Optimum clearances for shearing work of sheet metals

Y. OKADA*, S. YOSHIDA** and K. MITSUI***

* Graduate School of Science and Technology, Keio University
3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522 JAPAN
E-mail: mr032118@hc.cc.keio.ac.jp

** Graduate School of Science and Technology, Keio University
3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522 JAPAN
E-mail: satoshi1981@mpd.biglobe.ne.jp

*** Department of mechanical engineering, Keio University
3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522 JAPAN
E-mail: mitsui@mech.keio.ac.jp

1. Introduction

Recent rapid progress in the field of mechanical and electrical technologies accelerates the needs for precision manufacturing technologies. Etching and micro-EDM are general machining methods for sheet metals. However, shearing work is consequently appropriate for mass-production.

In general, shearing work of sheet metals are affected by the thickness of sheet metals, clearance of the die and punch [1], shearing velocity [2], [3], and so on. In particular, the clearance is the most important factor in the shearing work of sheet metals. For general shearing work of various sheet metals, the optimum clearances have been already proposed [4]. However, optimum clearances for thin sheet metals have not been proposed yet. It is not made clear that the optimum clearances for general shearing work can be applicable for also thin sheet metals or not. Recently, numerical simulation for clearances in shearing work of thin sheet metals and optimization seems to be started [5], but the research to propose the optimum clearances for thin sheet metals through experiments and measurements has not been reported.

From these points of view, the purposes of this study are, 1) development of a stamp out machine for thin sheet metals, 2) find out the relation between machining conditions and dimensional accuracy of holes and wear of the die, 3) proposal of the optimum clearances for shearing work for thin sheet metals.

2. Development of stamp out machine

In order to investigate optimum clearances in stamp out machining that is a kind of shearing work, it is an indispensable function to stamp out in the condition of the exact coincidence of the center of the die and punch. However, in ordinary stamp out machines, it is impossible to coincide the center of the die and punch exactly. Therefore, as shown in Fig.1, a stamp out machine, which enables adjustment of the center of the die and punch, has been developed.

The developed stamp out machine has the structure in which the die and punch are completely split into two parts. The coordinates of the center of the die and punch are measured by image processing system, and then both centers are adjusted by moving the die, which is set on PZTs driven X-Y micro-stage.

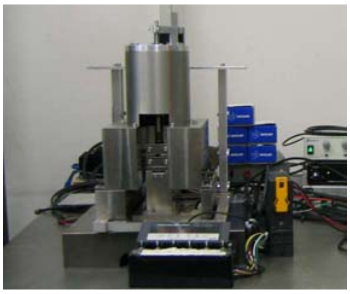

Fig.1 Stamp out machine

3. Measurement and adjustment systems for center of the die and punch

The 2D images of the die and punch are taken by an optical microscope with magnification 2, which is installed with a CCD camera (Fig.2). Then, these images are processed by machine vision software “Hexsight (by Adept Technology, Inc.) as shown in Fig.3.

In order to adjust the center of the die and punch, it is easier to move the die. The most popular devices of carrying a die are commercially available X-Y micro-stages. However, the stiffness of these X-Y micro-stages is not robust enough to survive the press load conditions applied through the die. From the reason, we have developed PZTs driven X-Y micro-stage, which consists of flexure hinge mechanisms, as shown in Fig.4.

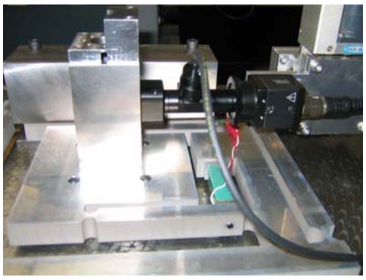

Fig.2 Layout of a CCD camera

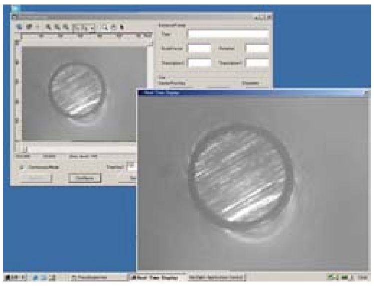

Fig.3 Machine vision software “Hexsight”

