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Theoretical analysis of quality of composite rod extrusion process

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In the article analysis of extrusion process of bimetallic rod was done. Round, two-layered rod made by explosive cladding of the aluminium rod (A1) and copper pipe (M1E) with appropriate chosen geometry was treated as a charge to analysed process. In the work influence of die shape and volume fraction of particular layers on a charge yield in the process was investigated. Theoretical analysis was prepared using commercial packet Forge2® based on FEM.

1. INTRODUCTION

The extrusion process is characterized by many advantages which are not appeared in others processes of plastic working like rolling or drawing, the general state of compressive stress with one elongate strain, which characterize the extrusion process, it is the state, which caused the highest plasticity of deformed metal. Therefore extrusion process can be applied to deform metals and alloys with low plasticity.

Authors were made several works connected with the research of character of metal flow during simultaneous extrusion of components of different materials with different thermo-mechanical properties [1,3,4]. A quality in this work is represented by amount of charge yield from extrudate.

2. SUBJECT OF RESEARCH

The goal of this work is determination the influence such variables like shape of die, percentage fraction of cladded layer and extrusion ratio on percentage of charge extruded product yield which is counted as a sum of lengths: good quality, nose crop and tailcrop related to length of good quality section related to whole length of extrudate (Fig.2). Bimetal samples were made by explosive method (outer layer is represented by copper) and treated as charge materials. In the investigation the following parameters were taken into consideration (Table 1).

Table 1. Dimensions of sample and parameters investigated in the work

	D_b diameter of charge [mm]	A_{Cu} percentage fraction of copper layer [%]	λ Extrusion ratio	L length of material charge [mm]	α half die angle [°]
1.	10	25; 50	2; 5	20	30; 45; 60
2.	14.4	15	3	40	30; 35; 40; 45; 50; 55; 60
3.	44	10	10	40	30; 35; 40; 45; 50; 55; 60

Composite billet for computer simulation of axisymmetric extrusion process was composed of a 99.5% pure aluminium core (EN AW-1050A according to PN-EN 573-3:1998 Norm) into an electrolytic copper clad made of E-Cu58 according to DIN Norm.

Computer simulation process of extrusion was realized in initial temperature 20°C both composite billet and die, the stress-strain curves for both materials were obtained by the compression test at room temperature based on the material data (Fig.1), the experiments were preformed at a constant punch velocity of 1 mm/s in all cases.

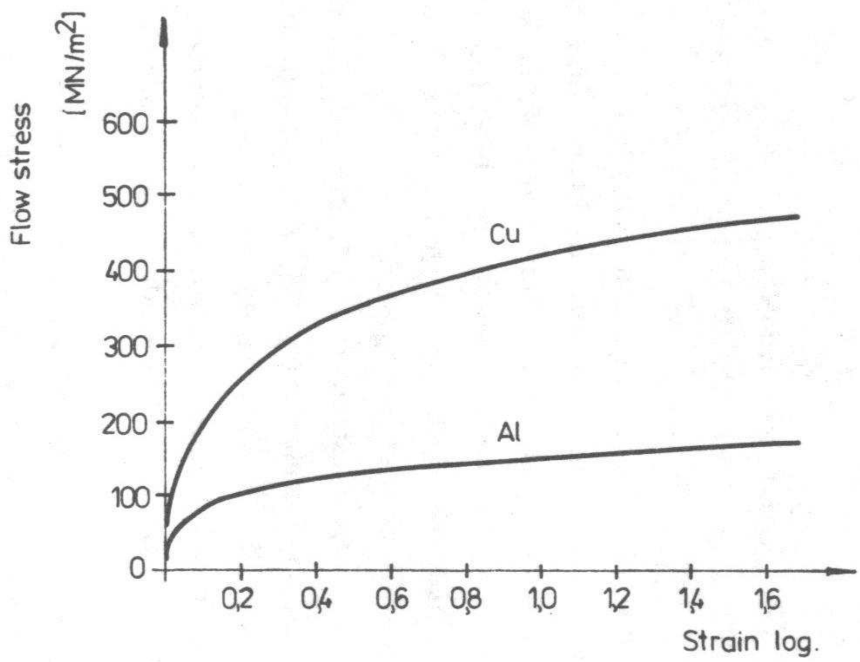

Figure 1. Stress-strain curves for copper and aluminium [2]

For the sake of different reological properties of composite materials, nature of bimetal charge flow phenomenon is considerably different then single material. Flow stress ratio σ_{Cu}/σ_{Al} equals 3.

Particular stages of composite Al/Cu flow are presented in figure 2.

