Journal for Technology of Plasticity, Vol. 28 (2003), Number 1-2

BENDING IN TWO STAGES

Branko Grizelj, University of Osijek,
Faculty of Mechanical Engineering in Slavonski Brod, Croatia

ABSTRACT

In manufacturing of working parts by metal forming there are a number of various methods, owing to sorts and largeness of parts as well as the demands for form and accuracy that cause different procedures and ways of bending process.
Elastic part of deformation causes aberration of form and accuracy in bending. The important criterion in validation of bended parts presents the aberration of bending angle. As a measure for angle accuracy, it can be taken into account a relative error of bending angle. For the improvement of accuracy it is used a model, that compensate the mechanical spring back. The influence of mechanical spring back on bending angle can be eliminated, if it is in certain range of opposite direction and the same amount.
The following elements extent influence on bending: press-brak, die, work piece geometry, product properties and friction.
In this paper are analysed the influences onto the precision bending in two stages.
Keywords: *bending, tool, part geometry, bending in two stages*

1. INTRODUCTION

The important criterion in evaluation of bent components is the bending angle. The relative bending angle error may represent the measure of angle accuracy of the bent parts.

$$O_a = \frac{\alpha_2 - \alpha_{wz}}{\alpha_{wz}}$$

Where we have:

α_2 – Bending angle after withdrawal of pressure,

α_{wz} – Die angle.

There are three types of die bending: opened, half-opened and closed, see Fig. 1

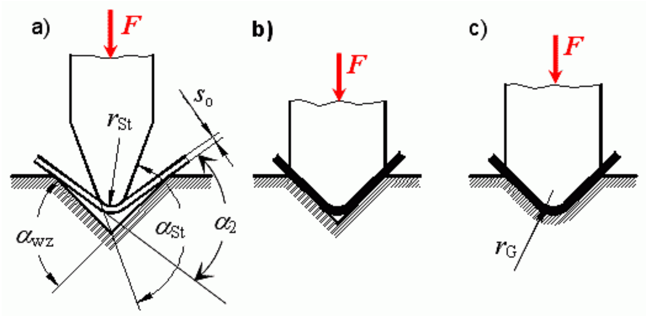

Fig. 1 Die designation

If the spring-back is avoided we may obtain close allowances of manufacture, Fig.2.

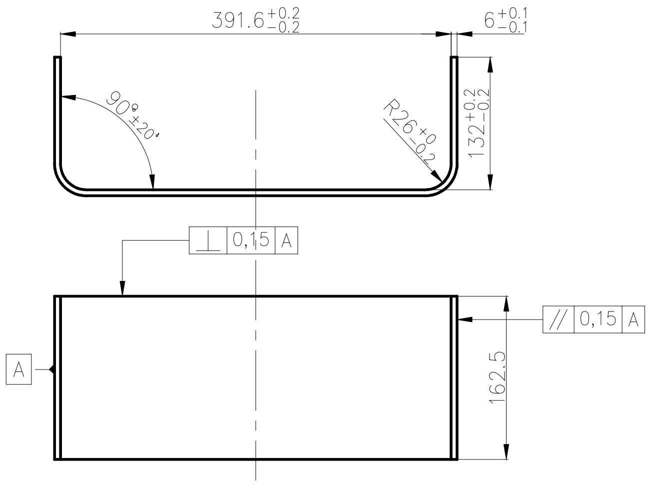

Fig. 2 Bending material RR St W 23

2. MODEL FOR COMPENSATION OF ELASTIC SPRING-BACK

In bending of metal plates we have the occurrence of phenomenon of elastic spring-back. This is possible if the plate is formed so that directions of loading forces on single areas are reverse, and the elastic spring-back in these areas equals them in size. In this way total elastic spring-back equals zero.

If this depicted model is transferred on plate bending, Fig. 3, then we must achieve that the part of spring-back from one bent leg has the same value as the part of the elastic spring-back of the bent leg, but in the reverse direction. If we bring closer the upper and bottom die to plate thickness of, then we have the situation that the plate rests completely on the upper die, so that the legs are flat when exposed to load, which is proved by constant curvature of the bend.

