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AN EXPERIMENTAL STUDY OF SPRINGBACK OF BENT SHEET METAL PARTS

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ABSTRACT
Bending is the uniform straining of material around a straight axis and is used commonly in various sheet metal industrial products. Since all materials have a finite modulus of elasticity, plastic deformation is followed by some elastic recovery when the load is removed. In bending processes this phenomenon is called springback. Springback occurs not only in flat sheets or plate, but also in bars, rods, etc., and is one of the key factors to influence the quality of bent sheet metal parts. The amount of springback should be known in order to produce bent sheet metal parts within acceptable tolerance limits. There are many parameters which have influence on springback, one of them is strain hardening.
The aim of the experimental work, described in the paper, was to determine the influence of the effective strain to springback ratio and springback angle of sheet metal specimens. Many experiments have been done to find out the amount of springback for different values of effective strain and different thickness of metal sheets. Different specimens were used for the experimental determination of springback ratio and springback angle and were bent in a special bending tool. Statistical analysis methods were used for determination of mathematical models. This study is considered to be helpful to understand springback phenomena in metal forming processes.
Keywords: Cold forming, bending, springback, statistical analysis;

1. INTRODUCTION

Bending belongs to the most widely applied types of sheet metal forming and has been investigated thoroughly. Although several improvements have been made in material formability and tool steels, many researchers are still active to describe accurately the phenomena occurring the process. Among them, the elastic springback, that occurs after the pressure of the forming tools has been removed and results from the change in strain produced by elastic recovery when the load is released, remains the fundamental problem in the practice of the sheet metal forming processes, especially bending [1, 2]

As a matter of fact, it causes deviations from the desired final shape and doesn't permit the conformity of the product shape with the design specifications. Springback is dependent on the elastic and plastic deformation behaviour of material, thickness and width of the sheet, tooling geometry.

The strain hardening during metal forming has also a great influence on the elastic springback ratio and the springback angle. Accurate prediction of the springback of metal sheets after a forming operation is of vital importance for the design of tools in the industry [3]

2. SPRINGBACK RATION AND ANGLE

A purely elastically bent sheet will return to its original configuration upon removal of the bending moment. After partially plastic bending, permanent deformation and residual stresses remain after unloading [4]. For the calculation of springback in the praxis, springback ratio K and springback angle $\Delta\alpha$ have to be determined. The expressions:

$$K = \frac{r_1 + 0{,}5 \cdot s}{r_2 + 0{,}5 \cdot s} \qquad (1)$$

$$K = \frac{\varphi_2}{\varphi_1} \qquad (2)$$

are called springback ratio [1]. If K is known from experiment, the springback angle is easily determined to be:

$$\Delta\alpha = \varphi_1 - \varphi_2 = \left(\frac{1}{K} - 1\right) \cdot \varphi_2 \qquad (3)$$

where s is the thickness of the bending material..

3. EXPERIMENTAL WORK

The aim of the experimental work was to determine the influence of the effective strain reached by cold drawing to springback ratio and springback angle of copper alloy CuCrZr. This is a copper – chrome – zirconium alloy with high electrical and thermal conductivity and excellent mechanical and physical properties also at elevated temperatures [5].

Alloy was deformed by cold drawing from initial diameter D_0 = 20 mm to six different diameters (Table 1). The drawing speed was 20 m/min and the angle of drawing die was δ = 28°.

Table 1. Cold drawing of CuCrZr alloy bars

Spec. Nr.	D_0 [mm]	D_k [mm]	Effective strain ε_e
I	20	19	0,102
II	20	18	0,211
III	20	17	0,325
IV	20	16	0,446
V	20	15	0,575
VI	20	14	0,713
0	20	20	/

From each of six different cold drawn bars, experimental specimens (thin strips) of dimensions 90mm x 12mm x 1mm and 90mm x 12mm x 1,5mm were made. These specimens were used for the experimental determination of springback ratio and springback angle and were bent in a special bending tool. Radius of the bending punch (r) was 5 mm. During the bending, the angle of the specimen profile and inner radius of the bent specimen were measured. Many experiments and measuring were done to assure accuracy. By insertion of measured results in the equation (1) it is possible to calculate the springback ratio for differently deformed specimens. Also tensile tests were done for determination of the influence of tensile stress and yield stress on springback ratio.

4. RESULTS AND DISCUSION

Results of experiments are presented in a form of diagrams on Fig. 1, 2, and 3. The diagram on Fig. 1 shows the influence of the effective strain on springback angle $\Delta\alpha$. Instead of specimen number, the x-axis shows the effective strain of specimens reached by cold drawing.

As we can see, the lowest value of springback angle is reached when effective strain is zero (non-deformed specimen). With increasing effective strain ε_e springback angle $\Delta\alpha$ also increases reaching the highest value at ε_e =0, 71 (specimen VI). At this point springback angle is 28% higher then springback angle of non-deformed specimen. Figure 2 shows the influence of effective strain ε_e on springback ratio K. At more deformed specimens the springback ratio is lower. Specimen VI has 5% lower springback ratio as non-deformed specimen (specimen 0). It can also be noticed that the value of K at the same effective strain is higher for thicker specimen (s=1,5mm).

