NEW METHOD OF BURR-LESS MICRO-BLANKING

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Abstract

Micro-forming is one of the most popular micro manufacturing processes for manufacturing vsmall metallic parts in sub millimetre range. The proposed process is called Micro-Blanking with Mutual Calibration - MBMC. It involves performing micro-blanking and then pushing the disk back through the resulting hole using a counter-punch. The product shape is corrected and the burr is eliminated. It is possible with proper selection of slack. A method has been proposed to determine the appropriate clearance value based on the results of FEM modeling assessed using the proposed parameters. FEM models are created based on the analysis of the results of only one specially designed MBMC process replacing a number of costly experiments. It is a process in which, with a nominal clearance of 5%, the punch axis is shifted in relation to the matrix axis by about 1/3 of the clearance. This results in a smoothly changing clearance in the range of 1.5 - 8.5%. Modeling parameters are adjusted to the separation surface shapes and burr occurrence obtained for individual clearances. The case of the MBMC process concerning a disk punched with a punch of 1 mm in diameter out of 0.25 mm thick CuZn37 brass in hardened condition was analyzed. A method of assessing the broadly understood quality of a punched micro-product was proposed, based on the analysis of the geometry of the cross-sectional outline of the punched disc and hole. Using this method, it was shown that the MBMC process increases the quality of the product in relation to the blanking alone in the range of 0.7 to 2.2% of clearance.

Keywords: Microforming, micro-blanking, burr-less blanking

1. INTRODUCTION

In today's global world international market demands are that mechanical components ought to be created to net shape or close to net shape with improved mechanical properties, a fine surface finish, sensible dimensional accuracy and material saving. Micro technology, one of the future key technologies, is gaining increasing interest in forming community. Microforming [1,2] is one of the most popular micro manufacturing processes for manufacturing metallic parts in sub millimetre range and there has been a rapid growth in developing this technology to produce a wide-range of micro products that have a variety of applications. In microforming, micro-blanking processes occupy an important place [3], the development of which is forecast due to the relative simplicity of the tools. In miniature punched products, the key role is played by the accuracy of their shape, which is related to the structure of the cut surface. This surface is related to the process parameters and the mechanical properties of the material being punched out. It should be noted that in the blanking processes, i.e. the processes of cutting along a line closed the product, there can be both rings and a hole. Their intersection surfaces are inextricably linked with each other. In microforming, the shape and quality of the cut surface play an important role, which often determine the quality of the entire product. It is visible especially in the case of products with low values of the ratio of the cross-sectional width of the punched product to the thickness of the sheet . The typical appearance of the intersection surface is shown in **Figure 1a**.

Characteristic areas are marked here, of which only shear zone is the desired one. Particularly messy is the burr, the elimination of which many scientists have worked and are working on [5,6]. It can be removed by an additional mechanical [7], chemical [8] or hybrid operations [9]. However, a better method seems to be modifying the micro-blanking process itself. Interesting solutions are presented further in **Figure 1**. A special blanking (Borsboom) consisting in preliminary grooving from the side opposite to the blanking and then cutting out the object **(1a)**, pushback blanking consisting in preliminary, partial cutting out in the phase of shear zone formation, and then pressing the object between flat anvils (**1b**), as a result of this second operation, the partially cut blank is separated as a result of return shearing, reciprocating blanking, denoting a partial cutting in the lower die with an upper punch, and then in return movement completion of cutting with the lower punch in the upper die (**1d**). The paper proposes a new method of micro-blanking called *Micro blanking with mutual calibration* - MBMC (**Figure 1e**). It consists of the elimination of forming failure caused by irregular edge conditions and burr. To rich that objective, already blanked object is than pushed back throu the hole. The obtained effect depends on many process parameters, which are difficult to determine experimentally, especially with miniature dimensions. That is why an important aspect concerning the process layout as well as its optimisation is the ability to predict the forming processes by simulation methods.