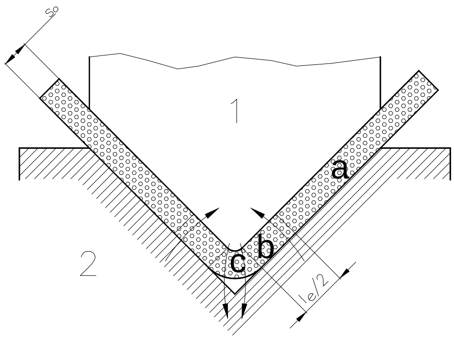

Fig. 3 Compensation of elastic spring-back in V- die

In principle such relations may be realized in two ways, either by choosing large enough distance, or if the material is shaped according to radius, where the leg length is formed in a plastic way.

3. BENDING IN TWO STAGES

3.1. DIE RADIUS

To achieve precise bending use of die width, which allows free bending, is required. In this way width of plastic zone l_u at the end of free bend depends on the bend radius.

The interdependence of relative bend angle error O_α and the specific maximal force F_{max} / b for different die radii is shown in Fig.4. In case of positive errors we have differences, which are greater with the increase of the force. Hereby we have increase of O_α accompanied by decrease of r_{st}.

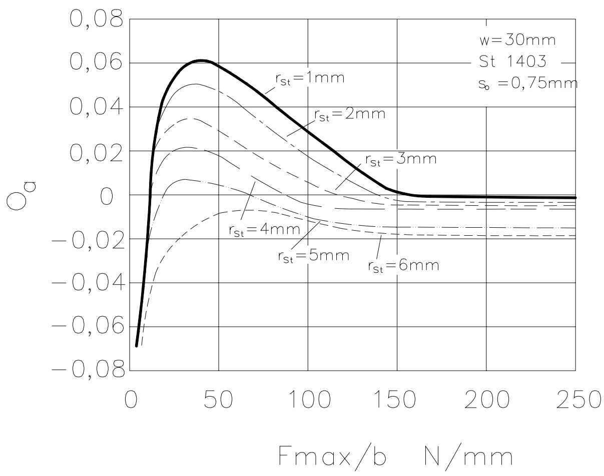

Fig.4 Interdependence of relative bend angle error and specific maximal force for various die radii in bending in half opened 90^0 V-dies

At forces F_{max} / b we have decrease of O_{α} with reduction of die radius.

3.2. BENDING IN TWO STAGES

The precise bending in two phases is presented on the Fig. 5.

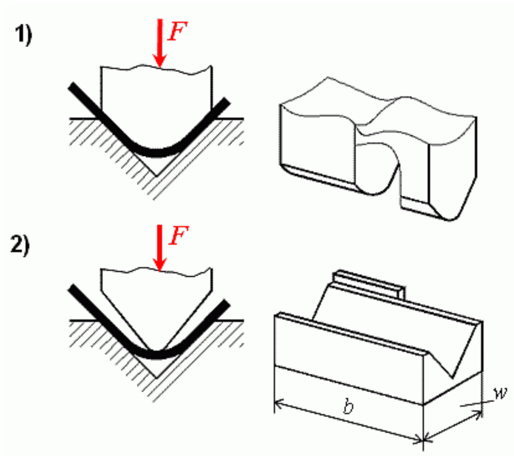

Figure 5. The precise bending in two stages

In the first stage the work piece has greater radii then it is needed (early stage of bending), but after that, the work piece is bended with demanded radii (final stage of bending).

Although is the cost of bending in two stage greater then in one bending stage, this has advantage in economical sense by small and medium series, because there is no supplementary finishing of the tool. By great series, it is accomplished through corresponding disposition of the tools (Fig. 5). The punches for early stage of bending and final bending are side by side. The width of the punch is equal to the width of the work piece. After early stage of bending the work piece is put beneath the punch for final bending. In next phases i.e. punch motion the both operation are performed simultaneously (on one work piece the early stage of bending, while on the other the final bending). On this way it is reduced the time that it almost as by bending in one stage.

