Journal for Technology of Plasticity, Vol. 34 (2009), Number 1-2

CHANGING OF TENSION STRESS OF IRONED ALUMINIUM WORK PIECE WALL

Adamović, D[1]., Stefanović, M[1]., Gulišija Z[2]., Aleksandrović, S.[1], Živković, M[1]., Devedžić, G[1].

[1] - Faculty of Mechanical Engineering Kragujevac, University of Kragujevac, Serbia
[2] - Institute for Technology of Nuclear and other Mineral Raw Materials, Belgrade, Serbia

ABSTRACT

The size and distribution of contact stresses in strain zone influence the stress-strain state of y formed work piece, the possibility for successful forming as well as the force needed for forming execution. The effects of friction forces in strain zone are various; on the outer surface (between work piece and die) these forces (F_{frD}) increase tension stresses, and on the inner surface (between work piece and punch, forces F_{frP}) they relieve the critical section, reducing stresses in the wall of work piece which is ironed. That is the main reason for achievement of high strain ratios and realization of the significant increase of relative depth at drawing.
The increase of friction on punch side reduces the critical tension stress, but the total drawing force increases. In the course of that, the force F_{frP} must not increase so much that, on contact surface of work piece, it leads to appearance of rough intrusions and micro-welding (or adhesion) of metal particles of work piece on tool, because it would lead to damaging of work piece and tool and make difficult the removal of work piece from the punch.
In this paper, the analyses of the influence of different parameters (die gradient angle, lubricant on die and punch, punch roughness, tool material etc) on stress of tension of ironed work piece wall were made.

Keywords: *ironing, wall tension stress, tribological conditions, forming parameters*

1 INTRODUCTION

In the ironing process, the occurrence of considerably high normal stresses on contact surfaces is characteristic, as well as the appearance of different directions of friction forces which act on outer and inner surface of the work piece being formed. The directions of friction forces are opposite because in the ironing process the work piece moves down along the die, and consequently the friction force on the outer surface has the direction opposite of the ironing direction. At the same time, on account of thinning, work piece is elongated and, in strain zone, it slides along the punch in the direction opposite of the ironing direction; consequently, the friction force on inner surface of work piece will have the direction same as ironing direction.

Ironing is performed in conditions of three dimensional state of strain, whereat all of the three main strains in general case are different from zero. However, it can be considered, without much imprecision, that the ironing process is performed in conditions of plane state of strain, where the main strains are: strain of compression in radial direction (thickness decrease) and strain in the direction of ironing axis (increase of work piece length). Strain in tangential direction can be considered equal to zero, since the clearance between punch and die is usually small compared to punch diameter.

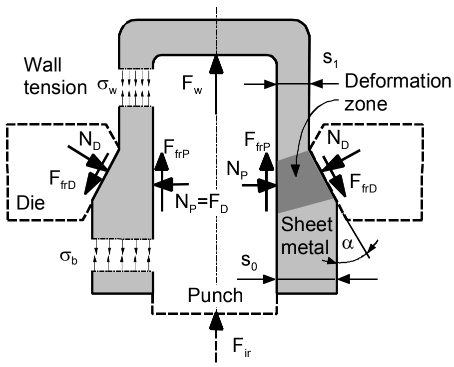


Fig. 1 - Scheme of forces acting upon sheet metal

The scheme of outer forces and work piece forming character lead to conclusion that axial stress is tensile, and radial stress is compressive, whereat axial stress increases above zero when entering the forming zone and reaches its maximum when exiting the forming zone (on the border between forming zone and wall of work piece which underwent forming).

Force F_w which acts upon work piece bottom, causes the appearance of tensile stresses in work piece wall, both in ironed work piece and in strain zone. Those tensile stresses have maximal value when the work piece exits the die and decrease to some minimal value which they have when work piece enters the strain zone. Minimal value of stress at die entrance (σ_b) can be [1]:

- equal to zero ($\sigma_b = 0$), if ironing is performed with one die,
- above zero ($\sigma_b > 0$), if ironing is performed through several dies and then that stress value is equal to the maximal value of wall tension stress when exiting the previous die, and
- below zero ($\sigma_b < 0$), if work piece is pushed from the back.