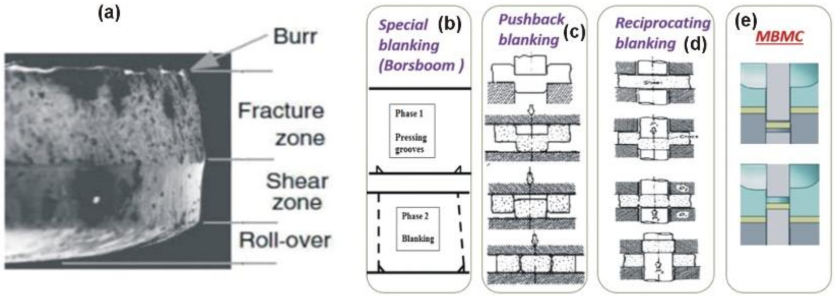

Figure 1 (a) Surface atributes; (b), (c), (d) burrless blanking methods [4]; (e) Blanking with mutual calibration

2. METHODOLOGY

The flow chart of used methodology is shown in **Figure 2a**. This ideology is brought out to increase the precision of the blanking products. Firstly we design the product using commercial Marc Mentat software, where finite element modelling is done and the model consists of one deformable and four rigid bodies, Long dash line shows the entire process. Solid lines define the various methods or steps carried out in this project. F.E.A analysis is carried through and F.E.A is parameterized with own parameters based on which the following operation is performed, see **Figure 2b**. This is a two-step process where micro-blanking is the first step and mutual calibration is the second one. First stage is for *PUNCH L* while second stage is for *PUNCH R*. The final design of each simulation is compared and the best result is carved out. When scaling down process dimensions to micro scale, so called scale or size-effects [10] appear and have to be considered [11]. Scale effects apply to all elements of the process [12]. In this work however, scale effect is considered only in relation to surface phenomena [13], which is expressed by adopting a high value of the friction coefficient in the simulations [14,15]. A test stand was prepared for partial verification of the simulation results. The MBMC process is carried out using a micro die-set [16] (**Figure 3**) placed on a precise Hounsfield H10S testing machine, which does not have an ejector system.

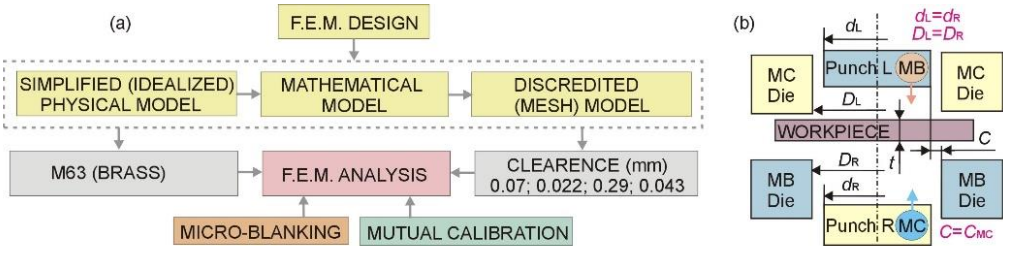

Figure 2 (a) Flow chart of used methodology; (b) Schematic description of used quantities

This inconvenience was eliminated by retrofitting for the mutual calibration (MC) process. The micro-blanking operation is carried out in accordance with **3b**. Then the punch *3* is replaced by the pusher *12* (**3c**) and the calibration is performed. The material used in the research is described in **Table 1.**

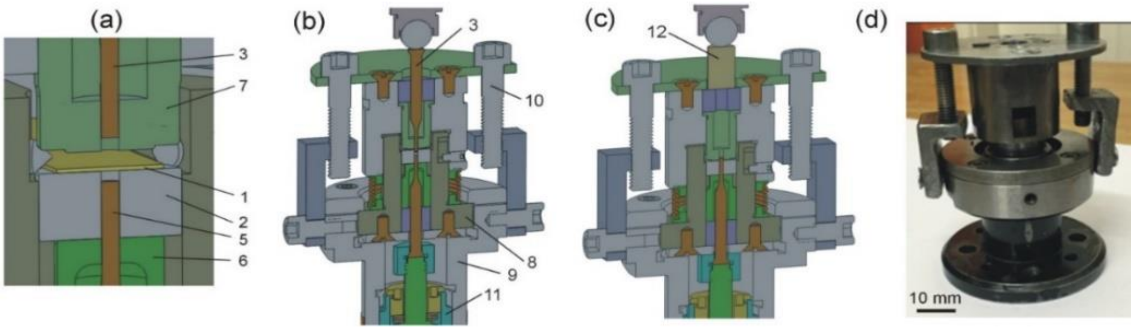

Figure 3 Micro die-set: (a) close up of tools; (b) set-up for micro-blanking; (c) set-up for MC; (d) owerview; Main parts: 1 - strip, 2- die, 3- punch, 5- lower punch, 6- lower slide, 7- upper slide. 8- die-set, 9- base, 10- binding screw, 11- base guide, 12- pusher.

