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# A Review: Ultra-thin Sheet Metal Micro-forming

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***Abstract***

*Current available micro-manufacturing technology and micro-forming draws the attention due to its high precision, low energy consumption and low cost products with better mechanical properties by manufacturers and researchers. However, due to the size effect, the traditional macro-forming cannot be applied to micro-forming directly. Therefore, manufacturing a micro-component by micro-forming process is a challenging field. When the parts become minimized, adhesive force and surface tension plays an important role. The manufacturing of micro-die, micro-punch, holding of micro-forming components and concentricity are also very difficult. In the meantime many research projects are carried out in several countries to improve the situation. The manufacturing of micro-forming components and micro-forming operation in a single setup can avoid the eccentricity problem. In the present study three micro-forming tools are designed and one of those manufactured.*

**Keywords:** *Micro-forming; deformation mechanism; flow stress, thickness effect; Microstructure,*

## 1. Introduction

There is currently a increasing demand for micro-forming in the field of electronic products, electro mechanical systems (MEMS), medical equipment, aerospace application and sensor technology. Examples of some typical products are micro-screw, IC carriers, fasteners, connecting elements, vehicle aircraft, packaging for consumable goods, cans for drinks, honey bee structure of aero plane, fuel shell and frames for TV/computer screens/monitors/displays etc. [1, 2]. New generation cell phones are becoming smaller and additional functions like multimedia sets, integrated organizers, mp3 players, pen/wrist watches with integrated cameras and a micro hard disc drive which can fit inside an egg shell have been developed in recent years [3, 4]. Lithographic technologies, especially in LIGA (lighogranthie gralvanoformung and abformung) processes have dominated in the manufacturing of micro-components. The LIGA process has good accuracy but the process is slow and costly. Therefore, this process is not suitable for mass production [5]. The miniaturization of parts in micro-forming leads to a significant size effect, grain size effect. Due to these effects, the conventional macro-forming phenomena cannot be applied to micro-forming directly. When the parts are minimized, adhesion force and surface tension play an important role.

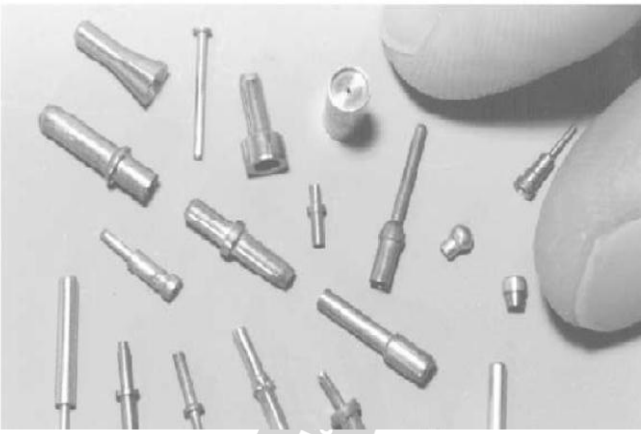

**Fig.1** Micro components

Therefore, manufacturing a micro component by micro-forming process is a challenging field. Therefore the formability study is needed to be necessary for micro-forming. Three FCC materials SS304, aluminum, brass are selected as working material of 30, 50 and 90 µm thickness. These materials are selected since they have different deformation behavior. The present study represents the grain growth is observed by annealing for all three materials and thickness. The mechanical property and microstructure of different annealed condition is observed by uniaxial tensile test and EBSD analysis. LDH test is performed for SS304 material and FLC is plotted. Three micro-forming tools are developed, two are designed and one is manufactured.

The early development of the micro-forming-machine was traditionally based on conventional forming machineries and focused on a different range of forming processes, which included stamping and bulk-forming processes. Struggle made by [7] and [8] validated the punching of thin sheet-metal by micro-punch. In [8] the punching proc ess was actuated by a high-force DC solenoid and material feeding was done by an automatic roll-feeder. The results established a successful punching process, different punch geometries being used. [7] Demonstrated an entirely manually-controlled punching process with a micro-punch

## 2. Micro forming manufacturing

The high-volume production of micro-components should be the main goal for the design of micro-manufacturing. When these products are designed, not only will functional requirements need to be considered, but also micro-manufacturing related factors will have to be taken into account. This is because manufacturing these products renders more significant challenges, compared to those for the manufacture of micro products

### *2.1. Factors negligible conventionally*

There is a limitation to how percentage conventional macro-scale machining can be scaled down for miniaturization. Beyond certain dimensions, factors that can be ignored with conventional machining suddenly play a big part in micro manufacturing: vibration, tool-offset, temperature, the rigidity of the tools and the structure of the machines, and chip removal, are more important because these factors have a greater influence on micro-products.

### *2.2. Volume production and automation*

Another issue occurred in current micro-process technology is in terms of process automation. Stand-alone and manual processes of the developed prototypes have required every aspect on the process to need manual adjustments. Most of the processes such as principal processes; pressing, milling, turning etc, and handling processes; material loading and unloading, tool positioning and aligning; were all manually configured and controlled by separate dedicated controllers to obtain precise and accurate motion and alignment. This time-consuming process has made micro-process suitable only for low yield-rate, and as-yet far removed from the potential of conventional processes. On top of this matter, manual adjustment tends to give greater parallax error compared to that with present automated closed-loop and programmable controllers that have error-compensation features.

