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Experimental Modeling to Facilitate Removal of Inclusion Contaminants from the Contact Surface in Transversal Extrusion Processes

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Abstract

The paper presents experimental optimization of geometrical conditions regarding the shape of billet's end pieces in the extrusion process of aluminum alloys. The experiments were performed using appropriately pre-treated plasticine as a substitute material. A special test stand was built using a Plexiglass die in order to make it possible to conduct observations and measurements of the modeled contamination surface. To find the best solution, a great number of shape variants of the billets and of their heating temperatures were experimentally analyzed. An attempt was made to find such a solution that could not only resolve the issue of the removal of contaminants from the contact surface of the pre- heated billets but also develop the least complicated technology of billet fabrication. The test results show how to develop the design process and production technology and also offer advice how to improve the quality of the produced profiles. Finally the authors recommend such a shape for the billets that will ensure effective removal of contaminants from the contact surfaces.

Keywords: Innovative Foundry Technologies and Materials**,** Transversal Extrusion of Aluminium Alloys, Experimental Modelling, Optimal Shape of Billet, Inclusion Contaminants

1. Introduction

The extrusion process can be assumed to be a continuing procedure in which billets of specified size and shape are fed one by one into a die. In the process they undergo welding [1, 2, 3]. The most common fabrication flaws are manifested in finished products as a result of structural changes in the material – there is a possibility of forming a fine-grained structure [4, 5].

The changes observed in the contact zone include numerous contaminants in the form of slag, oxides and blistering gas [6]. It is almost impossible entirely to eliminate the penetration of oxygen and nitrogen into the weld zone. In addition to the practical aspect of the problem, there is an important technological aspect, namely preparation of the right shape of billets and considerable time required by this process. In our model studies the following two aspects were taken into account: the right shape of billets to ensure maximum removal of contaminants from the contact surface during the extrusion process and the impact of the plastic flow kinematics on the welding process (elimination of the product's defects mainly caused by cracks in the billet's contact zone). [13, 14]. On the basis of the literature data [3, 4, 10, 11, 12], and the research conducted by the authors, it was possible to draw conclusions regarding the best possible technological solutions for the shape of the billets.

2. Experimental modelling and substitute material

Special modelling experiments using a substitute material were devised and carried out. After a number of tests with several modelling materials, plasticine with or no rape oil was selected as the best substitute due to the similarity of its characteristics at room temperature to that of aluminium at extrusion temperature [15]. Plasticine also makes it possible to analyze three-dimensional flows using modern visualisation techniques. For hot aluminium alloys the constitutive relation, i.e. the relation between equivalent stress σ_i and equivalent strain rate $\dot{e}_i$ can be approximated by:

$$\sigma_i = C \cdot \dot{e}_i^m \qquad (1)$$

where:

σ_i – actual yield stress [MPa],

$\dot{e}_i$ - strain rate [1/s].

The criterion of similarity assumes that exponentials m of real and modelling material must be equal. The values of constant C may be different. Additionally, the kinematics of plastic flow of the substitute material must be congruent with the real material. Compatibility of flow kinematics, when using plasticine as a substitute material, was confirmed in several experiments [11, 12, 14].

The test specimens were prepared in the shape of a parallelepiped made of homogeneous plasticine, the outer dimensions of the specimens being 200mm long, 80mm wide and 20mm thick. The end pieces of the specimens were rounded with radius R = 50 mm. Also, the contamination zone was modelled by inserting a piece of green coloured plasticine between the contacting billets to be clearly visible in the experiments.

The simulation of the degree of billet 's heating temperature was effected by mixing plasticine with an addition of rape oil. The addition was not bigger than 10 % of the whole volume of the specimen. A square grid on the face of the specimens is very useful for kinematics of plastic flow analysis. The deformation of the grid has been recorded with a camera and then processed on a computer to obtain a distribution of the flow velocities.

3. Experimental stand

In order to remove the contaminants in the form of slag and oxides an experimental stand shown in Fig 1 was used. The stand makes use a plastic flow model compatible with the transverse extrusion process in which plastically deformed material flows freely through the two openings measuring 20 x 20 mm in cross section. A transparent faceplate made of Plexiglass made it possible to supervise the flow and additionally visualize the process. Various options concerning the actual shape of the billet's interfaces were investigated. Apart from the variants related to the geometry of the billet's contact surface i.e. flat-flat or flat-rounded variants, configurations modeling the impact of the difference in the degree of billet's heating temperature (soft-hard) or no temperature difference were analysed. Furthermore, to carry out the kinematic analysis of plastic flow, the specimen surfaces were covered with square grids to investigate node displacements and deformations of the grid structure. This aspect of the research was concerned with solving the problem of a durable weld.