To limit the number of experiments, the device was equipped with eccentric tools. The dimensions of which, as well as process results are shown in **Figure 4**.

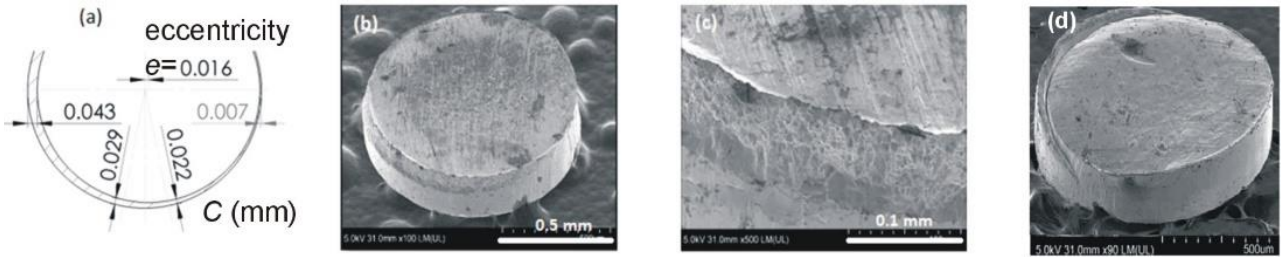

Figure 4 Eccentric tools for micro-blanking; (a) main dimensions, (b) blanked disc (c) close-up of burr in (b); (c) disc after MC

3. FEM EXPERIMENTS RESULTS

The FEM experimental program was carried out in the conditions established in the reconnaissance tests, using the material data collected in **Table 1**. A very important process parameter is the failure model. The Oyane model was selected. This model defines the cavity growth over the density. In this numerical analysis takes form (1).

$$\int_0^{\varepsilon_{eqf}}\left(1+\frac{1}{B}\frac{\sigma_m}{\sigma_{eq}}\right)d\varepsilon_{eq}=D \qquad (1)$$

where: ε_{eqf} - equivalent fracture strain, σ_m - mean stress,
σ_{eq} - equivalent stress, *B, D* - material constants.

Material constant B, damage threshold D and element removal threshold ERT in the MSC. Marc software can be specified.

These were estimated based on the literature [17] and own experiments. These material attributes you can find in **Table 1**. Element removal threshold *ERT*= 1.0. It means that all those elements, which reach this “Damage” value will be deleted. The FEM tests were carried out for various values of the clearence, considering this parameter as critical [18]. The test results are summarized in **Table 2**.

Table 2 Parameters of material used

Elastic properties		Plastic properties	Damage parameters			Surface parameters	Composition	
E (MPa)	v	Stress-strain curve (MPa)	*D*	*B*	*ERT*	Coefficient of friction	Cu (%)	Zn
110 000	0.34	$\sigma_p = 710 \cdot \varepsilon^{0.48}$	0.85	0.4	1.0	0.2	62-65	Rest

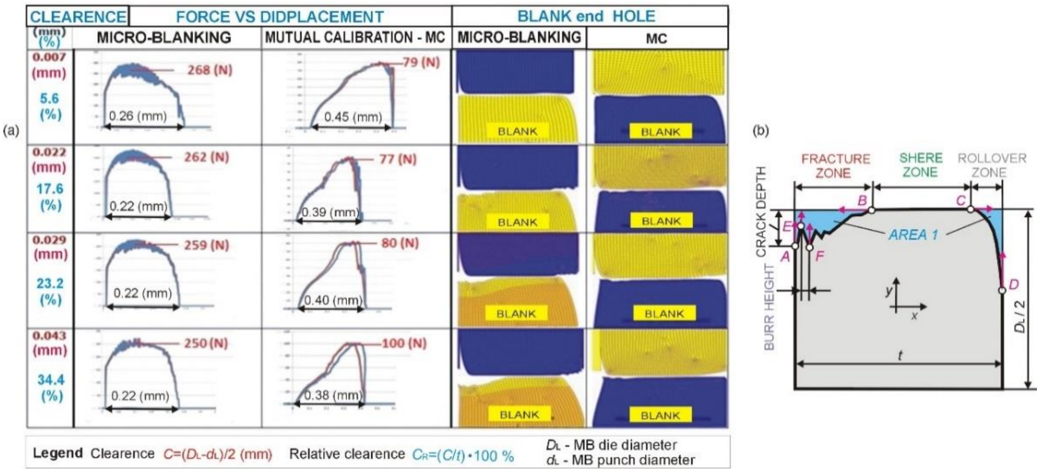

Figure 5 Results of FEM investigations, red curves are corrections because of elastic deflections [16]; (b) parametrisation of FEM results - description in paragraph 4.

