Observation for Multi-Layered DLC film after tribological test; after 5,000 shots for DLC film on substrate with radius of 100 µm (left) and after 50,000 shots for DLC film on substrate with radius of 600 µm (right).



Type: S-23 desk-top servo press machine
Max. Force 23kN, Max. speed 500spm,
Max Stroke: 15mm,
Slide Adjustment 15mm, Die height: 100mm
Dimensions: W340 x D330 x H545

Fig. 4. miniature desktop servo-press machine and its specification.

4. Press forming for single and unit parts

4.1 Development of miniature press machine

A miniature press machine with desktop size was developed for press forming and assembly of micro parts. Fig. 4 shows a photo of the machine and its specifications. The press is actuated by a servomotor and controllable precisely. It is possible to supply materials simultaneously in three directions during process.

4.2 Fabrication of Micro single parts

A two-steps punching process was carried out for fabrication of a micro gear with a central hole by

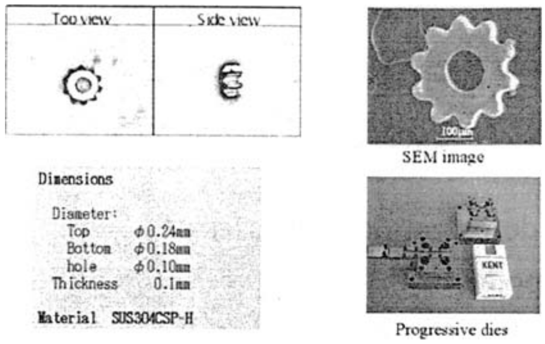


Fig. 5. Photo image of a micro gear and the dies for the press forming.

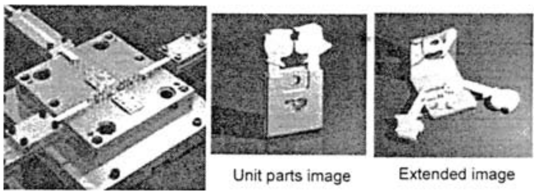


Fig. 6. Design image of press-forming dies and unit part.

using the micro fabrication system. In this case, alignment of elements of the die for each process step, and feeding and positioning of material at each step will be very important. Fig. 5 shows the photo of the gear and the specification. The gear was successfully fabricated and the error in concentric circles was about 3 μm. In this case, the process rate was 60 spm.

4.3 Fabrication of unit part

Fabrication of a unit part was carried out using the micro press forming system. A unit part with three components was designed as a sample shown in Fig. 6. Two movable components and a base plate are press-formed and assembled together in the same progressive die. The movable components are joined by dowel pins on the base plate and rotational around the pins. The process includes punching, bending, imprinting, pinning and so on. The process with 5 steps for punching the shape of functional elements, respectively, and 10 steps for punching and forming the base plate, and furthermore, 4 steps for joining and assembly were performed in this case. Fig. 7 shows the products fabricated by the process. The results show that the unit part was successfully fabricated by using the press forming in a progressive die. One of most important issues for fabrication of micro functional devices such as MEMS, Biochip and so on, is manipulation and assembly of the parts. The automatic manipulation and assembly in the progressive die manifests very higher potential for production of micro functional devices by using micro press forming.

5. Conclusions

A micro press forming and automatic assembly processes in a progressive die was developed and applied to fabricate micro single and unit parts. High-energy beams were introduced for fabrication of the micro die with feature of several micrometers and DLC coating for construction of film on the surface of the die for improving the wear-resistance. Several kinds of dies were fabricated by using the developed technology and applied to press-form micro-metallic parts. A punching process was utilized to fabricate a micro gear. Furthermore, a unit parts with free components was fabricated by using the press forming and automatic assembly processes.

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