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Application of Pressure Treatment Methods for Solid Processing of Silumin Chip Waste

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Abstract

In this article various technological schemes for processing waste in the form of chips of an alloy of an aluminum-silicon system are presented. It was noted that the processing of fine waste of the chips type is always accompanied by oxidation of the metal due to the large surface of contact with the air. To eliminate the loss of metal into oxides during re-melting, this study proposes processing chips by pressing to obtain briquettes (a method of hot extrusion is meant by 'pressing'). Processing involves the receipt of briquettes from rods. The processes of cold and hot briquetting were undertaken separately. The results of applying the scheme using real production waste are presented in this study. The tensile strength achieved was up to 270 MPa. The relative elongation to rupture was 10–25% and the area reduction after rupture was 25–45%. There were no large differences in the use of briquettes obtained by cold processing and hot processing. The conclusion is drawn about the overall effectiveness of the application of the waste processing without the use of the metal melting.

Keywords: silumin, shavings, extrusion, plastic deformation, heat treatment.

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1. Introduction

Two fundamentally different approaches are possible in solving problems aimed at finding and implementing the most effective ways of involving in the production turnover of bulk chip waste from aluminum alloys. The first, traditional, is based on their remelting in a free-filling or briquetted form, i.e., bringing it to a state of melt. The negative sides of this method, associated with significant surface oxidation and increased metal waste, lead to large losses; therefore, chips as secondary raw materials are the least valuable component of the charge [1, 2].

Another more promising in our opinion approach, implies a complete rejection of remelting of chip waste and consists in incorporating into the general technological scheme for their processing separate methods of powder metallurgy and pressure treatment, in particular, briquetting, hot extrusion and cold drawing operations [3, 4].

In this case, briquettes made of chips with a certain degree of conventionality can be considered as a kind of workpiece for producing press products and wire by traditional methods using standard equipment.

2. Research Methods

In this study, this approach was tested in relation to the processing of high-quality bulk chips of silumin AK12 produced during the machining of alloy wheels billets, manufactured at one of the enterprises included in the RUSAL holding. In general, the proposed technological scheme, which reflects the main stages of the manufacture of bar-wire products, is presented in Figure 1. At the same time, two ways of implementing the briquetting operation were considered at the stage of compacting chips into briquettes: cold, which was carried out at room temperature, and hot, which was carried out with pre-heating the mold together with the chips to a temperature of about 400 - 420 ° C.

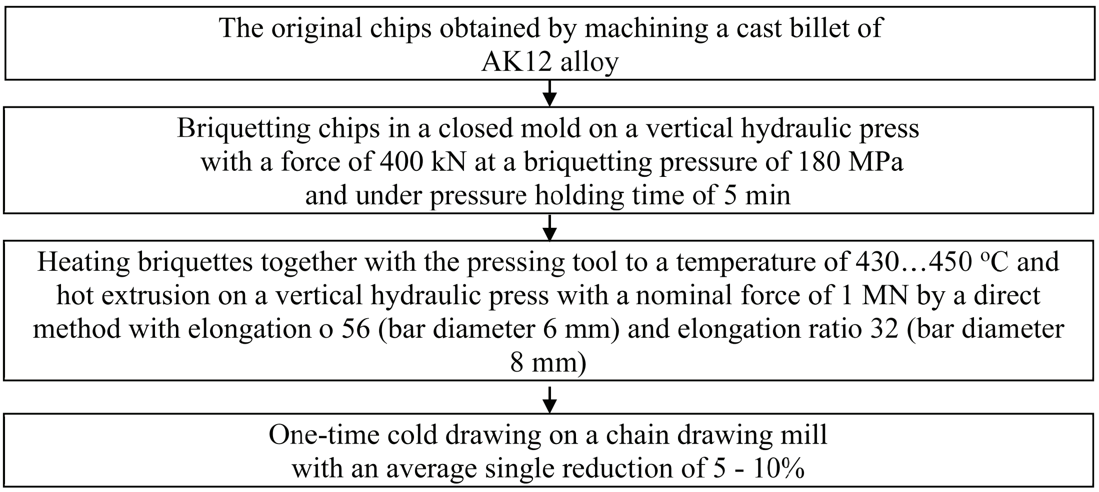

Figure 1: Technological scheme for the manufacture of bars and wires of circular cross-section from silumin chips using a traditional discrete extrusion scheme.