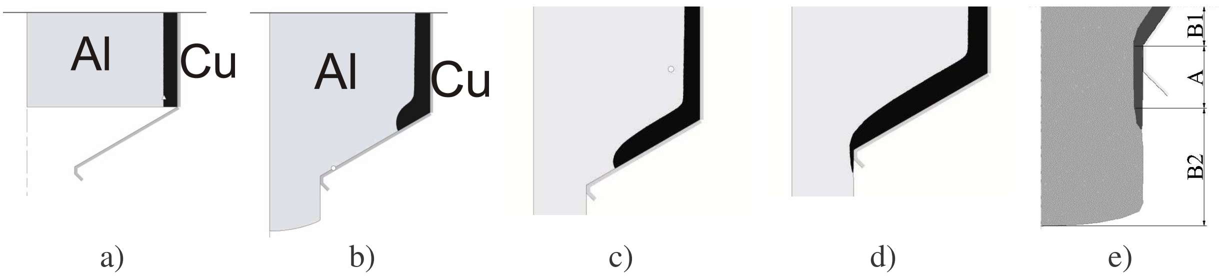

Figure 2. Stages in metal flow during the extrusion process of composite rod Al/Cu in deformation zone where A – length of rod with a good quality; B1 – length of nose crop; B2 length of tailcrop

How it can be seen in figure 2, nonhomogeneity of bimetal layer flow velocity is decreasing near die wall because of friction forces and additionally because of increasing the resistance to flow (outer layer is represented by copper clad). In figure 2e characteristic quality sections of extruded product were marked. In the process of extrusion charge yield is important economic value which conditions profitability of production.

3. TEST RESULTS

In figure 3 the influence of die shape on charge yield is presented. In the work three cases were analysed (see Table 1). Only for the first case the diagram was shown. As it is presented in figure 3 shape of die (die angle) has insignificant influence on charge yield. Only for 15% fracture of Cu (outer layer of composite rod) there is a difference, for 45° half die angle the charge yield equals 81% and for 30° and 60° equals 76%. And for 50% fracture of Cu the charge yield equals about 80% in all shape of dies. In case 2 and 3 (Table 1) are even smaller and charge yield equals exactly 88% for case 2 and 18% for case 3 for all investigated die shapes.

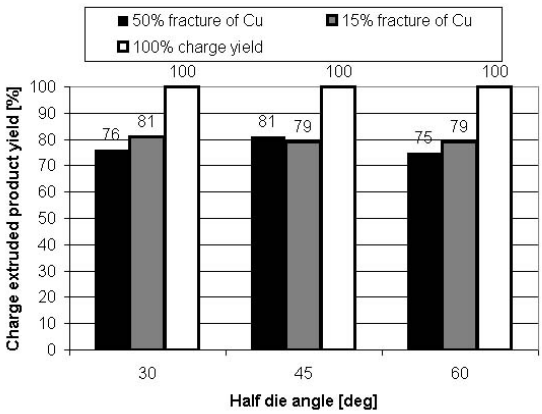

Figure 3. Influence of die shape on percentage charge extruded product yield

In figure 4 the charge yield was related to length of tailcrop which variable is more proper for different values of extrusion ratio. How it can be seen below the differences in length of tailcrop are tremendous. In process with extrusion ratio equal 10 the length of good product is only 30 mm for 170 mm long extrudate.

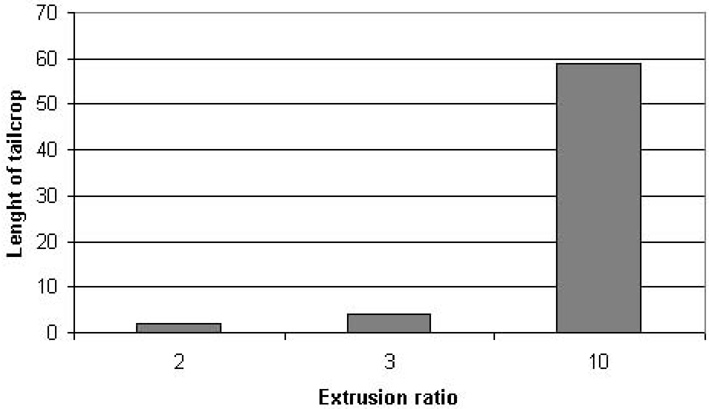

Figure 4. Influence of extrusion ratio on length of nose crop

4. CONCLUSIONS

Presented results allow to draw the following conclusions:

- the best case to extrusion bimetal rods with economic charge yield is observed for case 3
- with increasing extrusion ratio from the value 3 the fracture of charge yield is significant increasing
- shape of die as well as fracture of harder layer have low influence on the charge yield.

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