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# Study on micro nosing process assisted by ultrasonic vibration

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**Abstract.** This study used experiments to investigate the effect of ultrasonic vibration on the micro nosing process of copper cup. The billets with 1 mm diameter and length were backwards extruded to form the cups with 0.1 mm wall thickness and 1.8 mm height. The cups were then used in micro nosing processes. A forming system with the ultrasonic vibration has been developed and installed on a precision press to conduct the experiments. An optical fibre sensor and a precession load cell were equipped on the ram of the press in order to accurately measure the load and stroke of the process. Two forming conditions with and without ultrasonic vibrations of 20 kHz were considered in this study. The results show that the ultrasonic vibration can improve the materials flow which leads to an even diameter along the shrunk region of the nosed cup. Moreover, the ultrasonic vibration greatly reduces the load in the micro nosing process of the copper cup.

## 1 Introduction

Nosing process reducing the dimension of the open end of a container has been used for producing a wide variety of metal components with specific shapes and profiles. The process has also been developed to fabricate axisymmetric seamless reservoirs by a single-stage nosing process of thin-walled tubes [1]. As the demands of micro metal components constantly increase in the fields of portable products, precision instruments and medical devices, researchers are interested in the development of new nosing processes at micro scale. However, size effects may cause some problems such as nonhomogeneous materials flow and relatively higher friction in micro metal forming [2-5] that could also exist in the micro nosing process. By increasing the forming temperature and reducing the grain size of the billet, it is possible to improve materials flow and result in uniform deformations [6, 7]. Moreover, Yao et. al.[8] found that high-frequency vibration on the compression test of pure aluminium can reduce forming stress, surface roughness and friction. The high-frequency vibration leading to acoustic softening was considered to be a much more efficient method to activate plastic deformation than pure heating. In the study on the compression testing of martensitic stainless steel with superimposed ultrasonic vibration, Michalski et. al. [9] also reported that the force reduction and specimen heating can be

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achieved. Furthermore, Hu et. al. [10] investigated the effect of superimposed ultrasonic vibration on the compression tests of commercially pure aluminium, and showed that the ultrasonic dynamic impact effect was the dominating mechanism for stress reduction in compression condition. Bunget and Ngaile [11] studied the effect of ultrasonic vibration on the micro extrusion process and concluded that the forming load greatly decreased and the surface of the micro-extruded parts was significantly improved when the ultrasonic vibrations were imposed. The reviewed studies show that the ultrasonic vibration has high potential for improving the quality of the formed parts and reducing forming load in the metal forming process at micro scale.

The micro nosing process can be used to shrink the open end of a micro metal component or assemble micro metal parts. However, the process at micro scale may encounter high friction that could cause high forming load and defects. To reduce the friction effects, applying ultrasonic vibration on the micro nosing process could be one of methods. This study used experiments to investigate the effect of ultrasonic vibration on the micro nosing process of copper cup, and the deformation of the workpiece and forming load are discussed.

## 2 Experimental setup

### 2.1 Micro nosing process

In this study, the micro nosing process is to reduce the diameter of the open end of the cup which is fabricated by a micro backward extrusion process. As-received pure copper wires with 1 mm diameter were cut and ground into lengths of 1 mm as the billets for the backward extrusion processes to produce the cups with 1 mm outer diameter, 0.1 mm wall thickness and 1.8 mm height. The extruded cups were then used in micro nosing processes to shrink the diameter of the open end to 0.7 mm. Figures 1 and 2 present the schematic diagrams of the micro backward extrusion and micro nosing process, respectively, and the key dimensions. The conical die with a semi-die angle of $30^{o}$, as displayed in Figure 2(a), was used in the process.

### 2.2 Ultrasonic vibration forming system

To investigate the effect of the ultrasonic vibration on the micro nosing process, a forming system capable to superimpose ultrasonic vibration was established for the experiments. The system consists of an ultrasonic vibration signal generator, a piezoelectric transducer, a horn, and a die, as shown in Figure 3. The horn was made in titanium alloy and the die in tool steel was assembled with a tungsten carbide insert. Figure 4 shows the key dimensions and photos of the die for the micro nosing process. The established system was installed onto a precision press with a load capacity of 50 kN and a positioning accuracy of 10 μm as presented in Figure 5. Moreover, an optical fibre sensor with an accuracy of 1 μm and a load cell with an accuracy of 0.5 N, as shown in Figure 5(b), were installed on the ram of the press to measure the stroke and forming load of the process, respectively.

### 2.3 Procedure

The pure copper billets with 1 mm diameter and length were lubricated with oil and backwards extruded in a constant punch speed of 0.1 mm per second to form the cups for the use in the experiments of the micro nosing process. To investigate the influence of the ultrasonic vibration, the die was assisted by vibrations with a frequency of 20 kHz and an amplitude of 5 μm. The sampling rate for data acquisition was 7.2 kHz for the experiments with the ultrasonic vibration. Table 1 lists the conditions for the experiments of the micro backward extrusion and the nosing processes with and without ultrasonic vibration.