4. RESULTS ANALYSIS

The results of the experiments are the calculated forces of the processes and the obtained shapes of discs after MB and then MC. The results of both these processes, and especially the MC, are very sensitive to even small changes in FEM modeling parameters. The standard areas on the intersection surface (**Figure 1a**) were parameterized by establishing 6 characteristic points *A*, *B*, *C*, *D*, *E* and *F* on the cross-section outline, as shown in **Figure 5b.** Based on the positions of these points in the *x-y* coordinate system, numerical values, in millimeters, of these parameters were determined: *FRACTURE ZONE* = *B*x-*A*x; *SHEAR ZONE* = *C*x-*B*x; *ROLLOVER ZONE* = *D*x-*C*x; *DEPTH OF CRACK* = *B*y-*F*y; *BURR HEIGHT*= *E*y-*F*y. All the described attributes refer to the cross-sections of the blank and the hole, which are related to each other, and their distinction as product and waste depends only on assumption made. Generally understood product quality, associated with surface quality, is determined by two features: surface smoothness and compliance with the theoretical shape, which in our case is a rectangle. In **Figure 5b**, red arrows mark the trajectories of changes in the location of characteristic points in order to improve the quality of the product.

The second method used to determine the quality of the product is to determine the deviation of the outline of the obtained object from the rectangular outline. In this case, we do not specifically refer to the zones on the intersection surface. In this method, *AREA 1* is calculated. The larger *AREA 1* or its share in relation to the rectangle *t* x (D_L/2), the worse the quality. **Figure 6** summarizes the FEM studies. In parts (a) and (b), concerning blank and hole, respectively, regarding the subsequent tested clearances, the relative changes of the analyzed quantity occurring during MC process size is presented. Bars below the horizontal axis indicate a decrease in each value, bars above indicate an increase in each one. In turn, part (c) shows *AREA 1* for blank, and hole created during MB and MC processes. In section (d), for the blank and the hole, respectively, the change in the proportion of *AREA1* that occurs during the MC process is shown. If we compare the MB and MC process in general, after MC process in case of a blank the positive changes of all six parameters (zones of cross-section) were observed and on the whole investigated range of clearance, **Figure 6a.** In case of hole the biggest clearance inducted negative changes, **Figure 6b**. This tendency (greater difficulty in smoothing the cross-section shape according to the trajectories shown in **Figure 5b** by MC) is confirmed by the Area 1 parameter. For C_R = 11.6 % the blank shape deviation is still compensated in the MC process. In the case of a hole, this is no longer possible. The strong tendency for diminishing the burr in blank by MC process is present in all range of clearance. For the hole it faults down for clearance 11.6 % and bigger.