The dependency of relative error of the bending angle O_a from specific maximum force F_{max}/b are presented by bending in two stages on the Fig. 6. The width of the tool is w=20 mm, material St 1403 and thickness is s_o=0,75 mm.

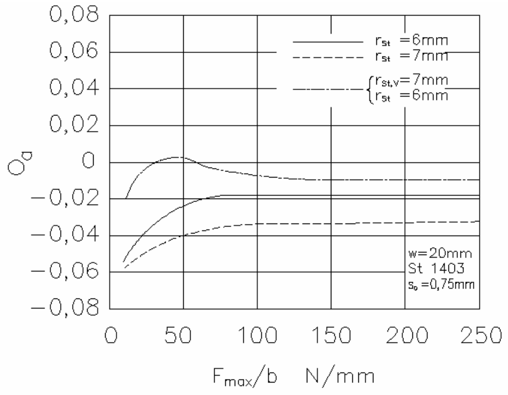

Figure 6. The dependence of relative error the bending angle from specific maximum force by bending in one stage as well as in precise bending in two stages by bending in half open tool 90^0-V

When the work piece is bended with the radii r_{St}=6 mm (full line), where this correspond with the radii of the work piece, then the relative error changes as it is expected by bending with the width of the tool $w<w_{opt}$. It is decreased in the field of lesser specific force, firstly very strong, and later achieved constant value by F_{max}/b =80 N/mm.

If it is applied r_{St}=7 mm instead of r_{St}=6 mm, then the form of the curve is similar (dotted line). All the same, the relative error is significantly greater. If that work piece is firstly bended with F_{max}/b =50 N/mm and bending radii r_{St}=7 mm, and after that it comes the final bending with radii r_{St}=6 mm, then the curve has form of that dot line on Fig. 4.

By applying, the precise bending in two stages it is interesting what influence has maximum specific force at the end of first stage of bending on the relative error of final bending. It is presented on the Fig. 7, for material St 1403 with corresponding symbols for relevant maximum specific force of first stage of bending and in continuation presented maximum specific force for final bending on the horizontal coordinate axis.

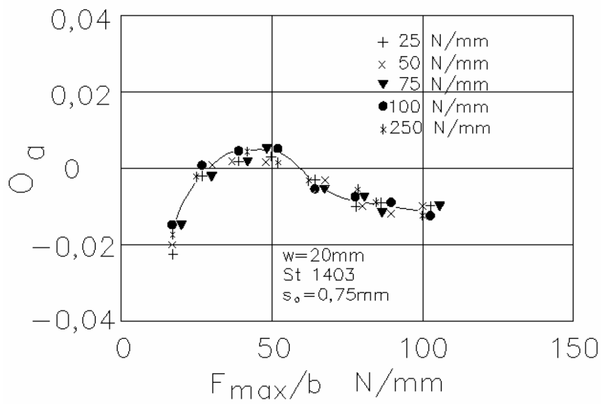

Figure 7. The dependence of relative error the bending angle from specific maximum force for various force in first stage of bending in half open tool 90^0-V

Although the differences of forces in first stage of bending are great, the difference of relative error the bending angle is sufficiently small. The reason is that on the geometry of bending arc by the same radii of the punch maximum specific force has negligible influence. By precise bending in one stage, the form of the bending arc and consequently the amount of positive maximum error, i.e. aberrations of bending angle-by changing the width of the tool. That is not possible by precise bending in two stages, because the maximum width of the tool is defined the shortest length of side.
The material is first bended with radii r_{St}=6, 7, 8 and 10 mm and after that finally bended with the punch that has r_{St}=5 mm. For all radii of first stage of bending it is achieved the positive relative error of bending angle. With increasing the bending radii comes greater angle of bending α_1 and according to that greater positive maximum error $O_{a\ max}$. In that case decreases the curve of the error of specific maximum force. In the area of maximum specific forces F_{max}/b=150 N/mm it decreases also relative error the bending angle proportionally with radii of first stage of bending.

