

THIXOFORMING PROCESS APPLIED TO ALUMINUM ALLOY ATSi5Cu1

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ABSTRACT: Thixoforming is a semi-solid process to obtain the thixotropic structure. The effective use of the semisolid process presumes good knowledge of the rnaterial behaviour.
The paper presents some experimental data about the thixoforming process applied to aluminum alloy ATSi5Cu1, very used in the Romanian machine building industry.
From many procedures for obtaining the semisolid slurry described in the paper, based on specialized literature [2, 3, 4] in particular, the accent is given to choose the mechanical mixture in the overheated mould until it reached the liquid alloy temperature.
The main results are based on reducing of stirring time for increasing the benefits of the new technology.
All procedures and results are described in the paper and also some specific conclusions are given.
The experimental data of the research, were obtained in the specific testing laboratory from Transilvania University of Brasov.
KEYWORDS: thixoforming, stirring, slurry, semi-solid forming.

1. INTRODUCTION

Processing of metallic materials in heat can be done starting from the liquid state phase (all casting procedures) or form the solid state phases (all procedures of plastic deformation).

With each of these procedures we can obtain pieces from metallic materials which includes technological elements from both techniques - casting and forging respectively [1, 4, 5].

The semisolid metal forming process (SSM) is developed like an efficient alternative of manufacturing parts to forms and dimensions more and more near to the final functional form, as result of the thixotropic behaviour, obtained by using special melting processes.

Forming in the semisolid state requires that the metal or alloy have a roughly spherical and fine grain microstructure in the moment when it enters in the forming die.

2. METHODS TO OBTAIN THIXOTROPIC STRUCTURES

As a result of the coexistence liquid + solid in slurry state, the metal has totally different properties respect to the solid state.

The forming stress of the metal in slurry state is very low. The forming stress depends on the liquid amount present in the metal and by reason of its appearance on the grains edges, the binding forces between grains are very low or even zero.

Consequently, the relative movement between the grains in slurry state can be easily realized. In conclusion it can be said that metal flow and forming is produced under low stress.

The solid state content f_s defined in percent, is an important parameter which express the state of slurry material.

When $f_s<80\%$ the slurry is consistent and easy to form and stirred.

When $f_s<60$ the slurry flow under gravitation force [8].

The slurry with a reduced solid content, can be agitated and mixed with other materials like: different metal powders, ceramic particles, graphite powder and so can be obtained diverse mixtures.

The metal in slurry state can be easily separated because of the low inter-grains binding forces.

Two slurry state metals can be easily combined thanks to the liquid diffusion phase of the two metals one each other and then their solidification together.

At present, there are seven basic methods which are used to obtain a thixotropic structure. These methods are:

- ✓ mechanical stirring;
- ✓ electromagnetical stirring;
- ✓ magnetohidrodynamichal stirring (MHD) in continuous casting, through vertical or horizontal stirring;

- ✓ ultrasonic stirring (which is not very efficient in obtaining thixotropic structure, but permit fine-grained microstructure);
- ✓ passive stining method;
- ✓ extrusion method;
- ✓ continuous casting with grain refining and PID process.

There are some other methods of producing billets with thixotropic structure by stirring: FIAT WEBER, ALLURES, STAMPAI, VIVEZ, etc. [6, 8].

It is found that the cooling rate of the melt during solidification under stirring is the most important factor influencing the microstructures of the billets [7, 8].

The average cooling rate T, during the continuous casting can be approximately expressed as:

$$T = \frac{\pi D^2}{4hA}(\mathrm{To} - \mathrm{Ts})V; \qquad (1)$$

where: T - is the average cooling rate;

h - the effective height of the melt;

A - the cross sectional area of the melt in the crystallizer;

D - the diameter of the billet;

V - the continuous casting speed;

To - the temperature when the melt enters the stining region ;

Ts-the solidus temperature.

The cooling speed influences the primary grains size; their sizes decrease ifcooling speed increase. In the same time, the amount of liquid between grains raise. The average speed of shearing stress has a very low influence on the primary grain size; if speed increase, grain size gets homogenized and they become better separated.

A thixotropic aluminum alloy, with a liquid phase content of 50 Yo, presents three major physic differences in comparison with the 100 % liquid, die-casting or obtained by squeeze casting process [6, 8]:

- A superior viscosity, even after fluidization through shearing stress produced during injection. This permits to inject of the thixotropic metal with relatively high speed, maintaining a laminar flow and so, realizing thinner parts respect to those obtained by die forming using liquid metal, having the same metallurgic quality: inclusion absence, thermal treatment and welding possibilities, high resistance and elongation values.
- Lower temperature - solidification enthalpy is almost twice lower. This permits the increase of productivity and service life of the dies.
- Lower solidification shrinkage - which reduces feeder difficulties, without a complete elimination of them. This gives to the parts special mechanic properties, if the defects like oxides or shrink holes are not present.

