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Wear behaviour in a combined micro blanking and deep drawing process

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ABSTRACT

A one stroke micro blanking and deep drawing process is used to produce micro cups in a high quantity (200 strokes per minute) with an outer diameter of 1 mm. For cutting and deep drawing one single hollow punch is used. The outer diameter punches the circular blank while the inner diameter serves as drawing ring. Investigations regarding the tool life show that the punching edge wears out quicker than the rest of the tool. Furthermore it is shown that the positioning of the tool has a high influence on the wear behaviour.

1. Introduction

The importance of micro parts has been increasing over the last decade, especially because of the higher influence in the daily life of technical devices as e.g. smart phones and tablet computers. For producing different geometric micro shapes various production processes, as micro blanking and deep drawing are necessary [1]. A relevant aspect for producing metal parts in a high quantity is the tool life, particular in micro metal forming. A long tool life helps to decrease the pre-production costs and increase the overall output. By producing 200 parts per minute a tool setup time of one hour means a loss of 12,000 parts. Especially the analysis of the wear behaviour of a tool is essential in micro forming. Even a low tool wear of a few micrometres has a high influence on the micro parts, because of their smaller dimension, as two dimensions are in the sub-micro range [1].

The wear behaviour, particular adhesive wear of aluminium sheet metal in macro forming is analysed in [2]. It is illustrated by calculation and experiments, that the adhesive wear is a result of local stress peaks. However, knowledge from the macro range cannot be transferred directly to micro range because of the so-called size effects [3]. Size effects can be categorised in three sections: density, shape and micro structure. A sample for a micro structure size effect is given in [4]. The grain size has an influence on the blanking process: the ratio of blanking clearance and grain size affects the blanking result. The blanking force reaches its maximum, if the grain size is the same as the blanking clearance.

To achieve wear behaviour in micro deep drawing the conventional way of producing circular blanks in the first process and executing deep drawing in a second process is time-consuming as further analysis showed [5]. Beside these two separated processes another point is relevant, which is the positioning of the circular blanks.

In Fig. 1 different defects are shown, as a scratched (circle) or dented (square) surface and a buckled (ellipse) circular blank. All these defects can appear by moving the circular blanks from one process step to another and by moving the specimen for positioning the circular blank for deep drawing. In this work the diameter of the circular blank is 1.7 mm.

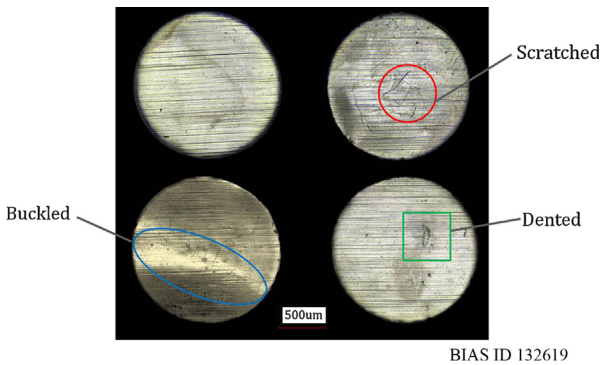

Fig. 1. Possible damages positioning circular blanks manual and a sound circular blank (top left).

The tribological conditions during a forming process, including the lubricant, take influence on the tool life and can cause tool failure. Furthermore the tool life is reduced by a bad tool design, critical corners or expressive contact pressure [6].

The lubricant influences micro parts beside friction, especially deep drawing parts in another way. The micro parts stick together because of the adhesion forces enhanced by the lubricants, which is also due to low weight of the parts, e.g. in this work the weight of a micro cup or the circular blank is around 1 mg. In addition, the thin wall of a micro deep drawing product can be deformed and the micro part is damaged by removing the lubricant.

To analyse the wear behaviour during a deep drawing process, a cutting and deep drawing process for producing a high quantity of micro cups with 200 strokes per minute is used in this paper.

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2. Experimental setup

Experiments were carried out with a follow-on tool (shown in Fig. 2), where a blanking and deep drawing process is combined in one process without positioning the circular blank to solve the positioning problem. The tool allows a high number of strokes, 200 micro cups per minute can be produced. The tool consists of 5 different plates, which are all guided by slide guides in a pillar guide. The plates have different functions, Plate 1 and 4 are fixed and Plate 2, 3 and 5 are movable (see Fig. 2).

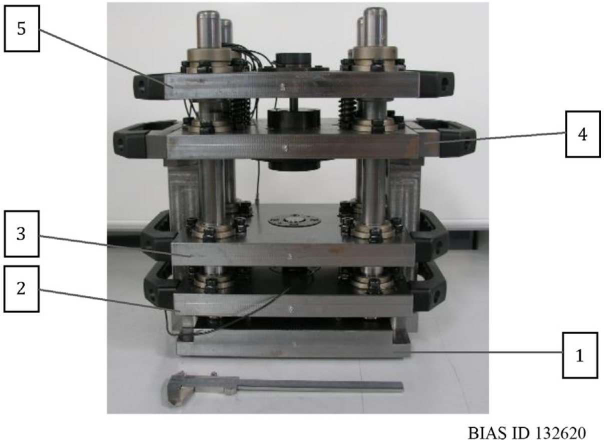

Fig. 2. Picture of the follow-on tool.