In the praxis it has to be chosen the radii of the punch for the first stage of bending with which it is achieved the error of bending equal to zero or small positive amount (in this case $r_{St.v}$=6 mm). With such radii it is accomplished the optimum according on the possibility of reproduction the bending angle and needed force. For the value of bending radii for first stage of $r_{St.v}$=10 mm in this case, it is obtained lesser maximum specific force by second passing through zero point of curve error then with optimal punch radii for first stage, but also it is obtained greater gradient of curve error and consequently lesser possibilities of reproduction the bending angle.

On the Fig. 8 it is presented the dependence of relative error the bending force from maximum bending force for material St 1403, Z StE 340 and P 340, radii of bending $r_{St.v.}$=6 mm and final bending radii r_{St} =5 mm.

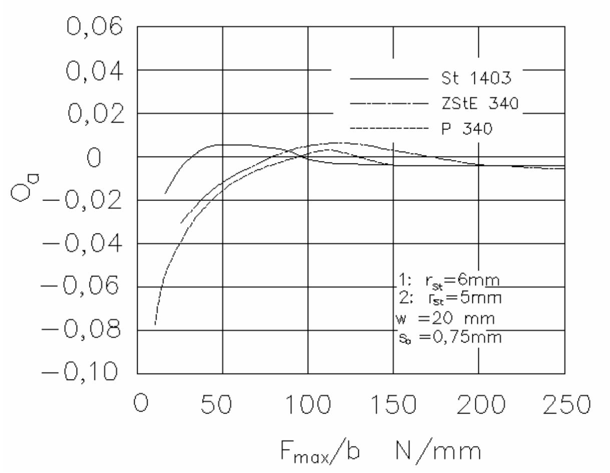

Figure 8. The dependence of relative error the bending angle from specific maximum force for various materials in the case of bending in two stages in half open tool 90^0-V

If one wishes to emphasise the accuracy of realising the angle according to DIN 7151, then it is demanded to determine the length of that angle. On the Fig. 9, the dependence between aberration of length and aberration of angle is presented.

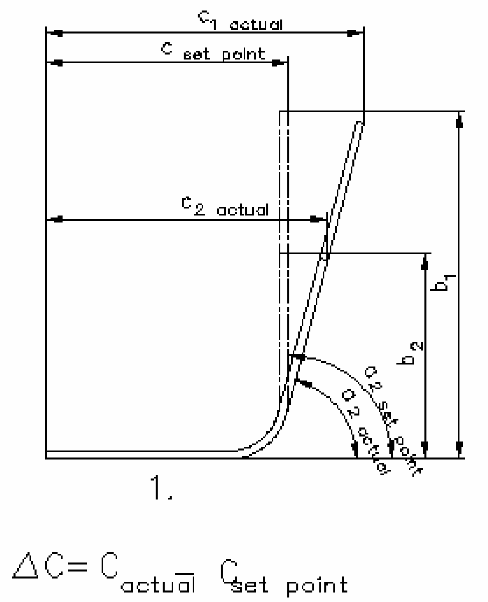

Figure 9. The dependence of length according to DIN 7151 and aberration the bending angle

In accordance to determined surface-as, for instance the surface for assembling-it is obtained the angle of bended part $\alpha_{2actual}$ and the length of the side b_1 depending of the length $C_{1\ actual}$.

4. CONCLUSION

Bending die geometry is obtained out of requirements regarding geometry of the bent components and their size. These parameters give in advance minimal and maximal sizes of the bent components. Shape of die, its width, curvature of the bottom die part, upper die angle and its radius and width exert influence on accuracy of bending [1-14].
In this paper are analysed the influences onto the precision bending in two stages, Fig. 1-9.

