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DISTORTION OF RING TYPE PARTS DURING FINE-BLANKING

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Distortion control is one of the most important concerns of the metal processing industry, which also includes the fine-blanking technology. Fine-blanking of sheet metal involves metal flow and shearing, which result in complex deformation. Distortion occurs during the removal of parts from the tool due to the relaxation of internal stresses. Internal stresses that are generated during fine-blanking have an important effect on the shape and size of parts after fine-blanking. The distortion of ring type products during fine-blanking was analysed by using dimension measurements, microscopic observation and numerical simulation.

Key words: Fine-blanking, distortion, internal stresses

Distorzija dijelova prstena tijekom preciznog utiskivanja. Kontrola distorzije je jedan od najvažnijih poslova u metaloprerađivačkoj industriji, što također vrijedi i za tehnologiju preciznog utiskivanja. Precizno utiskivanje trake uključuje tok i rezanje materijala, što se odražava na složenost deformacije. Distorzija nastaje tijekom uklanjanja dijelova iz alata zbog oslobađanja unutarnjih naprezanja. Promjena oblika tijekom preciznog utiskivanja prstenova analizirana je mjerenjima dimenzija, mikroskopskim zapažanjima i numeričkim simulacijama.

Ključne riječi: precizno utiskivanje, distorzija, unutarnja naprezanja

INTRODUCTION

The aim of the investigation was to analyze the distortion of ring type products during fine-blanking. Distortion control during the production cycle is an important need within the metals processing industry, therefore numerous investigations were performed [1-10].

It is possible that the shape and size of a product change when removing it from the tool during cold forming because of the relaxation of stresses. Internal stresses occur as a consequence of different strain levels at different locations at the same time. These differences are caused by the different strength of coexistent phases in the material, the different actual strain as a consequence of the tool shape and temperature gradients [11].

The influence of the above described process on the fine-blanked parts was analyzed.

The second important dimension criterion is the deviation from perpendicularity from the cutting edge to the face, the so called taper. Fine-blanked parts are always slightly tapered, therefore the inner shapes have a larger dimension on the die roll side (Figure 1). The amount of taper to be expected is about 0,0026 mm per millimetre of edge width. Taper is influenced by many factors, thus should be examined separately in each individual case [12].

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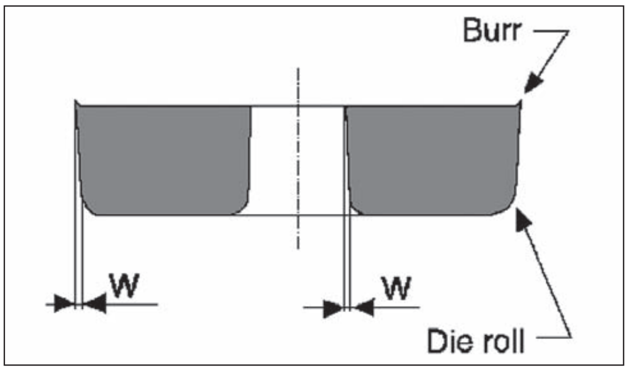

Figure 1 Taper-W of fine-blanked edges

EXPERIMENTAL SETUP

Distortion was analyzed during the fine-blanking of ring type products from a cold rolled steel sheet C15E (1.1141) with the chemical composition, given in Table 1. The mechanical properties of the used steel sheet are given in Table 2.

Table 1 **Chemical composition of used steel sheet C15E**

Element	C	Si	Mn	S	P
/mas.%	0,14	0,18	0,45	0,004	0,007

Table 2 **Mechanical properties of used steel sheet**

$Rp_{0,2}$ /MPa	Rm /MPa	$Rp_{0,2}$/Rm /-	n / -
285	405	0,70	0,205
C /MPa	E /GPa	A /%	
675	170	40	

A two row tool was used, which allowed us to determine the influence of the different positions of parts in