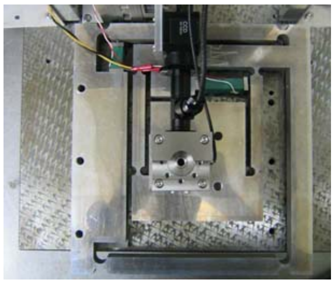

Fig.4 PZTs driven X-Y stage

4. Measuring instrument for Shape and Dimension of Micro-Components

In this study, quantitative measurements of dimension of holes, roll over and burrs, the ratio of a shear plane and a fractured section are very important. The measuring method that has small measuring force and applicable especially to the measurements of roll over and burrs is required. Then, a small 3D-CMM for the measurement of shape and dimension of micro-components [6], which had been developed in our laboratory, was used. The configuration of the apparatus is shown in Fig.5.

In the measuring instrument, the probe detecting proximity to the object through tunneling effect. So we can measure without contact to surface of a measuring target. A Z-axis micro-stage and a linear motor driven X-Y micro-stage are used for coarse positioning. For the fine positioning, PZTs driven X-Y-Z micro-stage that has 100 μm travel are set on the linear motor micro-stage. The measuring targets are set on the PZTs driven X-Y-Z micro-stage.

Another flexure hinges movable to X-Y-Z direction with piezoelectric actuators (PZTs) are set on the Z –axis micro-stage. The maximum driving range of these flexure hinges is about 10 μm along each axis. The flexure hinges equipped with PZTs are used as the probe over travel protection mechanism.

As for the radius of probe tip is 1 μm or less. The probe is fabricated by micro-EDM. The measuring resolution of the small 3D-CMM is 0.2 μm.

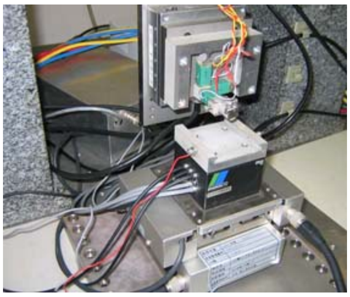

Fig.5 Small 3D-CMM

5. Experimental results

The machining conditions used in the experiments are shown in table 1. In the experiments, the center of the die and punch are adjusted by the previously mentioned procedures. The error of the adjustment is less than 1μm. After the stamp out experiments, we took photomicrographs of the cross section of the thin sheet metals with a laser microscope. The photographs of the cross section are shown in Fig.6 through Fig.10. We have measured the roll over and burrs by small 3D-CMM. The examples of the measurements are shown in Fig.11 and Fig.12.

In general shearing work of various sheet metals, optimum clearances for phosphorus bronze are 6%t to 10%t (for one side). From the result of our experiments, when the clearances are set at 5%t and 10%t, the thickness of a shear plane and a fractured section is nearly at 1:1 ratio. These results are consistent with the optimum clearances for general shearing work. When a clearance is set at 15%t, the thickness of a shear plane and a fractured section is nearly at 1:1 ratio. However, the clearance of 15%t is out of range in the optimum clearances for general shearing work. For phosphorus bronze (t=0.2mm), optimum clearances might have possibility larger than the optimum clearances for general shearing work. We would like to propose the optimum clearances with also roll over and burrs taken into consideration in future.

Table 1 The machining conditions used in the experiments

external diameter of a punch	1.000mm
internal diameter of dies	1.010, 1.020, 1.040, 1.060, 1.080mm
clearances (for one side)	2.5%t, 5%t, 10%t, 15%t, 20%t
material of work piece	phosphorus bronze JIS C5191 (ISO CuSn6)
thickness of work piece	0.2mm
pressure of a stripper	58.634N
velocity of stamp out	1.004mm/s

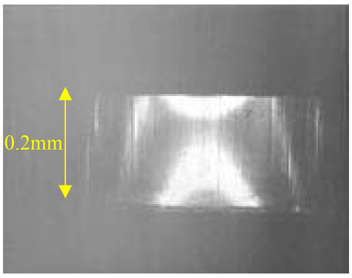

Fig.6 A cross section (clearance=2.5%t)

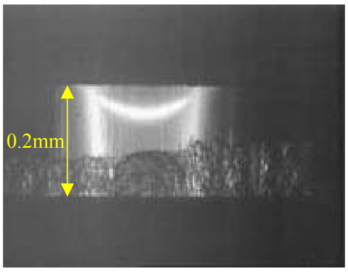

Fig.7 A cross section (clearance=5%t)

