ARCHIVES
Of
FOUNDRY ENGINEERING
Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 11
Special Issue
2/2011
195–198

38/2

The experimental tool for micro-extrusion of metals

J. Piwnik[a,b], K. Mogielnicki[c]*, M. Gabrylewski[d], P. Baranowski[e]
[a,c] The Department of Production Engineering, Bialystok Technical University – Wiejska street 45C, 15-351 Białystok, Poland
[b,d,e] Centralny Ośrodek Badawczo-Rozwojowy Aparatury Badawczej i Dydaktycznej **COBRABiD –** Łucka street 15, 00-842 Warsaw, Poland
*correspondence address: e-mail: k.mogielnicki@interia.pl

Received 11.04.2011; Approved for print on: 26.04.2011

Abstract
In paper the technological tools requirements, used for micro-extrusion of metals in cold and warm conditions are presented. The constructive principles for the micro-tools are also described. The influence of the size effect in a workpiece and a tool top layers roughness form on extrusion processes in microscale are showed. The tool, designed to an experimental verification of the size effect influence, in a tool roughness form, on the metal rod forward extrusion are presented. This tool is made in the form of two halves, joined together by the pegs and screws. It has bored two dies profiles with the same dimensions, the only difference is a degree of the containers roughness. That solution gives a possibility to specify the influence of the tool roughness degree on the extrusion forces, deformation process and a product quality. Described tool was designed in such a way to manufacture it with using conventional machining equipment.

Key words: Microforming; Micro-extrusion; Size effect; Tools

1. Introduction

Known and applied designs of metal forming devices, in event of adaptation for the micro-extrusion purposes, should be analyzed for curiosities that appears with small dimensions and adapted to the requirements of the process.

Tools used for the production of details by the microforming methods are very small, contain small number of parts with a close tolerance and have a high surface quality. Typical problems that appear when designing the micro-tools are: selection of the appropriate processing methods which ensure the desired accuracy of elements dimensions, selection of the materials with required physical and mechanical properties and application of the appropriate system facilitating forming process [1].

Micro-extrusion can be divided, as in the case of the macro-forming of metals, in to: forward extrusion, backward extrusion, combined – forward and backward extrusion (material flows in both directions) and lateral (material flows perpendicular to the direction of the punch motion). It may also be carried out in the cold or warm conditions. The temperature increase makes the micro-stamps to be exposed to high stresses. Extrusion of metals in microscale at elevated temperatures forces the application of additional design solutions, complicating the tools construction and reducing hardness and strength parameters of the punch and die.

While the conventional extrusion in warm conditions in the macroscale, deformed material is heated before placing in to the die. However, in microscale, the heat capacity of the workpiece is too low compared with the speed of cooling by contact with the surrounding air, a die and a punch. Therefore it is suggested to heat the workpiece by the hot parts of tool. To obtain an efficient thermal system, the quantity of parts with elevated temperature must be kept to a minimum and the heat source should be located close to the deformed object [2].

Designs of tools used for micro-extrusion of metals should take into account the specifications of this process. The implementation and cooperation components accuracy of these devices should represent a several micrometers. Their number should be limited to the necessary minimum in order to reduce the tolerance chain. These tools should be designed taking into account the size effect, which greatly influences on the plastic treatment process and on the product property [3].

2. Extruding of metals in micro-scale

The primary problem connected with microforming is so-called “size effect” resulted from the miniaturization [4]. This effect differs described process from conventional metal forming methods in macroscale and significantly affects the possibilities and limitations of this technology. Its presence causes the changes in the dynamics of deformation, which are not appeared in the case of traditional deformation processes. The cause of the size effect is an increase in the importance in microscale of factors overlooked in the case of a conventional extrusion, because of their negligible impact on the process [5,6]. In case of mikroforming there are starting to be important parameters such as: the number and size of the material grains, the degree of a tool and workpiece roughness, adhesion and Van der Waals forces at the tool-workpiece interface.

During extruding a bushes from cylindrical samples with using extrusion oil it was observed an increase in friction with the objects miniaturization [6]. This has led to the theory of open and closed lubricant pockets model or dynamic and static lubricant pockets model shown on fig.1 [4].

