Piezoelectric driven Micro-press for microforming

W. Presz a, *, B. Andersen b, T. Wanheim c

a Institute of Materials Processing, Warsaw University of Technology, ul. Narbutta 85, 02-524 Warsaw, Poland
b Noliac A/S, Hejreskovej 18, 3490 Kvistgaard, Denmark,
c Dpt. of Manufacturing Engineering and Management, Technical University of Denmark, 2800 Lyngby, Denmark
* Corresponding author: E-mail address: w.presz@wip.pw.edu.pl

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ABSTRACT

Purpose: Progressive miniaturisation generates necessity of micro-parts production also on the field of metal forming. At present small parts are produced with a big presses which were designed for manufacturing much bigger products. Further miniaturisation will not make possible to keep sufficient tolerances of products manufacturing with these standard presses.

Design/methodology/approach: It is suggested to set up special technological lines for micro-parts production. Such lines would consist of micro-machines based on piezoelectric actuators. The recent development of that kind of actuators assures even up to several kilo-Newton forces and movement accuracy theoretically in atomic scale. As a step for building the line, a micro-press with piezoelectric drive is being constructed.

Findings: The constructed press can work with direct actuator and can be also equipped with simple mechanical movement amplifier. Micro-indenting, micro-pressing and micro-backward extrusion were successfully carried on the press. Examples of simple sequential and incremental micro-forming processes were also performed.

Research limitations/implications: Equipping Micro-press with additional devices like x-y or x-y-z table positioning, automatic clamping and supplying systems etc. will able to extend its application to wide range of microforming processes.

Practical implications: Micro-press in intention is going to be a part of industrial micro-lines for micro-product.

Originality/value: The idea of building micro-parts with micro-machines standing as production micro-line seems to be quite natural but so far not realised. Presented Micro-press with original construction is another step to put this idea into reality.

Keywords: Plastic forming; Microforming; Micro-press; Piezo-driving

1. Introduction

The general trend towards higher integrated functional density in electronic and micro-mechanical components as well as the increasing application of micro-systems in many technological fields is still unbroken. It means that for the production engineers more and more geometrically complicated and smaller parts have to be designed and manufactured. Most of such parts called mini or micro parts, have been used in electronics and bio-medical applications which are the main fields of interest in large miniaturization. This tendency demands serious modification of well-known processes, to execution of which experience collected through years seems to be inadequate. One of such technologies is a technology of metal forming. A stormy development of its, in
principle new branch which is plastic micro-forming, is observed. Considerable diminishing sizes of products causes, that this technology gathers of completely new dimension and enters in yet weakly recognized areas of knowledge [1,2,3]. On the other hand many laboratories all over the World carry on intensive investigations of replacing technologies such etching, electro-embossing or laser cutting with metal forming technology. It is obvious that correctly driven cold metal forming process allows to obtain large dimension accuracy, very good surface quality and high strength proprieties of product [4]. This is opposite to product properties that can be reached with previously mentioned methods based on material removing. Additionally the new nano-materials and ultra-fine grain materials give for micro forming the new opportunities [5,6]. Fig.1 shows free surfaces of micro products manufactured with forward extrusion process. In case a the billet material was standard 1070 aluminium whether on case b the ultra fine grain (grain size about 0.6 $\mu$m) 1070 material was used. Metal forming is besides low material consuming and environment friendly technology. Nowadays most of all micro-parts are produced with technologies originally dedicated to considerably bigger products. Production is performed with presses and tooling with installed numbers of punches. An example of part - diode support and tooling for its production is shown in fig.1. It is manufactured with 10 tons eccentric press.

- **How it is possible, that so large machine is used to production of so small component?**

Most probably, the reason is very simple. Technologies for Industry orders were worked out to fit to already existing technological lines and machines, but orders refer to smaller and smaller parts. In result, brought this to so great differences in sizes of machines and produced by them components.

- **However will it be possible at further miniaturisation to maintain indispensable dimension accuracy using hitherto existing machines?**

![Fig. 1. Typical tooling for manufacturing diode connector from 0.2 mm sheet metal](image)

Most probably, not! Setting up special technological lines consisting from micro-machines to aim at manufacturing of micro-parts only, seems to be a solution. Micro-press (M-press) designed and constructed within this project is a step on the way for this goal.