5. LITERATURE

[1] H. Wilhelm: Das Verhalten von Blechen aus Titan und Titanlegirungen beim Biegen in V-Gesenk. Bänder Blech Rohre, s. 284-288, 17, 1976.
[2] B. Grizelj: Plate bending of spherical tank. Proceedings of the 6th International Conference on Technology of Plasticity, s. 643-644, Nurember 1999.
[3] B. Grizelj; M. Math & F. Matejiček: Application FEM for process plate bending. She Met, s.519-528, Birmingham 2000.
[4] B. Grizelj; D. Grizelj & D. Stanišić: The influence of press on enhancement of bending accuracy, CIM-2000, s. IV 037-IV 048, Korčula 2000.
[5] B. Grizelj; M. Math & P. Jović: Influence of die on improvement of bending accuracy. CIM-2000, s. IV 09-IV 017, Korčula 2000.
[6] B. Grizelj, P. Jović & D. Stanišić: Influence of part geometry and property of semi product of the improvement the accuracy of bending. CIM-2001, IV 033-IV 042, Korčula 2001.

[7] K. W. Kahl: Untersuchungen zur Verbesserung der Form – und Massgenauigkeit beim Biegen von Blechen. Diss. Universität Dortmund 1985.
[8] E. Dannemann: Die Abbildegenauigkeit beim Biegen im 90°-V Gesenk und ihre Beeinflussung durch Nachdrücken im Gesenk. IF U-Bericht Nr.8 Essen: Verlag W. Girardet 1969.
[9] B. Grizelj: Prilog istraživanju elastičnog vraćanja čeličnih dvostruko zakrivljenih ploča nakon izrade hladnom plastičnom deformacijom. Magistarski rad, FSB, Zagreb 1982.
[10] K. Lange: Lehrebuch der Umformtechnik Bd. 1-4 Berlin /Heidelberg/New York: Springer-Verlag 1988-1993.
[11] B. Grizelj: Doprinos analizi aksijalno-simetričnog savijanja lima. Doktorski rad, FSB, Zagreb 1995.
[12] B. Grizelj; P. Jović & D. Stanišić: The influence of friction on the accuracy of bending, CIM-2002, s. IV 029-IV 037, Brijuni 2002.
[12] B. Grizelj; & Z Vnučec: Precision bending in two stages, RIM-2003, s. 179-184, Bihać 2003.
[13] B. Grizelj; I. Muhlis Kenter & M. Math: Application FEM in plate bending, SHET METAL-2003, s. 573-580, Ulster 2003.
[14] B. Grizelj; & D. Grizelj: Bending plate, 7th ICTP-2002, s. 17993-1798, Yokohama 2002.

SAVIJANJE U DVE FAZE

Branko Grizelj

REZIME

Proces savijanja karakterističan je, između ostalog, i po tome što se u njemu pojavljuju značajne zaostale elastične deformacije. Ova pojava može znatno da utiče na tačnost delova dobijenih savijanjem.
Rad je usmeren na istraživanje tačnosti kod V-savijanja metalnih ploča. Pri tome se greška tačnosti ugla savijanja definiše kao:

$$O_a = \frac{\alpha_2 - \alpha_{wz}}{\alpha_{wz}}$$

α_2 – *ugao savijanja nakon dejstva sile,*

α_{wz} – *ugao alata*

U cilju postizanja visoke tačnosti u radu se elaborira savijanje u dve faze. U prvoj fazi radni predmet se savija na veći radijus nego što je potrebno a zatim, u drugoj fazi, savijanje se sprovodi na krajnji, zahtevani oblik.
Iako je taj postupak skuplji od klasičnog, on je pogodan za pojedinačnu i maloserijsku proizvodnju.
U okviru istraživanja utvrđene su zavisnosti između relativne greške ugla savijanja i specifične maksimalne sile F_{max} / b *. Pri tome je obrađen primer savijanja na alatu tipa* 90^o *– V, širine 20 mm a materijal je bio St 1403, debljine 0,75 mm.*
Takođe je razmatrana i zavisnost između dužine kraka (prema DIN-u 7151) i odstupanja ugla savijanja.
Kod primene principa savijanja u dve faze od značaja je i poznavanje uticaja maksimalne sile savijanja na kraju prve faze savijanja na relativnu grešku savijanja. I taj aspekt je elaboriran u radu i ilustrovan grafički (sl. 7).