3. EXPERIMENTAL RESULTS

The technology used in our case for obtaining alloys in the semisolid state with globular structure goes through the following stages:

- heating the metallic alloy in the field of liquid or partially liquid phase;

- vigorously stirring the alloy until it reaches the temperature where the value of the primary solid is (50 ÷ 65) %;

- isothermal maintaining the alloy at the above temperature and continuing stirring;

The obtained composition can be casted in the semisolid state or isothermally maintained for further use, like: plastic deformation or casting.

To highlight better the results obtained after deformation in slurry state of the aluminum alloys, there was made a research program in which were gathered samples through more methods of processing in heat of the aluminum alloys, starting each time from the molten alloy and these are:

- samples obtained through free casting in metallic mould;

- samples obtained through free casting and stirring in a slurry state in metallic mould;

- samples obtained through deformation in slurry state in metallic mould after stirring.

There were used for experiments all types of measuring tests and the same laboratory equipment, like:

- electric furnace, used for melting of aluminum alloy and also for pre-heating the mould and the plunger die, used for making the samples;

- mould and plunger die, made from 40Cr10 steel, used for making the samples;

- crucible for melting, designed especially for standard size, made from cast iron painted inside with refractory paint based on graphite, in more layers.

With the same type of paint and in the same way, are painted the mould and the plunger die, before each use;

- for making the semisolid slurry, there was used a stillness steel wire with Ø 2 mm diameter, power driven by a mixer with a rotating speed of 180 rot/min.

- 200 kN hydraulic press;

- universal testing machine.

In the research programme were made several standard test samples, which were tested according to SR EN 1002-1/1995 and samples for making metallographic analysis for structure of the processed alloy.

From the many procedures for obtaining the semisolid slurry, were chosen the mechanical mixture in the overheated mould until it reached the temperature of the liquid alloy.

For each sample set, were made minimum 10 determinations and then, was calculated their arithmetic average.

Some experimental results are given in Table 1 and Table 2.

In Fig. 1, are presented the tensile strength diagrams for ATSi5Cu1 aluminum alloy, considered after three technological stages of evolution.

The mechanical mixture process for obtaining the semisolid slurry, gives a good opportunity for increasing of gases volume in the basic metallic mass of samples, with an increasing of porosity, which will affect a decreasing of mechanical characteristics values for the final pieces.

Table 1. Experimental data with elongation results.

Elongation (δ) / The procedure for obtaining the samples	Sample set No. 1	Sample set No. 2	Sample set No. 3
	[%]	[%]	[%]
For AT Si 5 Cu 1			
Free classic casting	1,95	2,10	2,15
Casting from semisolid state	0,1	0,6	0,53
Plastic deformation after casting from semisolid state	4,8	4,91	4,75

Table 2. Experimental data with tensile strength results.

Tensile strength (σ_r) / The procedure for obtaining the samples	Sample set No. 1	Sample set No. 2	Sample set No. 3
	[MPa]	[MPa]	[MPa]
For AT Si 5 Cu 1			
Free classic casting	140,1	131	120,3
Casting from semisolid state	105,7	115,3	113,8
Plastic deformation after casting from semisolid state	180,5	179,4	177,8