### *2.3. Limitation on machinable materials Structure*

In parallel with the fairly early stage of micro-machine development, only ductile- and soft-materials with low-strength properties were chosen and studied as the test materials; mainly brass, copper and aluminum [4, 7-9]. The satisfactory machining of soft and ductile materials is easily achievable due to such materials exhibiting low mechanical strength and tending to deform easily under low applied load/force. Only simple micro-features were created successfully by the efforts made, which micro-features were far from being able to be used or applied. Soft materials are very limited in their usage and some manufacturers have found that these materials are not durable enough to meet the increasing demands of reliability and long life. Therefore, switching to harder and exotic materials is the only option available.

### *2.4. Tooling dimension Structure*

Another key-issue in micro-manufacturing development is tooling limitation. At present, 10μm end-mill tools have been realized, these tools being made from carbide (PMT). 25-50micron milling- and-drilling tools currently have been found satisfactory and can be found commercially [11-12]. Although micro-tooling development started more than a decade ago, there is still limitations existing, which limits the applicability of the tooling [13-14]. Only aspect ratios (the ratio of the tool diameter to the drilling depth) of 5 to 10 have been found suitable, and some have aspect ratios of even lower than five. Deeper-plunging and-drilling will result in tooling breakage, hence, makes the tooling unsuitable for the aerospace- and automotive-industries; which require very-high-strength material of low mass. The achievable accuracy of the drilled holes has not yet been intentional studied far and, furthermore, issue regarding the aligning of micro tools of sub-micron accuracy has not yet been explored far because no automatic machine is available at present capable of aligning tools of submicron precision [15].

### 2.5. Unwanted external forces Structure

Accurate positioning is also a main problem encountered in the control of micro-forming [16]. The external forces involved in physical contact, such as the electrostatic, sticking or adhesion effect, and Van Der Waals force, have become key issues and numerous studies have been made to understand the situation and the strategy necessary to eliminate those forces mathematically and practically [16-17].

### 2.6. Sensor dimension and performance Structure

More ever attention has to be paid to sensors accuracy available at the present time are bulky in size and the achievable precision is basically of the order of tenths of microns. Being considerable large in size makes the sensors difficulty to be positioned accurately on a tiny workspace, while this level of precision is not feasible for micro application, which requires minimum sub-micron precision. In addition, most of the calibration-precision capability of current machines is far less than the precision demanded on micro-handling.

### *2.7. Lubrication in micro-forming*

The surface quality affects lubrication in micro-forming. Two types of lubrication pockets have been found. The open lubricant pockets have roughness connected pockets open to edge and difficult to keep lubricated (Fig. 2). When force normal to surface is applied the lubricants escape and do not take part in transfer forming load. Generally the load applied acts on the asperities only. As a result higher normal pressure occurs on contact area, which leads to higher surface flattening and higher friction. But in the case of closed lubrication pockets, they do not have connection to the edge of the surface. Therefore the lubricants are blocked inside and pressurized during forming. These lubricants help to transmit load and the normal pressure on asperity decreases which results in low friction. The above discussion concludes that, the friction decreases in closed lubricant pockets as compared to open lubricant pockets [1].

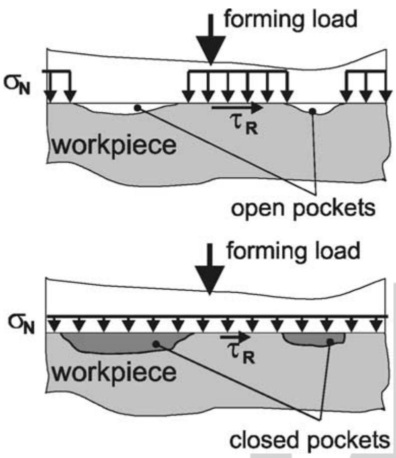


**Fig.2** Open and closed lubricant pockets [1]

*2.8. Size effect*

The size effect is concerned with friction and material behaviour, which are generally relevant for almost all forming processes. It is observed that, when the size is scaled down, flow stress decreases significantly flow stress decreases up to 30% in tensile tests of copper and aluminium when the sheet thickness reduces to 0.17 mm from 2 mm. [7–10].

## Conclusions

This paper describes a huge literature on micro-forming process, factors affecting the micro-forming process, different models developed in progressive research of micro-forming and the micro structure analysis.

**Summary of the findings :**

1) The miniaturization effect and friction behaviour has significant effect on micro-forming.
2) The flow stress varies directly with dimensions of the billets.
3) The flow stress is more at inner region as compared to surface.
4) The topography and microstructure analysis concludes that good surface quality and distribution of microstructure is obtained in micro-gear manufacturing.
5) Concentricity of micro-forming system is a great mproblem. It can be avoided by using single setup for manufacturing micro-forming components and performing micro-forming operations.

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