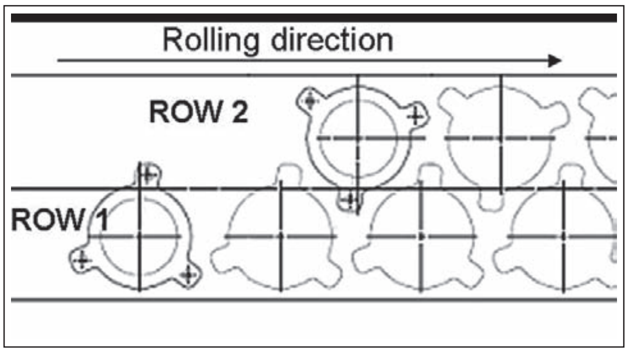

Figure 2 Position of both rows on steel sheet

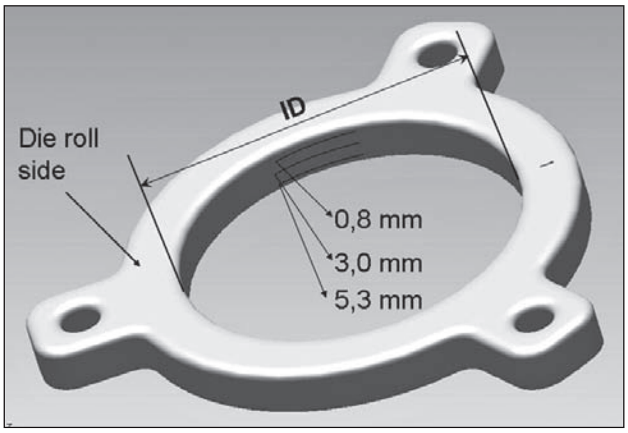

Figure 3 Schematically presented ring type sample and measured levels

the steel sheet on the distortion. The position of both rows is presented in Figure 2.

The ring type samples had a nominal inner diameter (ID) of 46,07 mm and a nominal outer diameter (OD) of 62,07 mm. The thickness of the steel sheet was 6 mm. The research work was focused on the changes of the inner hole size and shape. The ID was measured with a MarVision MS 442 3D measuring device with a resolution of 2,9 + L/100 μm. It was measured at three different locations according to the die roll and burr side; 0,8 mm, 3 mm and 5,3 mm from the die roll side of the product (Figure 3). Die roll indicates the starting point of cutting and burr the end point of cutting. Ninety samples were measured from row 1 and ninety samples from row 2.

The results were complemented by microscopic observations, residual stress measurement and numerical simulation of fine-blanking.

RESULT AND DISCUSSION

The shape of the inner hole is presented in Figure 4 and Figure 5. The angle 0° represents the direction of rolling. On both rows the effect of the ears and the edge of the steel sheet is visible – the radius is larger at those points. Row 1 and row 2 are symmetrically positioned (Figure 2) on the steel sheet, therefore the shape of the inner hole is also symmetrical (Figure 4 and Figure 5).

It was expected that taper between 0,8 mm and 5,3 mm from the die roll side would be 0,0117 mm. The