The purpose of the study was a phased comparative analysis of the mechanical properties of bar-wire products, obtained as a whole using a single approach to its manufacture from shavings of AK12 alloy (a general view of it is shown in Figure 2, a) in one case of cold-briquetted (see Figure 2, b), and in another - from hot-pressed (see Figure 2, c) briquette blanks.

Previously, experiments were carried out on briquetting the specified chips in a closed mold at different briquetting temperatures. Each time, the weight of a sample of chips was about 100 g. The diameter of the container was 42 mm. The maximum applied briquetting pressure was taken to be 180 MPa, holding at this pressure for 5 minutes.

a b c

Figure 2: Appearance of chips of AK12 alloy (a), cold-briquetted (b) and hot-pressed (c) briquette blanks.

In the course of briquetting and at the end of it, the value of the current and final integral density of briquettes was determined. The density values depending on the temperature and briquetting pressure are shown in Figure 3. It can be seen that these dependences, built in the temperature range from 20 to 400 ° C, are almost linear in nature, with some tendency to decrease in the compaction intensity with increasing briquetting temperature.

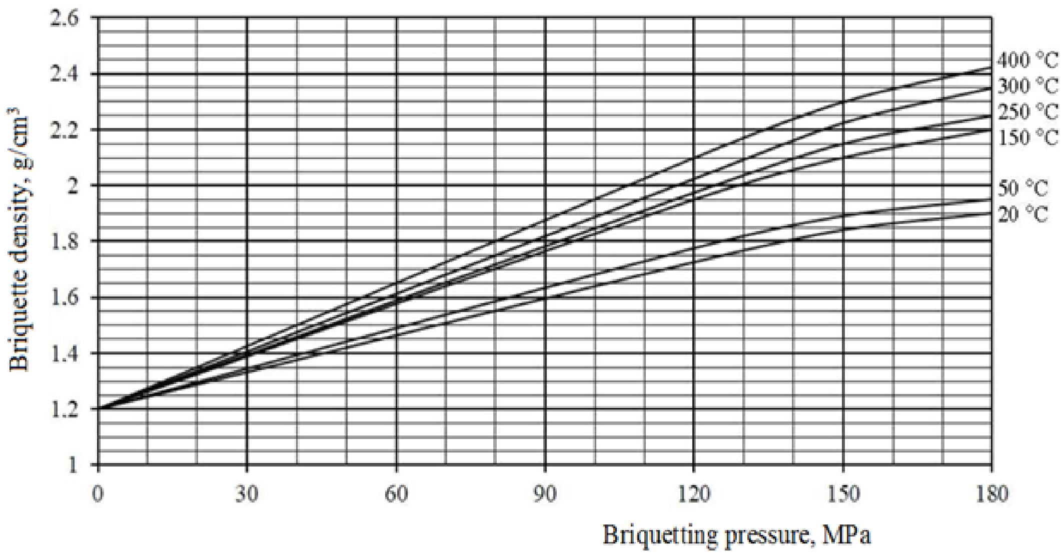

Figure 3: The dependence of the briquettes density on the briquetting pressure at different temperatures of briquetting.

It was established that the initial density of briquettes used for the manufacturing of rods depends primarily on the selected temperature and power conditions for the briquetting operation. With a decrease in the initial density, the time period before the outflow of the metal from the die increases, which is explained with the presence of a preliminary compaction stage.

In this case, it is important to take into account the amount of chip mass used. With its increase, the heterogeneity of the study increases when briquetting the entire volume of the compacted mass. A situation may arise that the applied pressure in the lower layers will be so small that compaction will not occur. The permission for such a sequence can be the use of a composite consisting of several parts of a briquette during hot extrusion. Only the length of the working sleeve of the container and the maximum developed force of the used press in this case will limit the total height of such a briquette.

The realized temperature-and-speed extrusion mode using both solid and composite briquette blanks obtained by both cold and hot chip briquetting remained unchanged. It corresponded to the parameters recommended for the hot pressing of rods from hardly deformable aluminum alloys, i.e., when the workpiece heating temperature was 430 - 450 °C, and the pressing speed 5 - 10 mm/s.