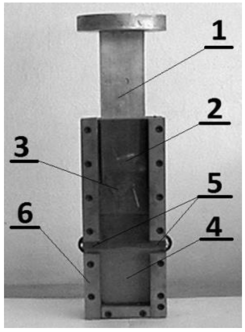

Fig. 1. Experimental stand: 1 – ram, 2 – plexiglass plate, 3 – top billet, 4 - bottom billet, 5 – channels, 6 - brackets

4. Results

A great number of experiments were conducted to analyze the influence of the shape of the billet's end on the contaminant removal methodology from the contact zone in transversal extrusion process.

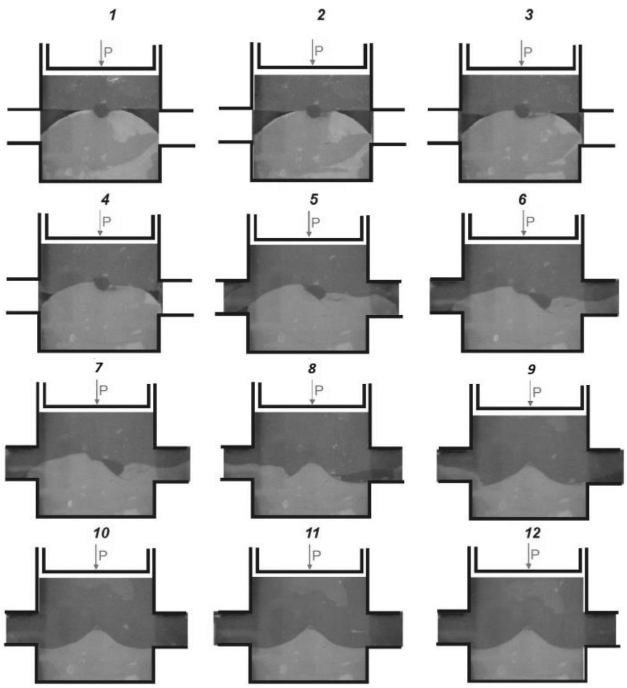

Fig. 2. Modelling of pollutant propagation into billet's contact zone (billet's material: "soft – soft", shape of end pieces: top flat, bottom – rounded R = 50 mm), ram speed: v = 5 mm/s

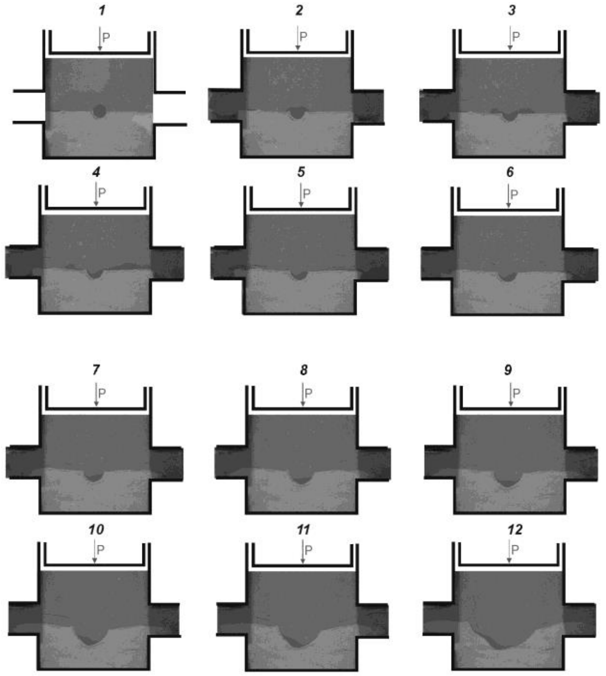

Fig. 3. Modelling of pollutant propagation into billet's contact zone (billet's material: "soft – hard", shape of end pieces: both – flat, ram speed: v = 5 mm/s

