ARCHIVES
Of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 11
Special Issue
2/2011
191–194

37/2

Numerical modeling of the welding phenomenon in forward aluminium extrusion process

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Received 11.04.2011; Approved for print on: 26.04.2011

Abstract
There is often need to use welding methods in the aluminium alloys extrusion processes. Welding methods while extruding are divided in to transverse and longitudinal one. In paper the energy criterions for transverse and longitudinal joining during extrusion of aluminium alloys in warm conditions are showed. Numerical simulation results for two cylindrical billets transverse joining, during forward extruding with using the flat punch are presented. Irregularity in the billets material flow and presence of a void are proved. In order to equalization the flowing billets volumes streams, the numerical model for forward extrusion of cylindrical billets, with using the punch with a toe and initially formed upper billet is proposed. The application of this method causes both transverse and longitudinal welding schemes appearing. Combination of two welding schemas gives the product, which has a core made of material from the upper billet and external layers of the lower billet.
Key words: Plastic treatment; Extrusion; Welding; Tool design

1. Introduction

There is often need to use joining methods in the aluminium alloys extrusion processes. For technological reasons there are two schemes for plastic joining during hot extruding [1,2,3]:
1. Joining of layers transversely located to the principal axis of the die. In this process two billets are welded in a container by the joint created at the billets interface. Transverse weld reduces strength parameters of the extruded objects [4,5].
2. Joining of the materials along the stream lines. During the hot extrusion of complex profiles the billet is split into separate metal streams by the bridges of the die. Under the influence of normal stress to the contact surface, there is joining of dividual parts in the desired profile form [6]. The primary problem in this phase of the process is to ensure such a state of stress, deformation and temperature, which will accomplish good weld quality. Good weld quality can be achieved only with use optimum shape of the

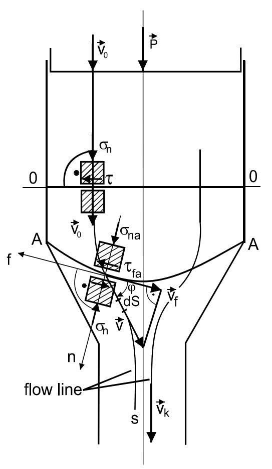


Fig. 1. Transverse welding in forward hot extrusion[8,9]

die, reasonable parameters of the workpiece temperature, proper load and speed of the punch [7].

As the flow kinematics of two cases are quite different, a separate welding criterions during hot extruding aluminium alloys have been proposed for each of them [8,9].

Figure 1 shows the diagram of the flow at the interface of two successive billets during forward extrusion. Physical factor for permanent coupling of the materials is the cumulation of the friction forces work in joining points during the material flow along the stream lines. The energy criterion for transverse adhesive welding at the leading surfaces of two billets are presented below.

$$E_d \geq E_d^*$$

$$E_d = \int_0^t b\ \tau_f\ v_f\, dt$$

where:
E_d – energy of deformation
E_d^* - energy ensured adhesion

This criterion takes into account the physical aspects of adhesion of aluminium alloys in hot extrusion process. Factor b relates to the nearing degree of the surfaces and their quality limited by layers of oxides.

For forward extrusion, permanent joint of the longitudinal streams occurs when the intensity of consumed deformation energy achieves a critical value (fig. 2).

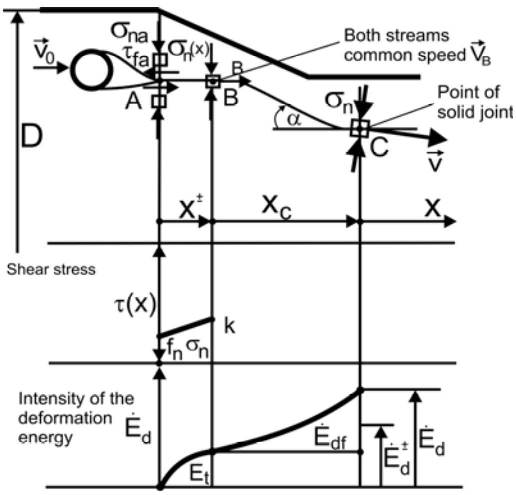


Fig. 2. Longitudinal welding in forward hot extrusion[8,9]

The longitudinal joining criterion prefers the role of the plastic deformation energy. Especially responsible factor in this case is the normal stress distribution and yield strength along the interface zone. The criterion for longitudinal energy welding is shown in the stress-condition form:

$$\int_{t^*}^{t_f} \frac{\sigma_n}{k}\, dt \geq C_{kr}$$

where:
C_{kr} – critical value of the coefficient of multiple deformation energy intensity caused by the shear stress k, which corresponding to yield shear stress

Based on the submitted criterions, some guidelines for extrusion process technology designing can be suggest. The quality of the joined product will increase if it will be taken into account following factors:

- Increase of the interface area,
- Increase in normal stresses,
- Increase in shear stresses,
- Increase in stream lines lengths,
- Increase in time of the material particles presence in the large normal stress area.