**2. Concept of Micro-press**

In intention, micro-press is a unit of computer controlled production line of micro-parts [7]. Kinematics of press is based on modern stacked multilayer ceramic actuators -SMCA [8]. Stormy development of this kind of piezoelectric materials is observed from a dozen of years [9]. These actuators mastered almost completely devices in which precise controlling of movement is required [10]: discs controllers, computer printers, manipulators, micro-switches, video cameras and many other. Since actuators refer to the effect of crystal shape changing under influence of voltage their movement accuracy is in atomic scale. It makes them perfectly suitable to utilisation in micro and nano-technologies. Good examples are piezo-driven systems for microforming as system for micro-extrusion [11] and system for creation of surface micro-geometries [12]. On the other hand it is now possible to design and manufacture piezo-actuators acting force as big as 25 kN [13]. Schematic diagram of M-press shows Fig.2. Base units of it are: frame with installed Piezoelectric Executive Unit PEU that works as a ram of M-press and table also driven with piezoelectric actuators. Movement of PEW and table with a help of displacement transducers controls computer. M-press is equipped with microscope with digital camera making possible observation of working space. This optical system might be also used to superintending of technological process.

![Fig. 2. Schematic diagram of M-press: 1- frame, 2- piezoelectric executive PEU, 3- piezoelectric stack, 4- punch, 5- table, 6- piezoelectric stack, 7- slug, 8- displacement transducer, 9- displacement transducer, 10- microscope with CCD camera](image)

![Fig. 3. M-press: a) with direct piezoelectric executive unit, PEU: 1- piezoelectric stack, 2- rubber washer, 3-ball joint, 4-springs, 5- punch, b) with amplified PEU : 1- piezoelectric stack, 2- displacement amplifier, 3- PEU body, 4- springs, 5- punch, d) amplified PEU position](image)
3. Construction of Micro-press

Modernised standard 4 pins guide die set with sliding runners is used as a frame of press. Upper plates position is fixed with buffers in dependence from required process. Executive unit uses especially for this press constructed SMCA of dimensions 10x10x140 mm. This unit is designed in two variants which use the same stack and can be easy transformed. In first variant SMCA works direct, fig.3a, and in second as Amplified SMCA with 4 times mechanical movement amplifier, fig.3b. In this construction mechanical amplification based was chosen however there are also known in such devices hydraulic amplifications [14]. Both variants of PEU are assembled on frame of press in manner shown in fig. 3.

Fig. 3. Outline press dimensions are 200 x 200 x 350 mm and dimensions of die sets space are 70 x 70 x 90 mm. Working Space can be observed by microscope equipped with CCD camera connected to PC. Special software permits to registration of process course. Several phases of micro-indenting process recorded with it are shown in fig. 4. General view of experiment stand shows fig. 5. For investigations press was additionally equipped with for that purpose especially designed strain gauges dynamometer connected with PC computer that let to measure and record process force.

Fig. 4. Micro-indenting process recorded with CCD camera

M-press with direct PEU was tested to obtain two experimental characteristics: voltage-displacement and voltage-force, fig.6. Based on them there was calculated force-displacement characteristic, fig.7 which delimitates press application. Second variant PEU with mechanical displacement amplifier causes lineal change of force-displacement characteristic. In this case the admissible displacement enlarges 4 times and admissible force diminishes also 4 times.

Fig. 5. Overview of experiment stand with Micro-press

Fig. 6. M-press experimental characteristics

Fig. 7. M-press functional characteristic

Fig. 8. Component after process steps: blanking, closed-die pressing and backward extrusion

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4. Application of Micro-press

M-press is suitable to perform in the small scale practically all cold metal forming processes that are possible to perform with big presses. An example for M-press application is pressing process
followed than with backward extrusion of preliminary punched aluminium disk. Components after each step and cross section of finally extruded cup are shown in fig.8. Extrusion process force recorded with M-press dynamometer shows Fig.9. Equipping of M-press with computer controlled and piezoelectric-driven x-y table allows to system to be used in sequential metal forming processes.

Fig. 9. Force in micro-extrusion process

This group of processes lies on step by step coming deformation of only limited area of slug that results in deformation of all planed volume. In preliminary experiments only one direction driven table with manual control was used to perform two kind of sequential processes: Creation of surface pattern. (This kind of surface treatment consists in performing of sequential stamping with shaped punch, fig.9a.) and incremental micro-indenting, fig. 9b. Second process consists in sequential indenting according to precise, computer controlled sequence of deformation steps performed with shaped punch in such a way that it leads to create of practically any shape cavity.

Fig. 10. Sequential forming: a) surface pattern creation , b) cavity forming

M-press might also be used for incremental microforming of foil materials [15]. These processes are planed for a future investigations.

5. Conclusions

- Micro-press equipped with x-y table and controlled with computer system is able to carry on a new* group of deformation processes – sequential forming.
* the idea of sequential forming is certainly well known, but synchronizing x-y movement of press table with a movement of press ram will open new possibilities.

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References