It is possible to ensure isothermal conditions of deformation during the extrusion of aluminum billets, including highly porous, i.e., the equality of the heating temperatures of the tool and the deformable metal. In the experiments, grease in the form of a mixture of graphite and oil was applied to the contact surfaces of the briquettes and heated together with tooling. For this, we used a unit equipped with a special stationary heating device.

For extrusion, bars with a diameter of 6 mm were obtained in pairs (the elongation ratio 56) and 8 mm (the elongation ratio 32). After extrusion, the front weakly deformed end with a length of about 80–100 mm was separated from the obtained rods. Next, one of the two pressed rods of each diameter, which were also obtained from billets of different types (solid or composite), went to the manufacture of samples for mechanical tensile tests.

In this case, individual fragments, from which they were machined, were taken from different places along the length of the bar. Other rods obtained under conditions identical with the former served as blanks for subsequent cold drawing.

Tensile tests were carried out according to GOST 10446-80 on a universal testing machine LFM 400. Dumbbell-shaped samples with a ratio of the dimensions of the working part length/diameter = 5 were made from press products and drawn rods with a diameter of 5 mm or more.

Fragments with a working length of about 50 mm were selected from a wire with a diameter of less than 5 mm. The entire course of the test was displayed on the display screen and, in the end, was formalized by the corresponding special protocol. Three samples were taken for each point, and their average values were taken as the result when determining the tensile strength, relative elongation and reduction area.

Subsequent cold drawing was carried out on the CVS-3 chain drawing mill along the following routes (arrow shows change in wire diameter by drawing transitions, mm):

a) 8 mm → 7.5 mm → 7.2 mm → 6.6 mm → 6.0 mm;

b) 6 mm → 5.7 mm → 5.4 mm → 5.0 mm.

The obtained semi-finished products were annealed upon reaching the final diameters of 6 and 5 mm using a single mode (temperature 400 ° C, time 1 h).

Analyzing the results, we can draw a number of conclusions.

The level of properties of bar-wire products from AK12 alloy shavings in the range of diameters from 5 to 8 mm is not fundamentally influenced by the way, by cold or hot briquetting, the briquette is formed, and what bar diameter is laid during the hot extrusion process.

So, for example, in a bar 8 mm in diameter, obtained with a drawing coefficient of 32, the strength, regardless of how the briquette is formed, is at the level of tensile strength of 160 - 175 MPa, and elongation is at the level of 15 - 20% and area reduction of 25 - 40%.

An increase in elongation ratio at extrusion to 56, corresponding to a decrease in the diameter of the extruded rod to 6 mm, causes a slight increase in the strength of the material. However, a significant change in the mechanical properties was not practically observed. This indicates the comparability of the state of the material of the pressed rod in the considered range of changes in the degrees of deformation during extrusion.

Additional cold working, as can be expected, causes an increase in the strength of the bar material with a simultaneous decrease in ductility. Moreover, the higher strains during drawing, the more these features of the change in properties, are manifested especially with regard to strength.

In particular, for example, with a total elongation of 19%, the tensile strength is of 210 - 230 MPa, and at elongation of 44% the strength is of 240 - 270 MPa. In this case, the relative elongation decreases to values of 2 ÷ 5%, and the area reduction to the values of 10 ÷ 20%.

Thus, we conclude that to obtain a wire with a diameter of 2 - 3 mm (such dimensions are recommended according to the technical specifications TU 1-808-274-2003 for welding wire from AK12 alloy), it is necessary to introduce into the general scheme for its manufacture as an intermediate technological and final operational annealing.

The experiments supporting these statements showed that after annealing according to the aforementioned regime at diameters of the order of 5…6 mm after cold deformation with elongation of 31% and 44%, respectively, the wire strength decreases to the level of 155 - 175 MPa, and the ductility on the contrary, it rises to the values of 10 - 25% and 25 - 45%.

The upper limits of these indicators correspond to products obtained from a cold-compacted preform-briquette, and the lower ones - from hot-pressed.

There are other proposals for the processing of silumin chip waste, for example, using the rolling – pressing process [5, 6], the stress state assessment for which was performed in [7]. Thermal extrusion regimes need to be optimized, as noted by the authors of [8, 9]. Too low processing temperatures there is a risk of pores and cracks.

Summary

In general, the application of solid-state chip processing methods allows for solving the problem of the influence of aluminum oxides on the process of remelting fine-grained waste from aluminum alloys.

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