Theoretical welding criteria may be effectively used only in connection with numerical simulation of the process. This is linked to the knowledge about the velocities and stresses distributions in the plastic flow area.

2. Numerical analysis

Numerical simulation results of two cylindrical billets transverse joining, during forward extruding with using a flat punch, throughout rectangular die are presented below (fig. 3).

Axisymmetric geometry of investigated processes allows considering one half of the billet, reducing calculation time this way. To carry out the simulation processes DEFORM 2D software was used. The billet material was considered as a plastic. As well as die, container and punch were treated as a rigid.

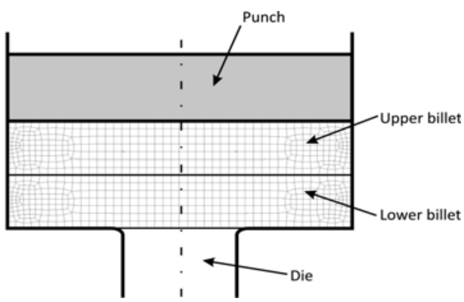


Fig. 3. Cylindrical billets joined while forward extruding with using a flat punch

Simulation revealed the irregular flow of both billets in this joining model (fig.4). It also appeared macrostructure discontinuity in the form of a void, which has an influence on weakening of the product strength property.

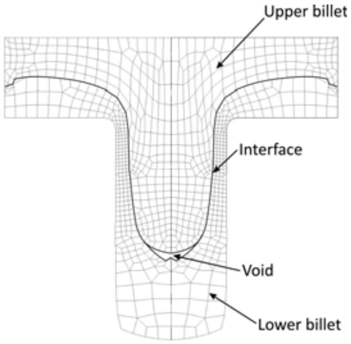


Fig. 4. Joining of cylindrical billets

Billets are started to be welded under the impact of the die area, where the velocities of both billets are aligned (fig. 5).

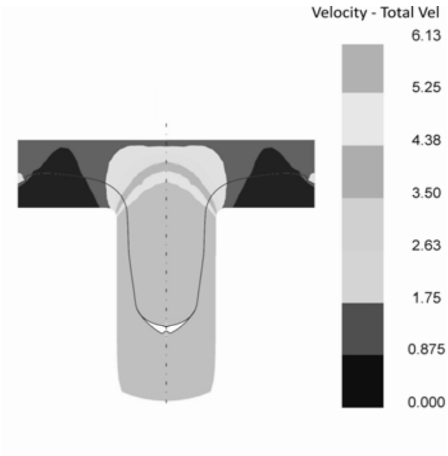


Fig. 5. Velocities of the joined cylindrical billets while forward extruding

In order to the flowing materials streams equalization, the numerical model for forward extruding of cylindrical objects with using the punch with a toe is proposed. After partial extruding of the lower billet (fig. 6a), it is attached to the process initially formed an upper one (fig 6b).

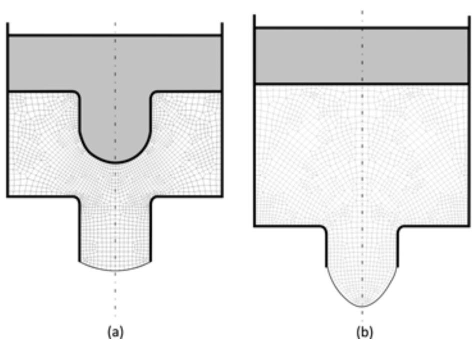


Fig. 6. a) forward extruding of the lower billet with use the punch with a toe; b) initially formed upper billet

Image of the joined billets flow nets shows a greater proportionality in materials flow (fig. 7). The size of the void is also markedly reduced, which favorably affects in the strength of the weld.

