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Microforming—from basic research to its realization

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Abstract

The production of miniature parts is gaining importance due to the trend of miniaturization which is increasingly determining the development of products ranging from mobile phones and computers to medical products. The application of conventional manufacturing processes for the production of such microparts is possible, but there are problems that result from the small dimensions. This fact applies also in the field of metal forming, however, in the meantime many research projects in several countries could improve this situation. This paper gives a review of the problems associated with miniaturization, the way of solution starting from basic research, and the results showing the progress of microforming today.

Keywords: Micro-metal forming; Material behaviour; Processes

1. Introduction

To start with, a definition: the term microforming, in the context of metal forming, is understood to be the production of parts or structures with at least two dimensions in the submillimetre range [1]. Parts of such a size are commonly used and more and more required in extremely high numbers, in particular for electronic components in micro-system technologies (MST) and micro-electromechanical systems (MEMS) as they characterize today many products pushing forward their miniaturization. Typical examples for such parts are pins for IC-carriers, fasteners, micro-screws, lead frames, sockets, and any kind of connecting element (Fig. 1).

Secondly, its history: in 1990 as awareness of the technology grew, the industry produced such parts—actually by turning and milling—the question arose as to why this could not be done by metal forming. For the metal forming society this is quite a justified question since forming is the predestined method of manufacturing near net shape parts especially when high production numbers and high production rates are required. However, at this time it became obvious, that there was no basic knowledge on microforming and practically no application visible, not even in the prototype stage. But there were some visions. One was given by Maeda [2] who proposed the development of a super micro-precision press-machine. This was one of the occasions to start basic research on microforming at the authors' institute. The first and rapidly yielding finding was that the know-how of metal forming cannot be easily scaled down to the micro-scale revealing simultaneously many other reasons why this technology is not applied to this day. It is well-recognized that it is not only the peculiarity of the process itself which has to be understood, but there are also many problems related to the tool and machine tool for which new solutions must be found. Meanwhile, a lot of research activities have been initiated worldwide covering this field of problems and showing that microforming is on a promising way towards its application in industrial production. It is not the intention of this paper to present the state of the art of microforming. This was given recently elsewhere [1]. The intention is to show by means of examples the necessity of basic research to realize this special application of metal forming.

2. Microforming system

A microforming system can be split up—like conventional forming processes—into four groups as shown in Fig. 2.

Beside the challenges that are also known in the field of conventional forming, like tool design, wear and appropriate treatment of the material, problems appear in microforming that are strongly coupled with miniaturization itself. These problems are observed in all four groups:

The *material* behaviour changes with miniaturization, caused by size effects that occur when a process is scaled down from conventional size to the micro-scale. The flow

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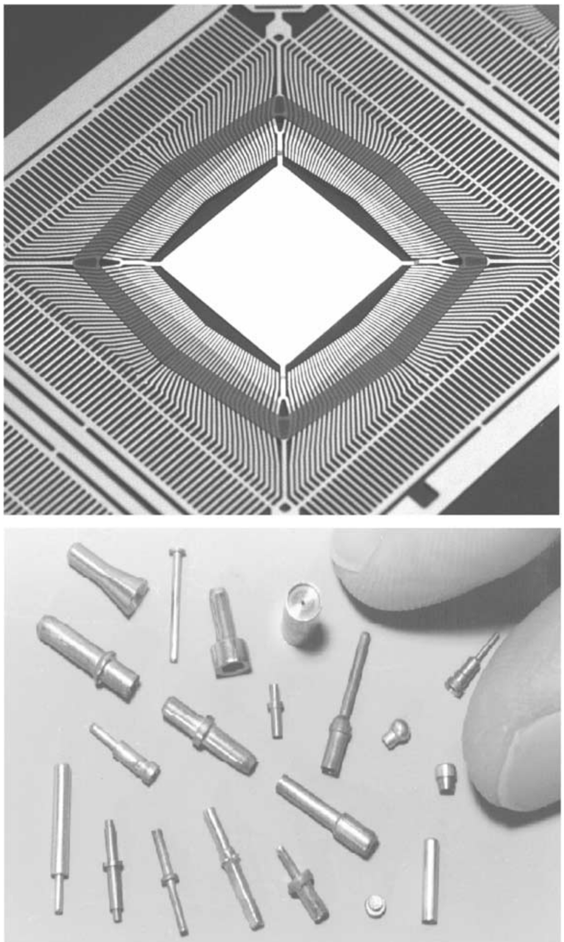