Wall tension stress in ironed part of work piece, among other things, depends on tribological conditions on contact surfaces between die and punch, on one side, and work piece on the other side. Friction coefficients on die and punch side differ from one another due to different materials and quality of punch and die surfaces. If friction coefficient on die side (μ_D) is different from friction coefficient on punch side (μ_P), then different ratios of those coefficients can influence the value of tensile stress σ_w.

To influence the value σ_w by considerable increase of friction coefficient μ_P is practically not allowed, since it would considerably decrease stability [2].

2 EXPERIMENTAL RESEARCHES

Experimental researches were carried out on the original tribo-model of ironing, which with bilateral symmetry imitates the zone of contact with die and punch [3]. This model enables realization of high contacting pressures and takes into consideration physical and geometrical conditions of the real process (material of die and punch, topography of contact surfaces, die cone angle - α etc.). The scheme of specified tribo-model is given in Fig. 2a, and appearance of device in Fig. 2b. Device for ironing is installed on special machine for investigation of sheet metals ERICHSEN 142/12.

Total drawing force F_{ir} represents the sum of friction force between punch and work-piece, F_{frP}, and force that acts upon the test specimen bottom, F_w (Fig. 1), that is:

$$F_{ir} = F_{frI} + F_w , \tag{1}$$

Force F_{ir} is measured on the machine, and friction force on punch side F_{frP}, is registered with the gauge with measuring bands.

Based on previous equation, the following is obtained:

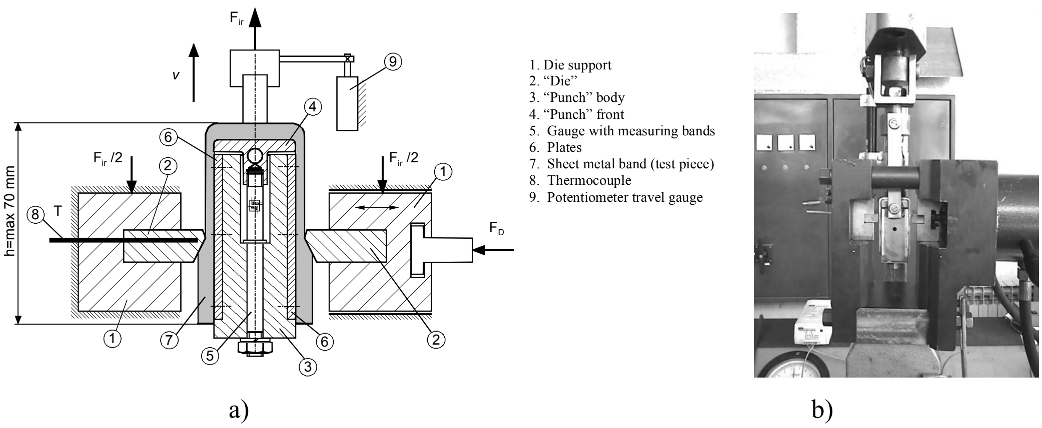
$$F_w = F_{ir} - F_{frP} , \tag{2}$$

Force F_w, which acts upon the band bottom (test specimen), burdens band walls by stress σ_w which can be calculated by the following expression:

$$\sigma_w = \frac{F_w}{2 \cdot b \cdot s_1} , \tag{3}$$

where at: b – test specimen width,

s_1 – test specimen thickness after thinning



a) b)

Fig. 2 - Scheme and appearance of model used in this paper.