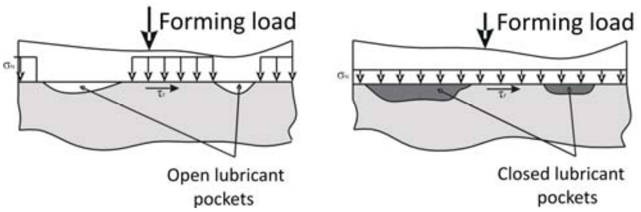
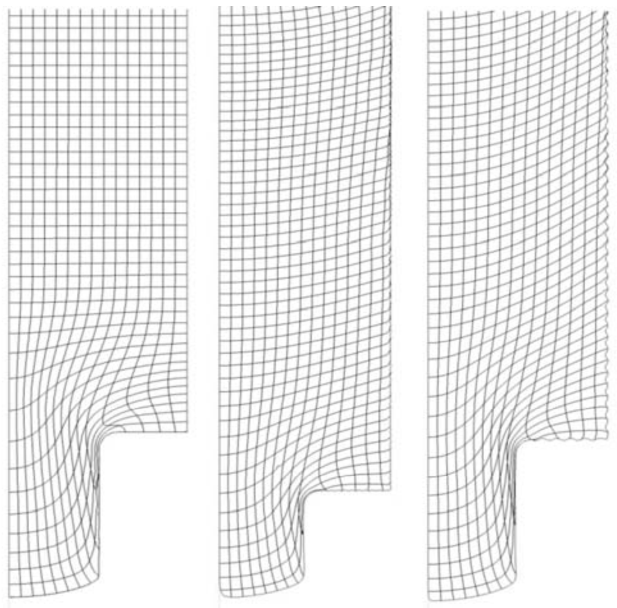


Fig. 1. Open and closed lubricant pockets [7].

The forming force, influencing on lubricated surface of the sample begins to form plastically the peeks of roughness, increasing the oil pressure trapped in the roughness valleys – closed lubricant pockets. Roughness valleys that have a connection to the surface cannot keep the lubricant – open lubricant pockets. With increasing normal pressure the lubricant escapes and is not able to support or transmit the forming load. Closed lubricant pockets on the contrary do not have a connection to the edge of the surface. The lubricant gets trapped in those pockets and pressurized during forming. The pressurized lubricant facilitates to transmit the forming load, thus reducing the normal pressure on the asperities, which results in lower friction. It can be summarized that closed lubricant pockets help to reduce friction (and surface flattening) in contrast to open lubricant pockets, which exist in a certain distance of the surface edge. [4,5,8].

Numerical simulations of micro-extrusion processes demonstrate the significant impact of the tool surface roughness on the material flow in dry conditions [9]. As the roughness parameters increase, increases the forming load and the image of the plasticity area is modifying. At the tool-workpiece interface it was observed a high level of material deformation. There are also changes in the material flow in the whole sample’s volume [10**]**.

Images of the material flow obtained in by the numerical analysis for forward metal rod extruding in containers with varying degrees of surface roughness are shown on fig.2. Image of the flow net exposes lack of material deformation in the container with a flat wall, with given constant friction factor at the interface (fig 2a). While the presence of the roughness – with zero friction factor at the contact, leads to deflection of cross lines at the whole longitudinal view of the container contents. The higher degree of roughness, the greater net transverse lines deformation (fig.2b and 2c).



a) b) c)

Fig. 2. Flow net of extruded metal rods with a interface characterized by: a) constant friction factor; b), c) triangular wave and 0 friction [**10].**

3. Experimental tool

To experimental verification of numerical analysis results for forward metal rod extruding in dry conditions [10] the tool has been constructed, because of which it will be able to define the real impact of the container roughness while processing (fig.3).

The tool has bored two dies profiles with the same dimensions, differing only in the roughness degree of the container walls. The containers are ø = 2*mm* in diameter while the dies ø = 1*mm* (fig.4). The dies frames were made of NC6 steel and the punches of bearing steel. After obtaining the desired shapes, the elements were hardened and their surfaces were polished. Axisymmetric geometry of the dies and containers elements were made in the form of two halves, joined together by the pegs and screws. The tool was designed in such a way to ensure the micro-tools requirements, with using a conventional machining equipment for their manufacture.

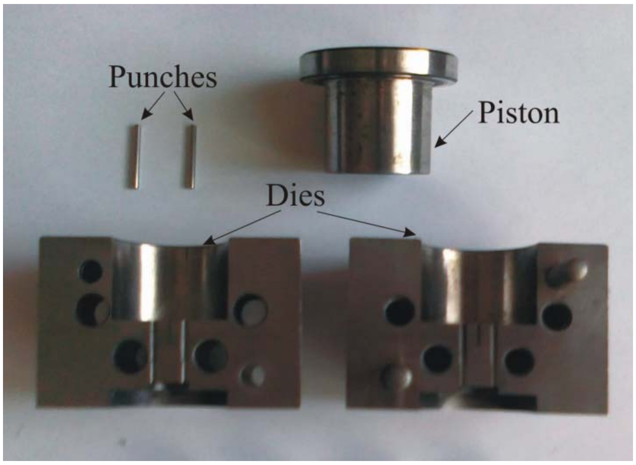


Fig. 3. View of tool for the metal rod forward micro-extrusion

The containers and dies holes were made by micro-wire EDM. In order to obtain the differential wall roughness these holes were bored with using various values of the current intensity.