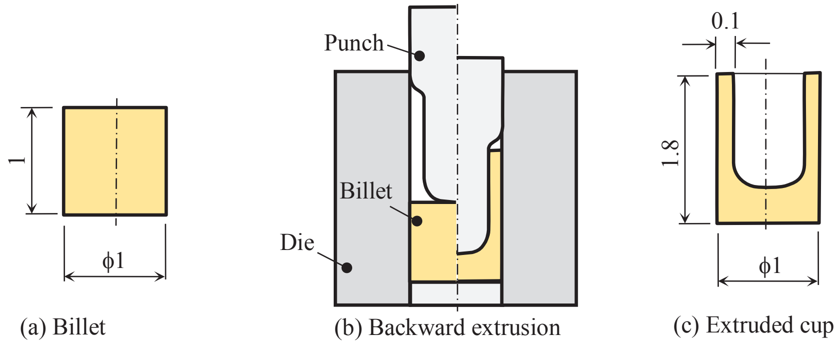



**Fig. 1.** Micro backward extrusion.

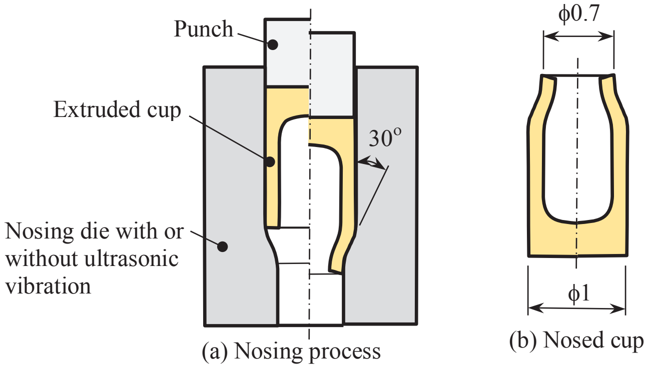



**Fig. 2** Micro nosing process.

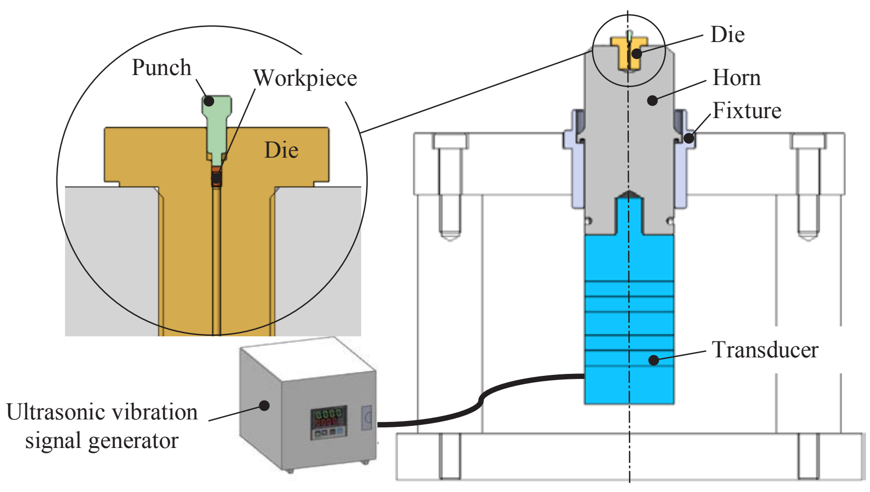
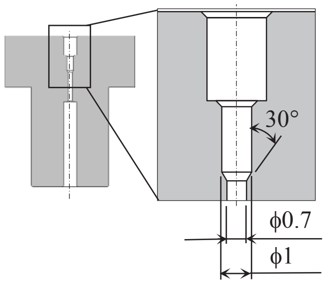
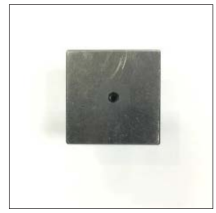



**Fig. 3.** Schematic diagram of the micro nosing system assisted by ultrasonic vibration.




(a) Key dimensions of nosing die

(b) Front view

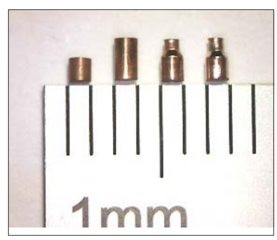


(c) Top

**Fig. 4.** Key dimensions and photos of the nosing die.

(a) Ultrasonic vibration device installed on the press


(b) Load cell installed on the ram of the press




(c) Billet, extruded cup, nosed cup and nosed cup from the process with ultrasonic vibration (from left to right)

**Fig. 5.** Experimental setup.

**Table 1.** Conditions for experiments of micro backward extrusion and micro nosing process.

| Conditions | | Micro backward extrusion and micro nosing process without ultrasonic vibration | Micro nosing process with ultrasonic vibration |
|---|---|---|---|
| Punch speed, mm/s | | 0.1 | |
| Stroke, mm | | 0.64 | |
| Lubricant | | Oil | |
| Sampling rate for data acquisition, Hz | | 120 | 7200 |
| Ultrasonic vibration on the die | Frequency, kHz | None | 20 |
| | Amplitude, μm | None | 5 |