The process of making work pieces by ironing is influenced by many factors.
On the basis of analysis of researches and preliminary investigations so far, the following factors were selected, which will be the subject of experimental researches:

- Type of investigated material – AlMg3 (DIN: AlMg3 F24),
- Die gradient angle - α=5°; 10°; 15°; 20°,
- Material of tool (die/punch) - TS/TS; Cr/Cr; TiN/TiN; HM/TS (TS – tool steel, Cr – hard chrome plated coating, TiN –titan nitride coating, HM – hard metal),
- Punch roughness, expressed by average roughness height - Ra=0.01; 0.09; 0.4 µm, which is consistent with surface qualities N1; N3; N5 respectively,
- Type of lubricant on die side – L5 (paraffin based oil with special additives, kinematical viscosity at 40°C - 80 mm^2/s); L6 (paraffin based oil with special additives, kinematical viscosity at 40°C - 190 mm^2/s);
- Type of lubricant on punch side – L6 (paraffin based oil with special additives, kinematical viscosity at 40°C - 190 mm^2/s),
- Blank holding force - F_D = 8.7 ; 17.4 ; 26.1 kN,
- Forming speed - v = 20 mm/min.

In addition to specified influential parameters, there is a whole sequence of others, such as: smoothing zone height, punch radius, work piece bottom thickness, number of dies for ironing, ratio of inner and outer work piece diameter, ratio of dies radii in multistage tool, ratio of work piece height and diameter etc. [4], which have not been taken into consideration in this paper due to the objective reasons. Mechanical properties of investigated material are given in table 1.

Table 1. *Mechanical properties of investigated materials*

Material	Angle, °	R_p, *MPa*	R_m, *MPa*	R_p/R_m, -	A, %	n, -	r, -	E, *MPa*
AlMg3	0°	201.1	251.0	0.801	12.0	0.13545	0.40510	0.701×10^5

3 EXPERIMENTAL RESULTS

In dependence of ratio of drawing force and friction force on punch, the force acting upon work piece bottom F_w can range from $F_w = 0$, when $F_{frP} = F_{ir}$, up to $F_w = F_{ir}$, when $F_{frP} = 0$. Consequently, wall tension stress can range from $\sigma_w = 0$ up to $\sigma_w = F_{ir}/(2s_1b)$.Contact conditions should be selected that the smallest possible σ_w is obtained.
Trends of changes of drawing force and friction force on the punch on sliding path influence the change of tension stress, which can be: constant, increasing or decreasing (Fig. 3).
Since drawing force and friction force on punch play an important part in expression for tension stress, and they largely depend on blank holding force and die gradient angle, it is logical to expect that the influence of these factors will also influence wall tension stress significantly [3].
Fig. 4 shows the dependence of wall tension stress on sliding path at various blank holding forces. Wall tension stress increases with the increase of blank holding force. Average values of stress σ_w for various blank holding forces and all levels of investigated factors are shown in Fig. 5. The increase of blank holding force leads to increase of wall tension stress.

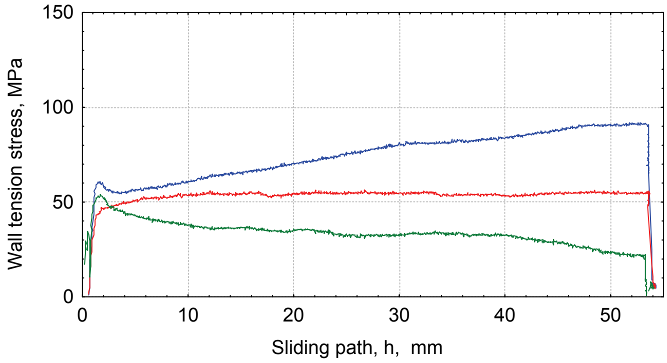


Fig. 3 - Change of wall tension stress on sliding path

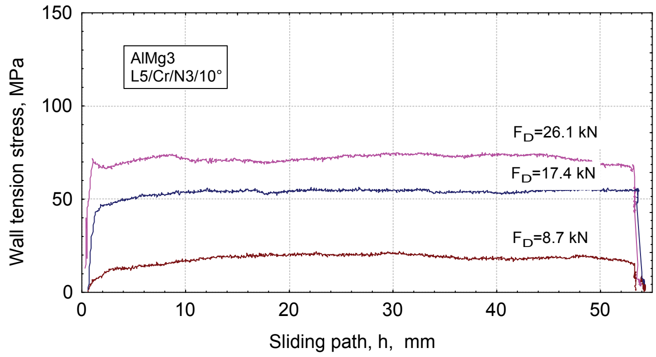


Fig. 4 - Change of wall tension stress on sliding path for various blank holding forces