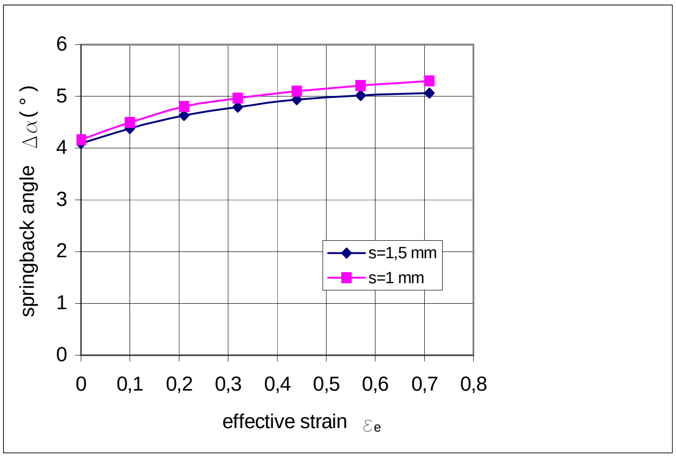

Figure 1. Springback angle as a function of effective strain of specimens (r=5mm)

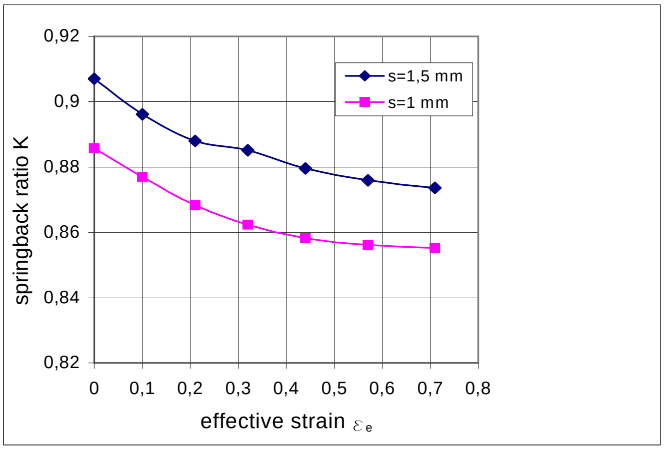

Figure 2. Springback ratio as a function of effective strain of specimens (r=5mm)

The influence of tensile (R_m) and yield stress ($R_{p0,2}$) on springback ratio K is presented in the diagram on Fig.3, which shows us that springback ratio decreases with increasing tensile and yield stress.

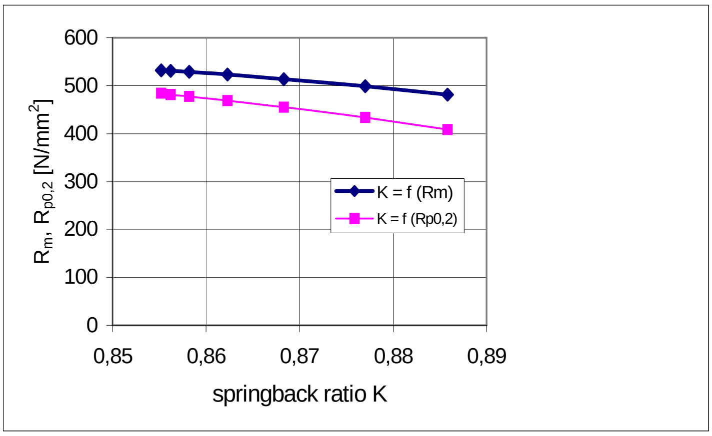

Figure 3. Springback ratio as a function of yield stress ($R_{p0,2}$) and tensile stress (R_m) of specimens (s=1mm, r=5mm)

Results of the experimental work can be presented in equations by using statistical analysis methods, for example regression analysis [6]. By using regression analysis the influence of parameters on springback ratio and springback angle can be represented in a form of equations:

For s=1, 5mm:

$$\Delta\alpha = 4{,}1026 + 2{,}8763 \cdot \varepsilon_e - 2{,}1605 \cdot \varepsilon_e^2 \quad (4)$$

$$Ke = 0{,}9057 - 0{,}0884 \cdot \varepsilon_e + 0{,}0616 \cdot \varepsilon_e^2 \quad (5)$$

For s = 1mm:

$$\Delta\alpha = 4{,}1876 + 3{,}1746 \cdot \varepsilon e - 2{,}2907 \cdot \varepsilon_e^2 \quad (6)$$

$$Ke = 0{,}8857 - 0{,}0973 \cdot \varepsilon_e + 0{,}0766 \cdot \varepsilon_e^2 \quad (7)$$

By using equations (4) to (7) it is possible to determine springback ratio and springback angle for every value of effective strain inside experimental area (from 0 to 0,71). The difference between measured and calculated values is less then 3%. Results are accurate for the values of r and s as noticed on the diagrams (Fig. 1 to Fig. 3).

Our experimental work and results that we calculated have confirmed the influence of the effective strain to springback ratio and springback angle. With higher effective strain springback angle also increases while springback ratio decreases. Springback ratio depends also on thickness of the sheet to be bend and on proportion r/s. The results indicate higher springback ratio and lower springback angle for thicker material. Conclusions of the research can be used for the design of tools for bending of CuCrZr alloys.

5. REFERENCES

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