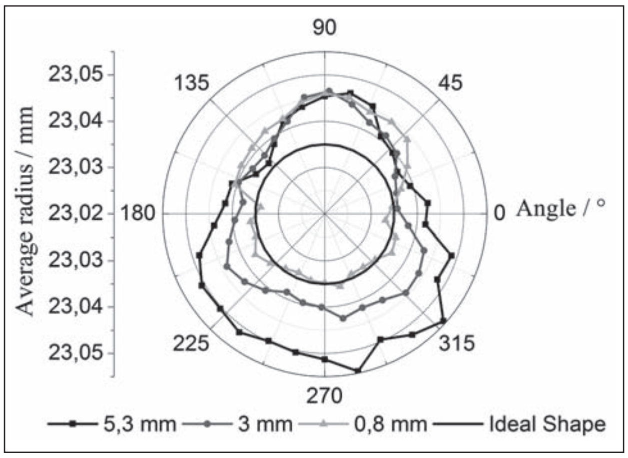

Figure 4 Shape of inner hole of parts from row 1

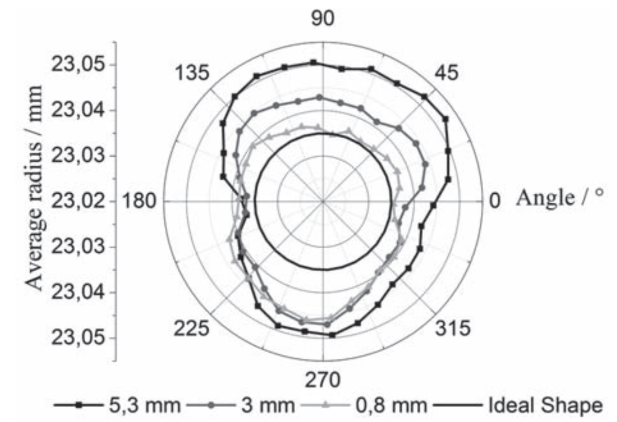

Figure 5 Shape of inner hole of parts from row 2

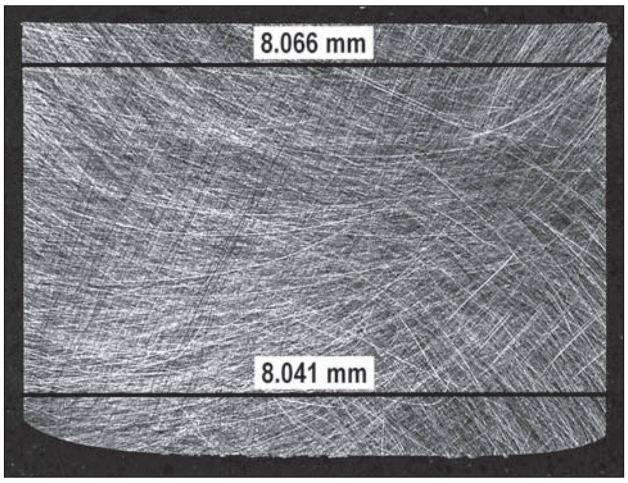

Figure 6 Taper measured under stereomicroscope

measured taper (Figure 6) was 0,0125 mm, which is in good agreement with the expected theoretical taper. Thus the radius at 0,8 mm should be 0,0125 mm larger than at 5,3 mm. But this is not true, considering the results presented in Figure 4 and Figure 5. Quite the opposite, the radius is larger at most points at 5,3 mm. This could be explained by the uneven deformation during fine-blanking, which resulted in the generation of internal residual stresses that are released during the removal of parts from the tool.

In Figure 7 uneven deformation during fine-blanking is presented with the help of microscopic observa-

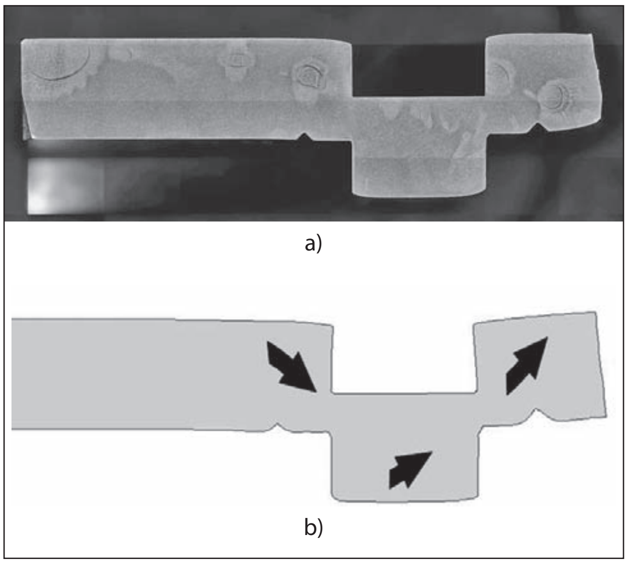

Figure 7 Deformation during fine-blanking;
a) stereomicroscope, b) Contour from numerical simulation. Displacement increases 10 times

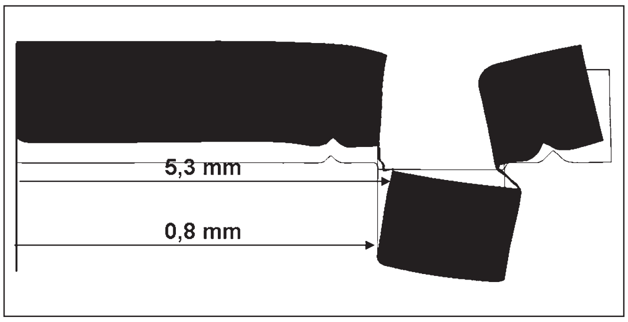

Figure 8 Distortion after fine blanking and removal of parts from tool. Contour from numerical simulation. Displacement increases 40 times

tion and numerical simulation. The fine-blanking process was interrupted at punch penetration of 4 mm into the steel sheet. Similar deformation was observed in both cases. On one hand this confirms the model for numerical simulation and on the other it provides an insight into uneven deformation that occurs during the fine-blanking process. The material on the inner side of the ring part bends towards the ring and the material on the outer side away from it, therefore the ring type part is bended slightly towards the outside cutting edge. Such uneven deformation results in the distortion of parts as a consequence of the relaxation of internal stresses after they are removed from the tool.