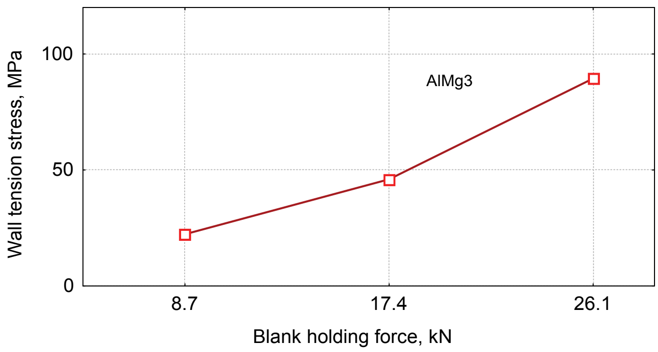


Fig. 5 - Change of wall tension stress in dependence on sliding path

Change of stress σ_w in dependence on sliding path for various die gradient angles is shown in Fig. 6. The increase of die gradient angle leads to increase of wall tension stress σ_w. Dependence of average values of stress σ_w on die gradient angle is shown in Fig. 7. The increase of die gradient angle leads to increase of wall tension stress for all levels of other analysed factors.

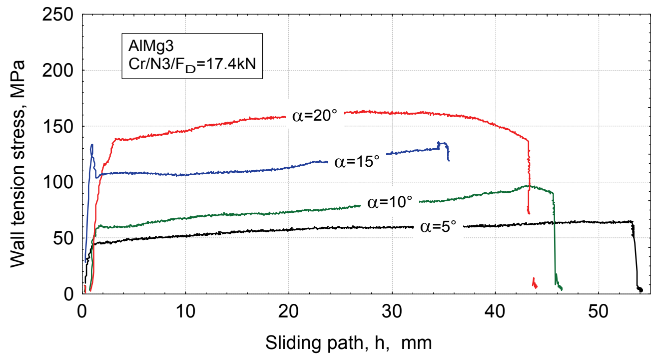


Fig. 6 - Change of wall tension stress in dependence on sliding path for various die gradient angles

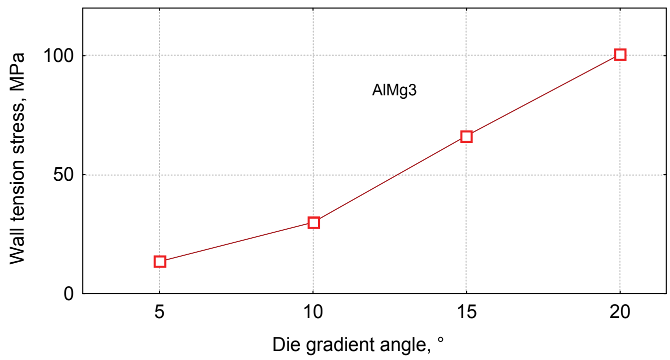


Fig. 7 - Change of wall tension stress in dependence on die gradient angle

Dependence of wall tension stress on die gradient angle at various levels of blank holding force is given in Fig. 8. In all the cases, the stress σ_w increases with the increase of angle α.
Average values of wall tension stress at application of various lubricants are shown in Fig. 9. Smaller stress is obtained by applying lubricant L6 [5].
Stress σ_w (average values) for various tool materials is shown in Fig. 10. The smallest vales of stress σ_w are obtained with tools made of alloyed tool steel (TS), and the largest stress is obtained with hard metal tool (HM) [6].