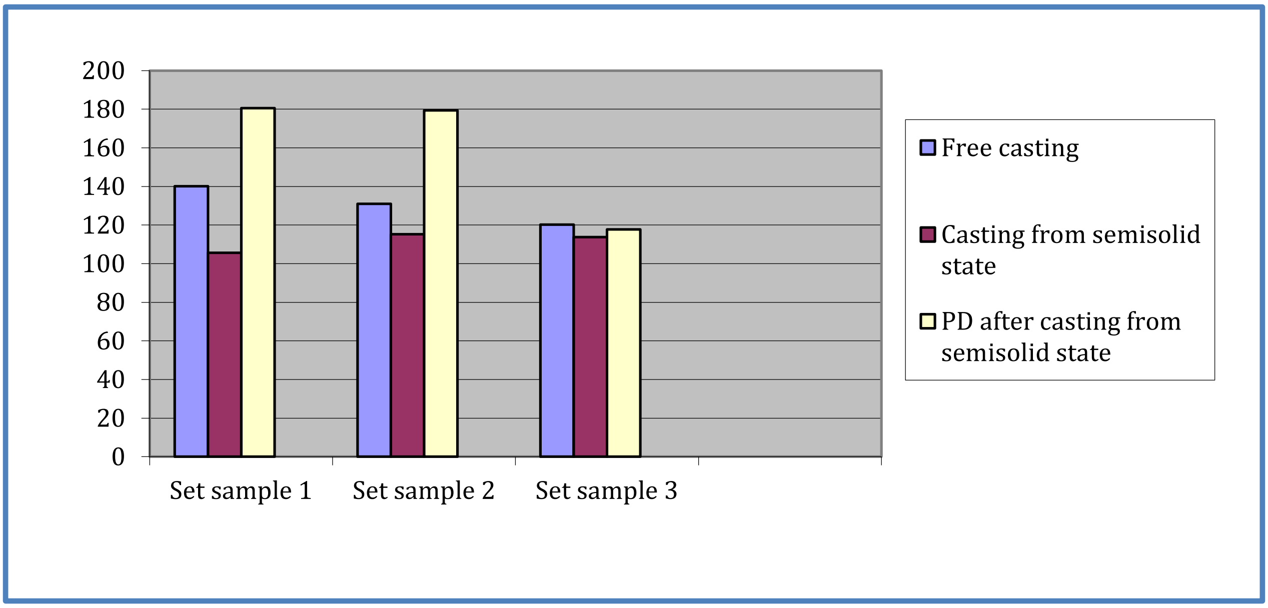

Figure 1. The tensile strength diagram – σ_r [MPa] for different procedures.

The metallographic structure for samples, made for the two different procedures for ATSi5Cu1 alloy, are presented in Figures 2 and 3 [9].

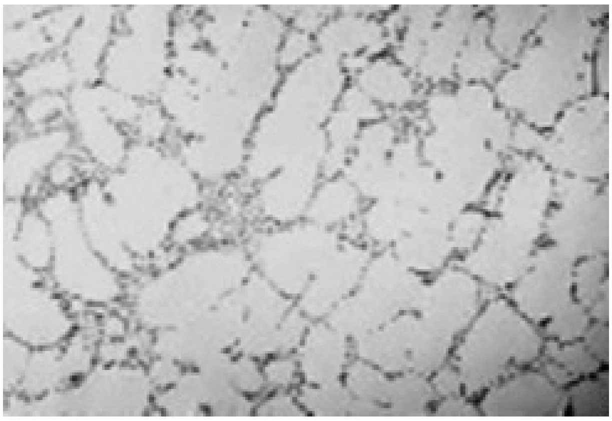

Figure 2. ATSi5Cu1 alloy free casted from semisolid state (x300) [9].

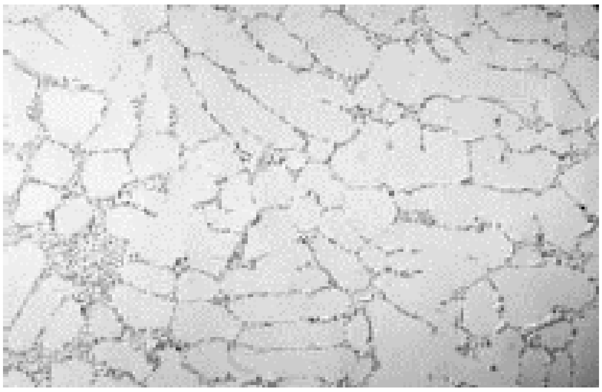

Figure 3. ATSi5Cu1 alloy plastic deformed after stirring (x300) [9].

4. CONCLUSIONS AND REMARKS

After analyzing the above data, we can conclude that the globular structure obtained by deformation in semisolid state, leads to obtaining some mechanical characteristics better than other procedures taken into consideration.

From a closer examination of figures 2 and 3, it can be observed that between the structures taken for study, there are a series of differences, and these are:

- firstly, the plastic deformed samples in semisolid state don't have micro-porosities, even if the necessary to deformation is small;
- the homogeneously of the structure of samples deformed in semisolid state is bigger than in the case of samples made through other procedures taken into consideration.

The values of the extent at breaking [5] in the case of deformation in semisolid state, are in average twice higher than the values obtained in the case of samples made by free casting and four times higher than in the case of samples made through deformation in semisolid state, structure which favorites the metal flow after certain directions.

The tensile strength resistance of the deformed samples in semisolid state is higher, in average with 25 % than in the samples made through casting in semisolid state.

Although the obtained structure is spherical in both cases: the casting in semisolid state and deformation in semisolid state, the better mechanical characteristics obtained in the case of samples made through plastic deformation after casting from semisolid state, can be explained by the high compact characteristic of the samples, obtained after pressing, so we can conclude that the technological process of deformation in semisolid state of the metallic materials, has a series of advantages, unlike the conventional procedures of processing in heat [9].

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