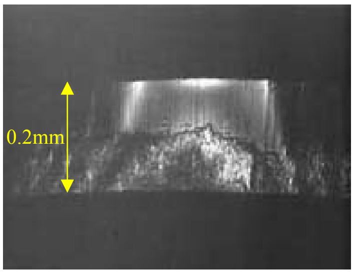

Fig.8 A cross section (clearance=10%t)

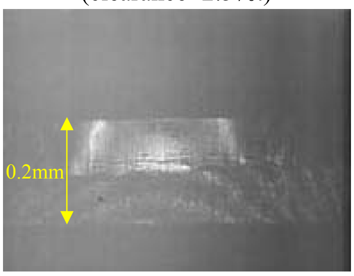

Fig.9 A cross section (clearance=15%t)

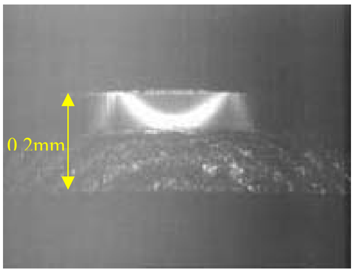

Fig.10 A cross section (clearance=20%t)

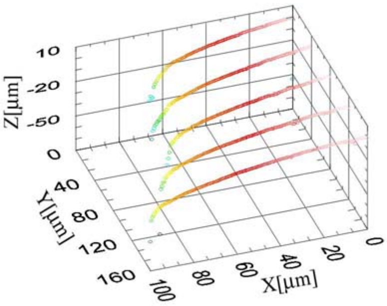

Fig.11 result of measuring of roll over (clearance=10%t)

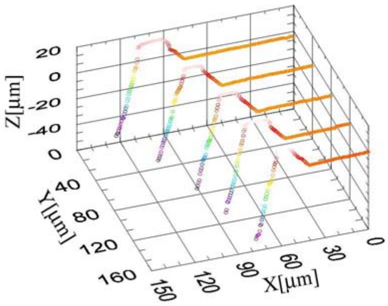

Fig.12 result of measuring of burrs (clearance=10%t)

6. Conclusions and Acknowledgements

In this report, we have tried to make clear the optimum clearances for thin sheet metals stamp out machining through experiments and measurements. The results are summarized as follows:

(1) For phosphorus bronze (t=0.2mm), when the clearances are set at 5%t and 10%t, the thickness of a shear plane and a fractured section is nearly at 1:1 ratio. The result is almost same as the optimum clearances for general shearing work.

(2) For phosphorus bronze (t=0.2mm), when the clearance between the die and punch is 15%t, the ratio of a shear plane and a fractured section is nearly at 1:1 ratio. The result is different from the optimum clearances for general shearing work.

(3) For phosphorus bronze (t=0.2mm), optimum clearances have possibility larger than the optimum clearances for general shearing work.

The authors gratefully acknowledge the contribution of AMADA foundation for metal work technology that supported this study.

7. References

[1] Shinzi FUKUI and Teizo MAEDA: A commentary on the optimum clearances of shearing tools of sheet metal, Journal of the Japan society of precision engineering, (in Japanese), Vol.25, No.11 (1959) 602-629.

[2] Teizo MAEDA: Velocity Effect on Shearing of Sheet Metal Vol.1, Journal of the Japan society of precision engineering, (in Japanese), Vol.25, No.8 (1959) 364-379.

[3] Teizo MAEDA: Velocity Effect on Shearing of Sheet Metal Vol.2, Journal of the Japan society of precision engineering, (in Japanese), Vol.25, No.11 (1959) 439-451.

[4] Japanese Society of Die and Mould Technology, Die and Mould Handbook, (in Japanese), NIKKAN KOGYO SHIMBUN, LTD. (1989) 335.

[5] QIN S-J, LI H-B, PENG J-G, and LI S-B: Numerical simulation and optimization of clearance in sheet shearing process, Transaction of nonferrous metals society of china, Vol.13, No.2 (2003) 407-411.

[6] Toshiya SHIRAMATSU, Kenichi KITANO, Masayoshi KAWADA and Kimiyuki MITSUI: Development of Measuring Method for Shape and Dimension of Micro-Components (Modification of the Original Measuring System, Calibration of the Probes and the Results of Dimensional Measurements), JSME International Journal, Series C, Vol.47, No.1 (2004) 369-376.