The result of distortion after cutting and removal of parts from the tool is presented in Figure 8. It was noticeable that parts were distorted in such a way that the radius at 5,3 mm should have been larger than at 0,3 mm, which is in good agreement with the results presented in Figure 4 and Figure 5. The orientation of this distortion is opposite to the orientation of distortion due to taper. When analyzing the overall distortion we must consider the distortion that occurs as a consequence of taper and uneven deformation. Thus on the internal shapes the larger dimension is not always on the die roll side.

Different parameters affect the above described distortion, thus the radius and difference at 5,3 and 0,8 mm are not the same all over the trajectory. An important thing is the amount of the surrounding material, therefore the difference at 5,3 and 0,8 mm is the maximum at the edge of the steel sheet; angles from 225° to 315° for row 1 and from 45 ° to 135° for parts from row 2. With parts from row 2 the difference is greater at angles from 270° to 45°, where there is less surrounding material than at angles from 135° to 270°. When comparing the radius at angles from 0° to 180° for parts from row 1 and the radius at angles 180° to 360° for parts from row 2 it is visible that the difference is greater with samples from row 2 that have less surrounding material. What is more, the radius for row 1 at 0,8 mm was bigger than at 5,3 mm, which means that distortion due to taper is more significant than the uneven deformation that occurs because of the surrounding material. It is believed that an important role is also played by the mechanical properties of the steel sheet and the condition of the tool, especial the clearance between active elements that becomes larger during the production cycle as a consequence of wear. Greater clearances allow greater horizontal movement of active elements during cutting, which can affect the direction and magnitude of distortion. Additional research work is necessary.

The hole-drilling strain-gauge method was used to determine the residual stresses after fine-blanking on the die roll and burr side. Residual stresses were measured on the ear of the ring type parts. The results are presented in Figure 9 and Figure 10. Measurements confirm the uneven deformation and uneven generation of internal stresses. Part of the internal stresses is re-

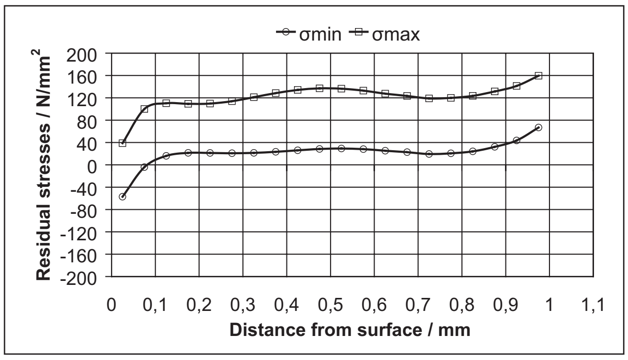

Figure 9 Residual stresses on die roll side of parts

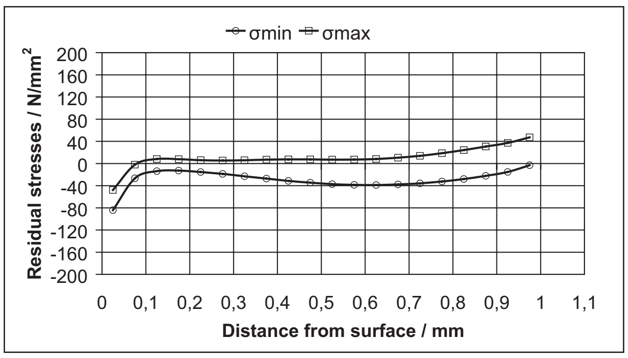

Figure 10 Residual stresses on burr side of parts

lived by distortion during the removal of parts from the tool, while the other part stays locked in. Stresses are higher and tensile on the die roll side, whilst lower and compressive on the burr side.

CONCLUSION

Distortion during fine-blanking is a complex phenomenon and can be affected by several different parameters.

The first important thing is characteristic for fine-blanking – deviation from perpendicularity from the cutting edge to the face, the so called taper. The magnitude and particular orientation of taper are well known.

The second thing is distortion due to the relaxation of internal stresses during the removal of parts from the tool, which is more complex and is influenced by many different factors, such as: the shape and position of parts in the steel sheet, the mechanical properties of the steel sheet and the condition of tools.

Both of the above described processes affect the distortion of parts during fine-blanking. They can counterbalance or amplify each other, depending on the distortion caused by internal stresses. In our example they counterbalance.

In order to have control over the distortion of fine-blanked parts one has to control the amount of taper and above all distortion due to the relaxation of residual stresses. First of all, a lot of attention needs to be focused on choosing the right position of parts on the steel sheet, the right steel sheet properties and the right tool design. Secondly, good control is needed over steel sheet properties and the condition of tools.

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Note: The responsible translator for English language is Urška Letonja, MOAR translating, Slovenia