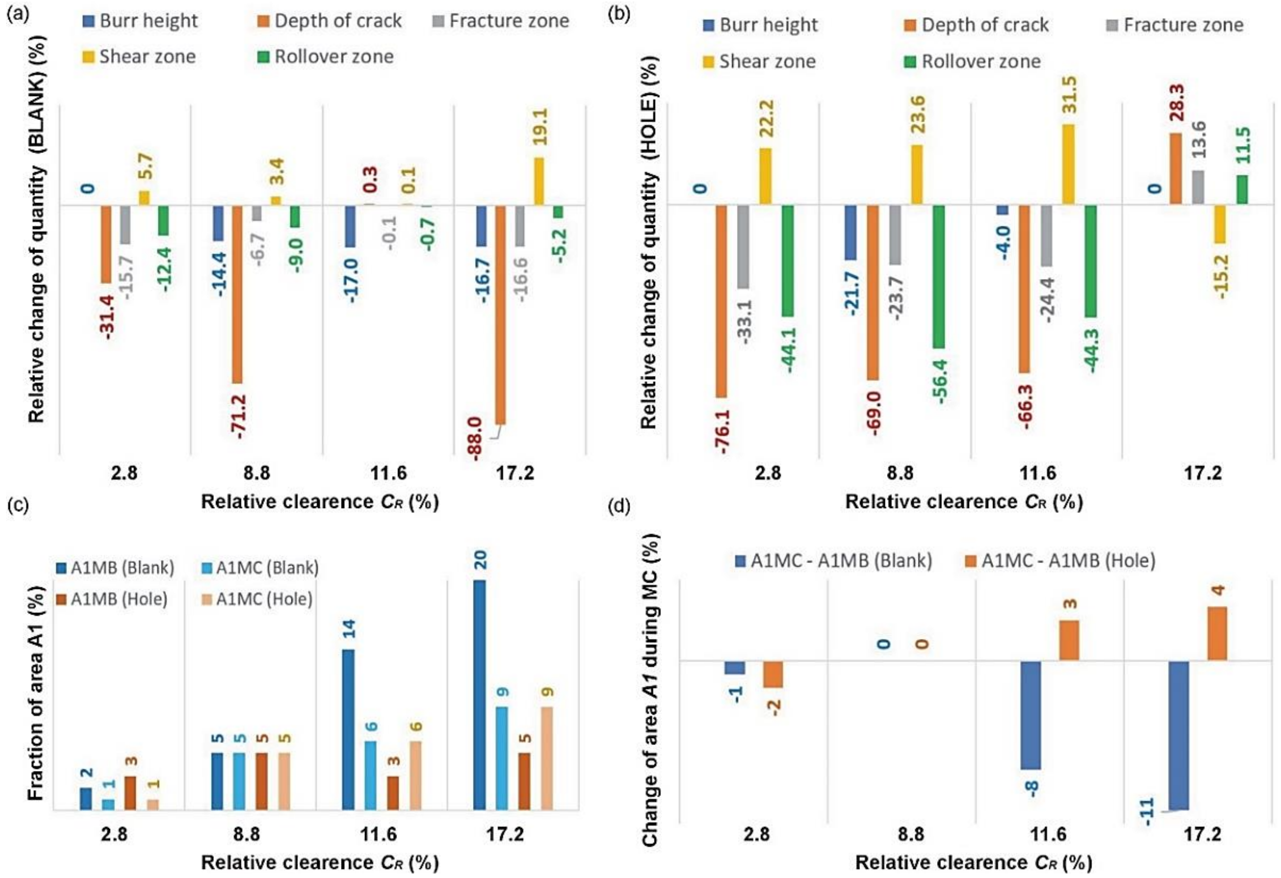

Figure 6 (a) Relative changes in the geometrical parameters of the 'blank' section (after the MB process) as a result of the MC process, (b) Relative changes in the geometrical parameters of the section of the 'hole' (after the MB process) as a result of the MC process; (c) Percentage of *Area 1* after the MB and MC process; (d) Change in *Area 1* percentage due to the MC process

In general, the MC process applied after the MB process provides positive changes in the shape of the blank and the hole within a limited range of the relative clearence, which should be in the range of 2.8% to 8.8%. This applies to both the blank and the hole. The determined values depend on the material properties and can be used for materials of similar toughness.

5. CONCLUSION

The conducted exploratory studies, including FEM modeling and partial laboratory verification in terms of improving the broadly understood quality of micro-blanked elements, in this case micro-blanking of a disc with a diameter of 1 (mm) out of 0.25 (mm) thick brass sheet metal, allow for the formulation of the following conclusions.

A new process was proposed, Micro-blanking with Mutual Calibration (MBMC), increasing the precision of the blanking products. The process does not increase the load on the tools. It consists of two operations: blanking and calibration, which consists in pushing the blanked disk back through the hole.

Numerical modelling was carried out in Marc Mentat software. 2D, axis-symmetrical, static model of elastic plastic material with hardening and Oyane damage effect. The model consists of one deformable and four rigid bodies which act as the punch, the counterpunch the die and the blank holder.

During each simulation, both operations (micro-blanking and calibration) are taken into account. In a number of different FEM simulation various process pattern were observed which depends on the adopted conditions of friction, the parameters of fracture and tools clearance. From which the last (clearance) was observed as critical.

A method of numerical determination of the quality of the blanked micro-product obtained by simulation was proposed, understood here as the geometric quality of the intersection outline. It was broken down into its components: roll-over, sheer zone, fracture zone and burr. The share of these components was analyzed, of which only the sheer zone is desired.

The proposed method of fast determination of the impact of tools clearance on the quality of products produced in *MCMB* process, involving the use of eccentric tools, was applied.

The consequence of the application of variable clearance at the periphery of the component after first operation is its difference appearance, at the periphery, after the second operation. Too big relative clearance (more than 23 (%)) causes sliding of the material and formation of folds. The clearance reduction leads to the elimination of this phenomenon. The optimum size of the clearance that gives the alignment of the slide surface, and burr elimination was found to be 2.8 - 8.8 (%).

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