Fig. 1. Microparts: lead frame, pitch 0.3 mm (top) and extruded parts (Shinko, NME).

stress, the anisotropy, the ductility and the forming limit of materials are influenced by these size effects, which has to be considered when designing a microforming process.

Also phenomena that are assigned to the *process* depend on the size. Examples are the forming forces, the spring-back, the scatter of the results or friction. It should be emphasized that the size effects concerning the material and the process have to be considered during the process design and layout and also affect the applicability of FE-based simulations.

The main problem regarding the *tools* lies in their manufacturing, since it is difficult to create the very small contours, which are necessary. Especially inner shapes, e.g. for extrusion dies, with close tolerances and an adequate surface quality are difficult to make. However, new manufacturing methods have been developed in order to overcome these difficulties. For instance, an embossing tool has been developed with dimensions down to 200 nm made by an electron beam lithography-etching process [1,3].

Also the problems associated with *machines* or *equipment* grow with miniaturization. The clearance or the backlash between the machine parts that are negligible for conventional forming processes may have a detrimental influence on the accuracy of the produced parts. The handling of material and parts is difficult, since the surfaces where they can be gripped are very small and the part weight is low compared with adhesion forces; as a result, the parts do not separate from a gripper by themselves. Additionally, they have to be placed with tolerances of a few microns, e.g. into a die of a multi-station former.

The development of adequate measuring technology, suited to measure the smallest contours of tools and parts, respectively, is another challenge. Finally, the small dimensions demand production in clean rooms, which causes additional costs. Therefore, the development and use of small machines could lead to a more economic production.

In recent years many research activities have started dealing with the investigation of these problems. The focus of the present paper is on the area of materials and processes, cf. the following section. In Section 4 an outline of actual research will be given to show also the progress within other areas that are altogether indispensable to push forward this new technology.

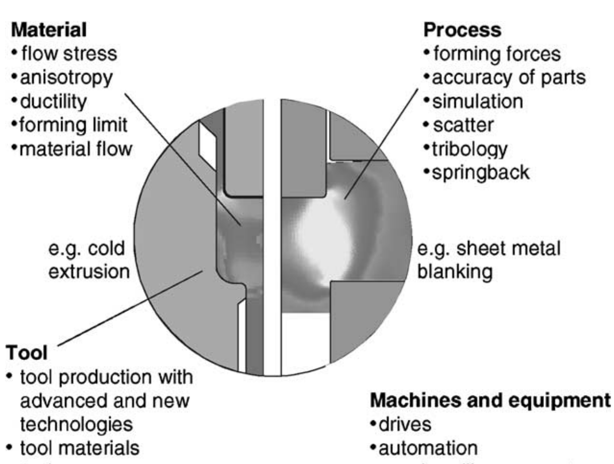

Fig. 2. Problems in the microworld (LFT).

3. Microforming process

The comparison of microforming processes with conventional ones shows that some parameters remain constant when scaling down the dimensions. The microstructure of the material, for instance, is independent of the dimensions of the process. Another example is the topography of the surface, which is also invariant. As a result, the ratio between the dimensions of a part and parameters of the microstructure or surface changes with miniaturization. This leads to the so-called size effects, which prevent the application of the know-how of conventional forming processes in the field of microforming. Therefore, investigations were necessary in order to quantify these size effects. The strategy was to scale down forming processes systematically [4,5].

At first, studies with basic experiments have been realized. The investigated processes were simple with the aim