The micro cup production steps are shown in Fig. 3 and are separated in four different process steps. Blank feeding is the first process step to produce micro cups in the follow-on tool, as shown in step 1, for each circular blank the blank material is moved 5 mm. The deep drawing punch is mounted in plate 5 and guided by the blank holder mounted in plate 4. Before blanking, the blank material is held, step 2. For blanking in step 3, the blanking and deep drawing tool combination moves upwards and cuts the circular blank with its outer diameter. In step 4, the last process step, the circular blank is deep drawn to a micro cup. The steps 1–3 are done by the lower axis of the press and the deep drawing step is performed by the upper axis.

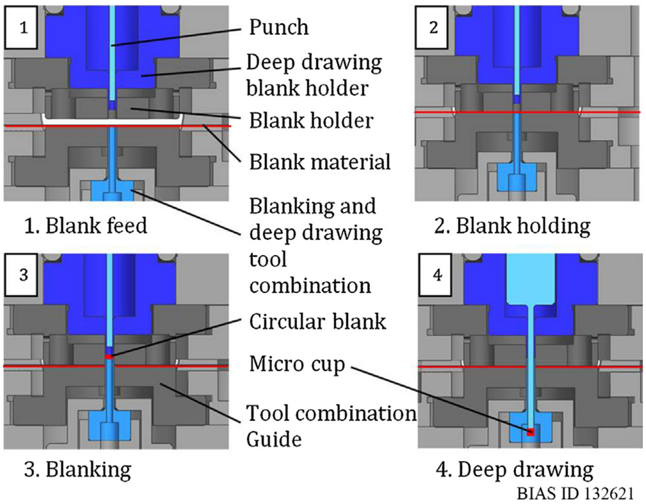

Fig. 3. Process steps producing a micro cup.

The follow-on tool is used in a highly dynamic press, engineered at BIAS [7], with two separately movable axes. Each axis can apply 15 kN with a maximum velocity of 3 m/s and a maximum stroke rate of 1250 strokes per minute can be achieved at a stroke of 1 mm. It is possible to run the press force or position controlled. In this work the process is position controlled and a stroke rate of 200/min is used. The whole experimental setup is shown schematically in Fig. 4.

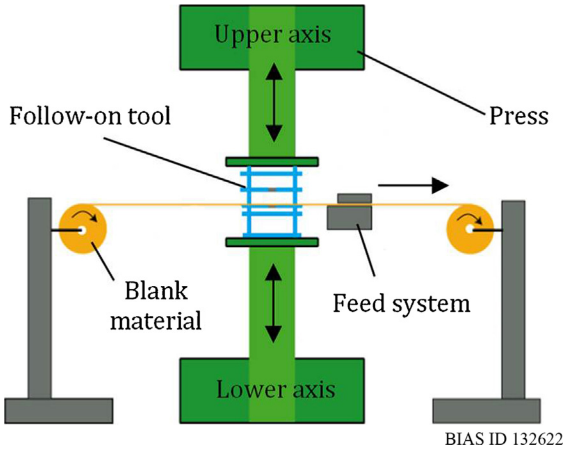

Fig. 4. Micro cup production schematic with press (middle), follow-on toll, blank material and feed system.

By a feed system (Zehnder und Sommer EDV 040–220 DG) the blank material is feed through the follow-on tool, micro cups are produced as explained. Each axis has a force sensor form Kistler (Type 9311B, max. force 5 kN, calibration range: 50 N max. error 0.1%), from both sensors a force-time-table is recorded for each single micro cup by a measurement speed of 5 kHz. The maximum force of the upper axis is the maximum deep drawing force and that of the lower axis the blanking force; the largest force occurs during the blanking process.

Surface measurements of the tool and the micro cups are done by an optical and contact-free 3D laser scanning microscope (Keyence VK-9710), measuring an uncertainty of 1 nm and a maximum magnification of 18,000. The process and geometrical parameters for all the experiments are shown in Table 1.

Table 1
Process and geometrical parameters of the blanking and deep drawing tool combination.

Punch diameter, d_p	0.9 mm
Punch radius, r_p	0.2 mm
Blanking diameter, r_b	1.7 mm
Inner diameter of deep drawing die, D_Z	1.0 mm
Drawing gap, d_g	0.075 mm
Blank material	Al99.5 and E-Cu58
Blank thickness, S_0	0.05 mm
Tool material	X155CrVMo 12 1
Lubricant	Lubrimax Edel C, Steidle GmbH

3. 3. Wear behaviour

3.1. Long term test with lubricant

Fig. 5 shows the top view of a blanking and deep drawing tool combination as machined (left side) and the main characteristics of wear behaviour (right side) during forming using lubricant. An edge disruption (arrow, right picture) can be detected after 300,000 produced micro cups of E-Cu58. As shown by the red three-quarter circle the outer diameter decreases.

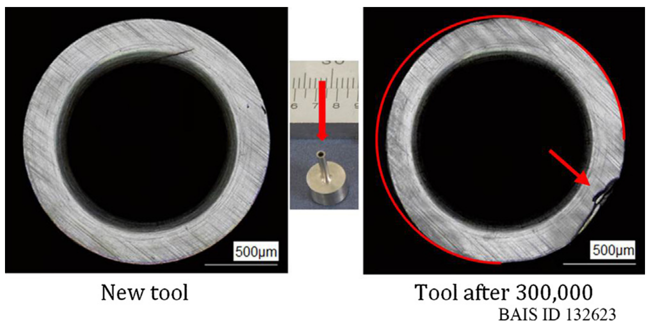

Fig. 5. Comparison between a new tool and a tool after producing 300,000 micro cups using lubricant.