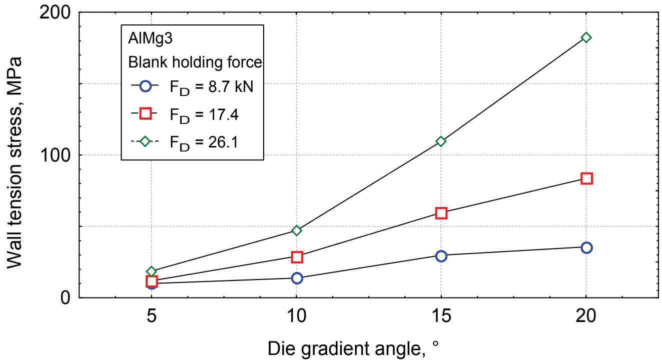


Fig. 8 - Change of wall tension stress in dependence on die gradient angle for various blank holding forces

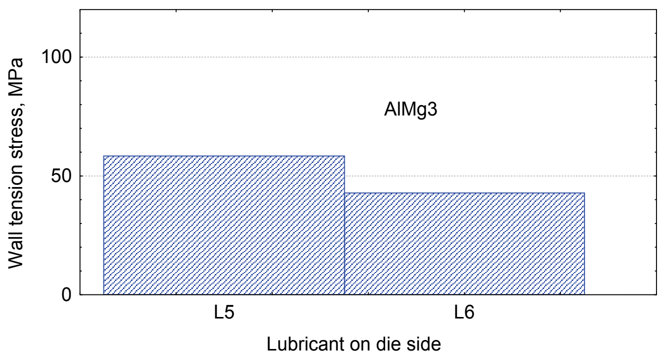


Fig.9 - Average values of wall tension stress for various lubricants on die

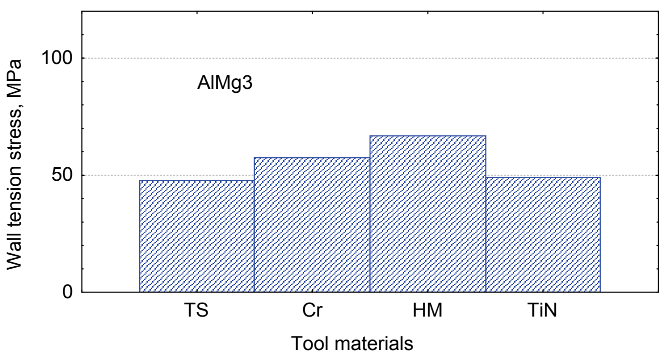


Fig. 10 - Average values of wall tension stress for various tool materials

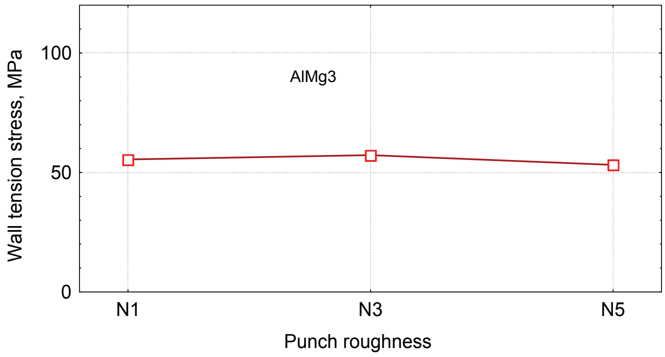
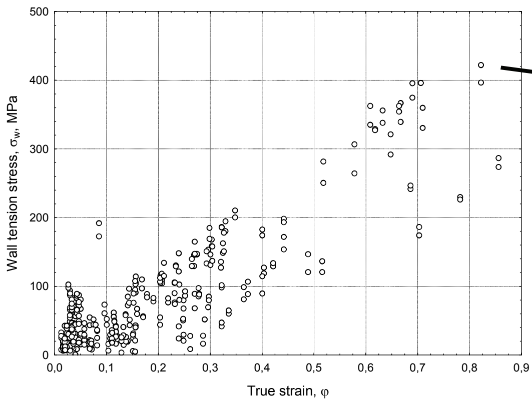
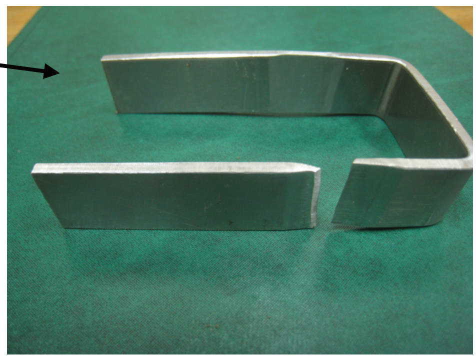