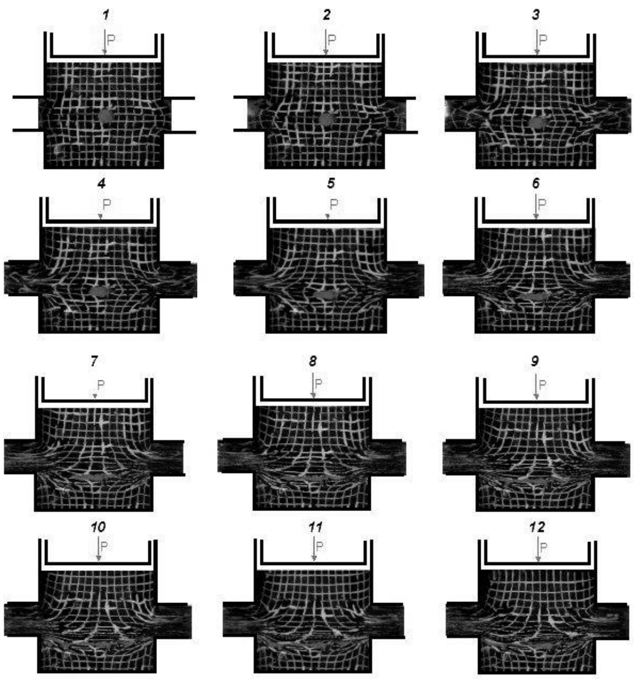

Fig. 4. Modelling of pollutant propagation into billet's contact zone and the kinematics of plastic flow(billet's material: "hard – hard", shape of end pieces: both – flat, ram speed: v = 5 mm/s

The influence of the shape of billet's end pieces on the removal process of contaminants is shown in Figs. 2. and 3. Additionally, a configuration type "soft-hard" (Fig. 3.) is used to reflect the degree billet's initial pre-heating. The method of assessing the differences of material characteristics is described in Section 2 of this paper. The tests were conducted at the ram's speed v = 5 mm/s.

Fig. 4 shows a sample analysis of the kinematics of the plastic flow during the displacement of the modeled contamination zone. The images of the deformed grid in the configuration with both end pieces flat, clearly show the difficulties of removing the contaminants and illustrate the deformations characteristic of transversal extrusion.

5. Discussion of the test results

Test results given in Section 4 present the problem of modeling the influence of the shape of the billet's end pieces on the kinematics of plastic flow and the process of creating a permanent weld. In addition, the process of the removal of contaminants from the contact zone is analysed. The test results are presented for some selected variants concerning the shape of the billet's end pieces and also temperature differences of adjacent billet parts as well as the influence of the degree of heating on the contaminant removal method from the contact zone. The presented figures illustrate the simulation of the removal of inclusion contaminants depending on the initial geometry of billet's end pieces and variants of heating.

As mentioned earlier, the objective of the analysis was to find the optimal variant which is understood as the one that provides such conditions of deformation kinematics that will ensure the removal of contaminants while at the same time make it technologically uncomplicated to prepare the desired shapes of the billets.

By analyzing the process of removing contaminants from the contact zone, it is essential to reject the variant shown in Fig. 2. Both of the billets in conjunction with varying degrees of heating cause the closing of the contact zone and the inability of the propagation of contaminants and oxide layer. Also a variant with flat end pieces but no difference in the degree of heating fails to bring the expected good results in the form of removing contaminants from the contact zone (Fig. 4.).

The above observations lead us to one major conclusion, namely that the flat end pieces although the simplest to make and, as a result, the most advantageous from technological point of view, fail to eliminate the phenomenon of contamination zone closure and cause difficulty in removing it. The most favourable results are illustrated in Fig. 3. In considering the described variants, it should be stated that the best solution is the following option: the top flat piece and bottom convex piece. Making an evaluation of the suitability of a particular variant, apart from the experimental model, we examined the kinematics of plastic flow and theoretical descriptions of the problem. [10 ÷ 12]. The variant, in which the top billet's end piece is flat and bottom billet's end piece is convex, creates the best configuration for the removal of both contaminants and oxides. It is also advantageous from the technological point of view. After closing the free zone between the billets, we can also observe a favorable picture of deformation that makes it possible to obtain a durable weld.

6. Conclusions

Experimental modelling using plasticine as a substitute material have resulted in choosing an optimal variant for the transverse extrusion process. Direct application of the test results to the manufacturing process should improve not only the quality but also the strength of the profiles obtained during the continuous extrusion process. It was found that the interface parameters could be significantly improved, provided the proposed design solution to remove pollutants from the billet's interfaces was used. This removal during the transverse extrusion process may be facilitated by creating billet's end pieces with optimal shapes. The configuration: top billet's end piece flat - bottom billet's end piece convex, is not technologically complicated.

For the process concave shape of press disc is required. This shape is pressed on top part of the billet when the extrusion process is stopped. Next a standard billet with flat end pieces must be loaded into the container.

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