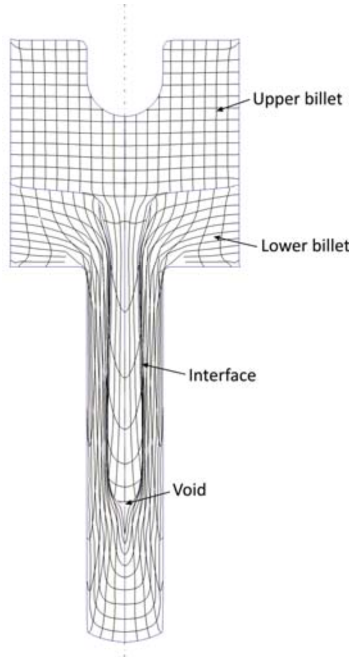


Fig. 7. Deformation of the initially square flow nets of the joined billets

From the welded billets velocities distributions (fig. 8) it can be read that joining begins in the container, out of the die influence. The characteristic shape of the punch causes, that both billets have the same velocity at the interface throughout the duration of process.

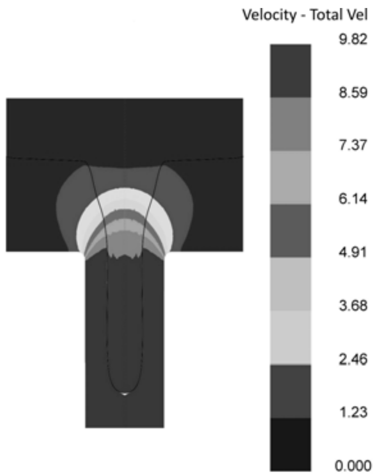
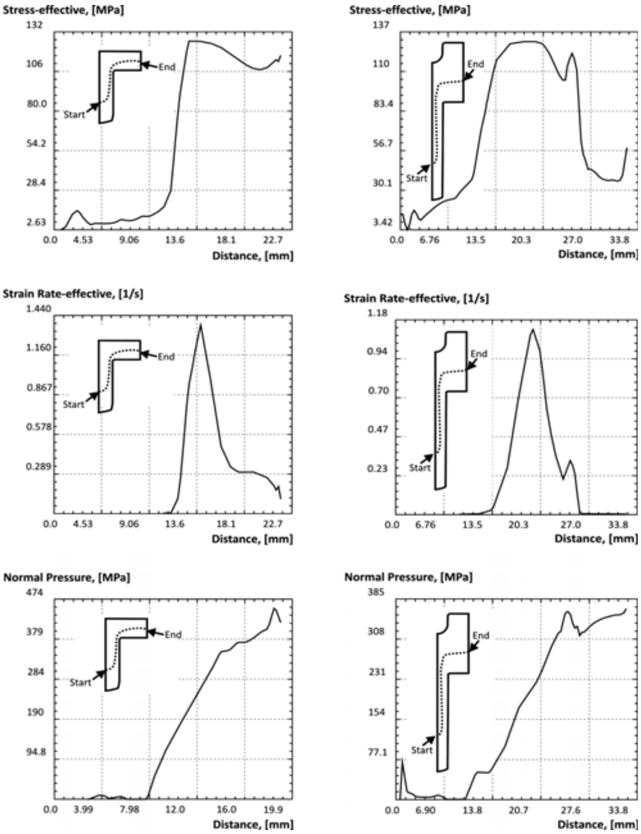


Fig. 8. Velocities of the joined cylindrical billets during forward extruding with using the punch with a toe

Welding parameters at the interface, for the case of extrusion with use a flat punch and for a punch witch a toe are similar (fig.9). However, during extruding with using the punch with a toe, a combination of the transverse and longitudinal joining appears. That increases the time of the material particles presence in the large normal stress area, increasing the quality of the joint.



(a) (b)

Fig. 9. a) Welding parameters at the interface of the joined billets with using a flat punch; b) Welding parameters at the interface during the extruding with using the punch with a toe

3. Conclusions

Welding of cylindrical billets during forward extruding with use a flat punch is characterised by an irregularity in a streams flow and by large size of the void. These drawbacks can be eliminated by applying the stamp with a toe and initial formation of the upper billet. Material layers situated in vicinity to the interface of joined objects have the same velocity throughout the flow in this case. The application of this method allows to get better results, because of the fact, that both schemes of transverse and longitudinal welding appears in this case. Combination of two welding schemas gives the product, which has a core made of material from the upper billet and external layers from the lower billet.

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