Fig. 11 - Average values of wall tension stress for various punch roughnesses

Since punch roughness has a significant influence on the value of friction force on punch (the increase of roughness leads to increase of friction force on punch), it is logical that the increase of punch roughness leads to decrease of wall tension stress, but only at higher roughness values, which is shown in Fig. 11.
Dependence of wall tension stress on strain is shown in Fig. 12a, where it is obvious that the increase of strain leads to increase of stress σ_w. When the stress values are exceeded so much that the work piece wall can no longer endure, wall fracture occurs. The characteristic example of sample fracture due to increase of wall tension stress is shown in Fig. 12b.



a)



b)

Fig. 12 - Change of wall tension stress in dependence on strain (a) and the appearance of fractured test specimen (b)

Higher values of friction coefficient on punch side go with higher values of friction force between punch and work piece [7]. At the same time, the increase of friction coefficient on punch, force by which work piece wall is tensioned, decreases [8]. Since the increase of friction force on punch is larger than decrease of wall tension force, drawing force increases. Previous statement is shown in Fig. 13. Similar results were obtained in papers [9, 10] by investigating technically pure box-shaped aluminium samples and steel samples.

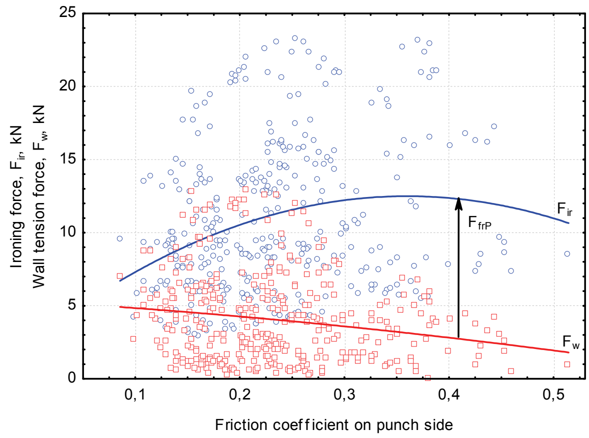


Fig. 13 - Dependence of drawing force (F_{ir}) and wall tension force (F_w) on friction coefficient on punch side

4 CONCLUSION

For successful forming, it is necessary that the wall tension stress has the smallest possible value, which means that the contact conditions should be selected in such a way that the smallest possible σ_w is obtained.
Trends of changes of drawing force and friction force on the punch on sliding path influence the change of tension stress, which can be: constant, increasing or decreasing
Increase of friction coefficient on punch can lead to decrease of wall tension stress, but at the same time drawing force will increase. On the other hand, the change of drawing force does not give undivided evidence on proper change of tensile stresses in critical work piece section. When small drawing forces are applied, small wall tension stresses are obtained regularly, while when large drawing forces are applied, in dependence on realised contact conditions, it is possible to obtain both large and small values of wall tension stress.

REFERENCES

[1] Avitzur, B.: Handbook of Metal-Forming processes, JOHN WILEY & SONS Inc., New York, 1983.

[2] Adamović D. (1999), Stefanović M., Vujinović T.: Analysis of the Influence of Friction on Stress-strain Characteristics of Ironing by Upper-bound Method, YUTRIB99, Kragujevac, 1999.

[3] Adamovic D.: Behaviour of Materials in Contact in Cold Plastic Forming Processes with High Working Pressures, Doctoral Thesis, the Faculty of mechanical Engineering in Kragujevac, Kragujevac, (2002), (in Serbian)

[4] Adamović, D., Stefanović, M., Lazić, V.: Istraživanje uticajnih parametara na proces dubokog izvlačenja sa stanjenjem debljine zida, DEMI 2002, Banja Luka, str. 166-171.