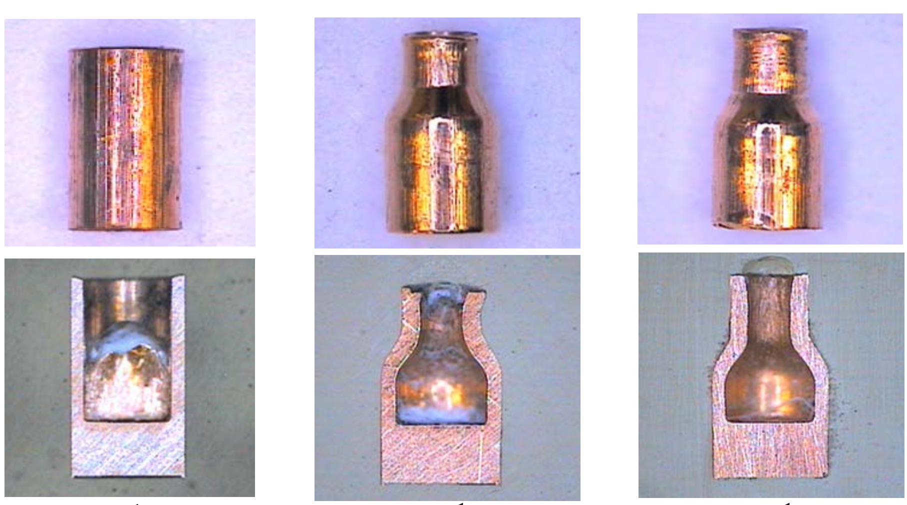
# 3 Results and discussions

## 3.1 Deformation

The extruded cup, presented in Figure 6(a), with uniform rim and wall thickness implies the materials flowed homogeneously in the micro backward extrusion process. Figure 6(b) presents the nosed cup in which the open end has been shrunk by the micro nosing process without the ultrasonic vibration. It clearly shows the shrunk region has a neck with a smaller diameter. The phenomenon might be caused by the friction effect which led to difficulties in materials flow along the shrunk region as the nosing process progressed. With the die assisted by the ultrasonic vibration, an even outer diameter in the nosed cup can be produced, as shown in Figure 6(c). The above results show that the ultrasonic vibration can improve the materials flows and thus result in better quality of the product in the micro nosing process.

## 3.2 Load

The load from the nosing process without ultrasonic vibration gradually increased with the stroke to the maximum value of about 120 N as displayed in Figure 7. However, the load curve varied with different peak values in the nosing process with the ultrasonic vibration. The high frequency variation of the load curve is a typical phenomenon in an ultrasonic vibration assisted forming process. Moreover, the curve showed two ranges of peak values. In the early stage of the nosing process, the extruded cup might be sliding in the die cavity that resulted in an average load of about 5 N and the most peak values within a range of about 20 N. In the later stage after the stroke of about 0.2 mm, the average load clearly increased to the value of about 30 N, then gradually increased to the maximum value of about 45 N. The most peak values were in a range of 50 N. The comparison in the load curves clearly shows that the ultrasonic vibration can significantly reduce the load in the nosing process of the micro copper cup.




(a) Extruded cup (b) Nosed cup without ultrasonic vibration (c) Nosed cup with ultrasonic vibration

**Fig. 6.** Fabricated parts.

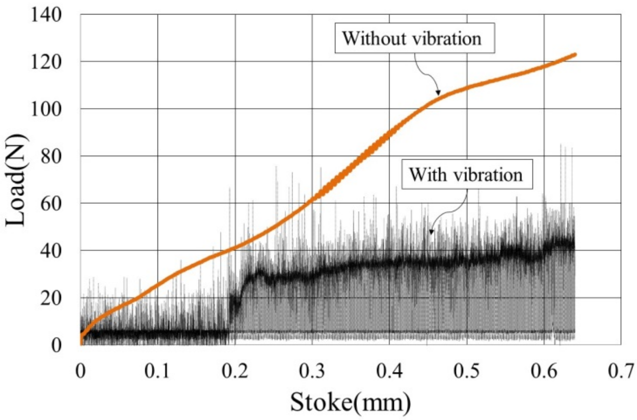



**Fig. 7.** Load curves of nosing processes.

## 4 Conclusions

The study investigated the effect of ultrasonic vibration on the deformation and forming load in the micro nosing process of copper cup. Two forming conditions with and without the ultrasonic vibrations were considered in the study. The results clearly show that the ultrasonic vibration can improve the materials flow which leads to an even diameter along the shrunk region of the nosed cup. Moreover, the ultrasonic vibration greatly reduces the load in the micro nosing process of the copper cup.

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