4. Summary

Tools for micro-extrusion in their construction should contain a number of compromises. They should have a small quantity of components and a high precision level of implementation. In addition, when designing this type of equipment it should be taken into account the size effect, far influenced on the plastic metal processing in microscale. The tool presented in this article were designed in such a way to produce it with using conventional machining equipment, with taking in to account constructional conditions required for micro-tools. Containers with the different top layers roughness allow to achieve following objectives:

1. To verify the theoretical assumptions correctness – a cognitive objective.
2. To determine the real impact of the container roughness on the extrusion loads, the deformation process, and the quality of the product – a scientific goal.
3. To determine technological process parameters, which lead to formulate the assumptions for numerical modeling of metal extrusion in microscale – an utility purpose.

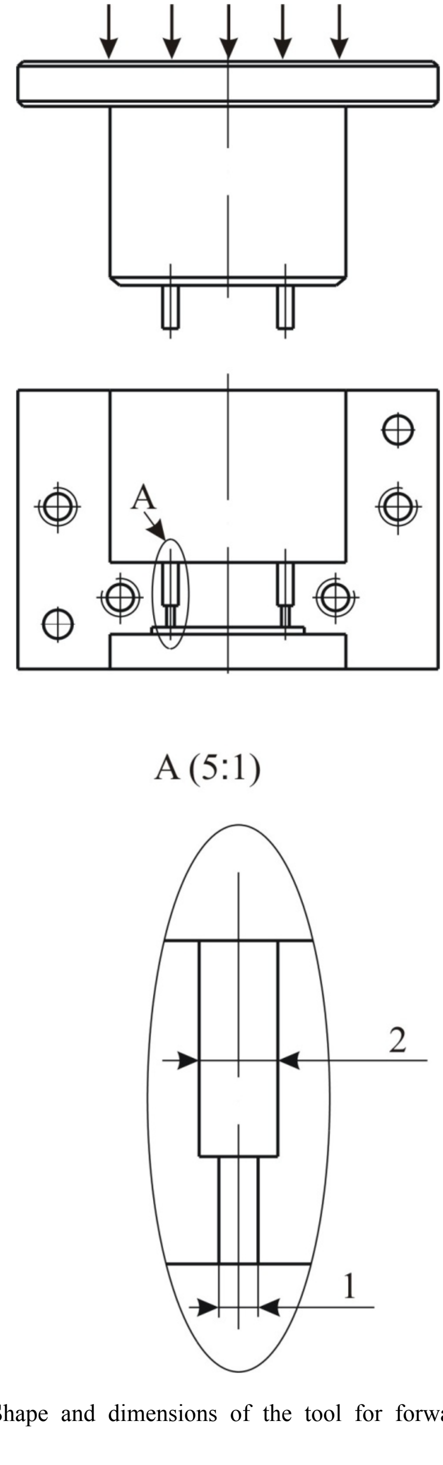


Fig. 4. Shape and dimensions of the tool for forward micro-extrusion

References

[1] K. Mogielnicki, K. Garbala, J. Piwnik: Overview of Tooling Concept for Microforming, Aparatura Badawcza i Dydaktyczna, 2010, 113-118.

[2] M. Arentoft, S. Bruschi, A. Ghiotti, N.A. Paldan, J.V. Holstein: Microforming of Lightweight Metals in Warm conditions. Proc. of the 11th ESAFORM, Lyon, 2008.

[3] J. Piwnik, K. Mogielnicki, K. Garbala: Problems related to micro-extrusion process, Aparatura Badawcza i Dydaktyczna, 2009, 26-31.

[4] U. Engel, R. Eckstein: Microforming – from basic research to its realization, Journal of Materials Processing Technology, 2002, 125 – 126.

[5] F. Vollertsen, H. Schulze Niehoff, Z. Hu: State of the art in microforming, International Journal of Machine Tools & Manufacture, 2006, 1172-1179.

[6] N. Tiesler: Grundlegende Untersuchungen zum Fließpressen metallischer Kleinstteile, Bamberg, Meisenbach Verlag, 2002.

[7] N.Tiesler, U. Engel: Microforming – Effects of miniaturisation, Metal Forming 2000, Proceedings of the 8th int. conf. on metal forming, Balkema, Rotterdam, 2000, 355-360.

[8] F. Vollertsen, Z. Hu, H. Schulze Niehoff, C. Theiler: State of the art in micro forming and investigations into micro deep drawing. Journal of Materials Processing Technology, 2004, 70-79.

[9] J. Piwnik, K. Mogielnicki: The friction influence on stress in micro extrusion, Archives of Foundry Engineering, 2010, 451-454.

[10] J. Piwnik, K. Mogielnicki: Deformations in micro extrusion of metals, Archives of Foundry Engineering, 2010, 87-90.