[5] D., Adamović, M., Stefanović, M., Zivković, F., Živić: Estimation of Lubricants for Ironing of Steel Pieces, Tribology in industry, Volume 29, No. 3&4, YU ISSN 0354-8996, Kragujevac, December 2007., p. 21-27.

[6] D. Adamović, M., Stefanović, V., Lazić: Investigation of the influenze of tool material and lubricant onto the process paramerers and quality of work piece surface at ironing, Journal for Technology of Plasticity, Novi Sad, Vol. 28 (2003), Number 1-2, pp. 41-55.

[7] D., Adamović, M., Stefanović, M., Zivković, F., Živić: Investigation of Influence og Tribological Conditions on Friction Coefficient During Multiphase Ironing for Steel and Aluminium Sheet Metal, Tribology in industry, Volume 28, No. 3&4, YU ISSN 0354-8996, Kragujevac, December 2006., p. 29-34.

[8] D. Adamović, M. Stefanović, M. Plančak, S. Aleksandrović: Analysis of Change of Total Ironing Force and Friction Force on Punch at Ironing, Journal for Technology of Plasticity, Vol.33(2008), Nr.1-2, Novi Sad, 2008. pp. 23-37.

[9] Saito, M., Saiki, H., Kawai, N.: Experimental Analysis of Ironing of Thin Metal Cups, Trans. ASME, J. Eng. Ind., Vol. 111, 1989., 56-62

[10] Adamović, D., Stefanović, M., Živković, M., Devedžić, G.: Uticaj parametara dubokog izvlačenja sa stanjenjem debljine na napon zatezanja zida izvlačenog čeličnog dela, 33rd Conference on production engineering of serbia 2009 with foreign participants Belgrade, 16-17.06.2009. pp. 109-112.

PROMENA NAPONA ZATEZANJA U ZIDU KOMADA OD ALUMINIJUMA PRI DUBOKOM IZVLAČENJU SA STANJENJEM

Adamović, D[1]., Stefanović, M[1]., Gulišija Z[2]., Aleksandrović, S.[1], Živković, M[1]., Devedžić, G[1].

[1] – Mašinski fakultet u Kragujevcu, Univerzitet u Kragujevcu, Srbija
[2] - Institut za tehnologiju nuklearnih i drugih mineralnih sirovina, Beograd, Srbija

REZIME

Od veličine i raspodele kontaktnih napona u zoni deformacije zavisi naponsko-deformaciono stanje plastično deformisanog komada, mogućnost uspešnog deformisanja, kao i potrebna sila za izvodjenje deformisanja. Dejstvo sila trenja u zoni deformisanja je različito; na spoljašnjoj površini (izmedju komada i matrice) ove sile (F_{trM}) povećavaju napone zatezanja, a na unutrašnjoj (izmedju komada i izvlakača, sile F_{trI}) rasterećuju kritičan presek, umanjujući napone u zidu dela koji se izvlači. To je glavni razlog za postizanje visokih stepena deformacije i ostvarivanje znatnih priraštaja relativne dubine pri izvlačenju.

Povećanje trenja na strani izvlakača umanjuje kritični zatežući napon, ali se ukupna sila izvlačenja povećava. Pri tome sila F_{trI} ne sme toliko da poraste da se na kontaktnoj površini komada pojave gruba zadiranja i mikro privarivanja (ili nalepljivanja) čestica metala radnog komada na alat, što bi dovelo do oštećenja radnog komada i alata i otežalo skidanje radnog komada sa izvlakača.

U ovom radu napravljena je analiza uticaja različitih parametara (ugao nagiba matrice, mazivo na matrici i izvlakaču, hrapavost izvlakača, materijal alata itd.) na napon zatezanja zida izvlačenog dela.

Ključne reči*: duboko izvlačenje sa stanjenjem debljine zida, napon zatezanja zida, tribološki uslovi, parametri deformisanja*

.