ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2005, Tome III, Fascicole 3

ASPECTS CONCERNING THE PROCESSING METHODS OF METALLIC ALLOYS IN THE SEMISOLID STATE

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ABSTRACT:
The paper shows some particularities of the die forging in semisolid state of the metallic materials, points out the advantages of using this process for producing the pieces and present a new method of semisolid processing in the semisolid state. Through this method, that is a variant of the Rheo-casting process, is eliminated the operations of pouring into the crucible and reheating for the homogenization of the temperature of the ingot, operations that consumes much energy and time.

KEYWORDS:
semisolid state, thixotropy, thixo-forming, rheo-casting

1. INTRODUCTION

The development and the realization of new materials, with better property and performances and with lower costs, and finding of new methods of processing, mixed or unconventional, that permit the obtained of the parts with highly mechanics characteristics, at low prices, constitute two the major aims of the metallurgical industry and of the materials processing.

Relative new classes of the forming technologies, which realize these qualities, are the techniques of processing materials in the semisolid state. Based on the student discovery from Massachusetts Institute of Technology (MIT), in the 70 years, these techniques of processing were used-up first in SUA.

Today, efforts for the development and implementation of these done on entire world because these offers many advantages as comparing to the conventional processing methods (casting in liquid state and forging, die-forging, stamping in solid state), advantages that come out of the behavior and characteristics of the materials in semisolid state. So, due to the heat content, lower than that of the liquid metal, high processing speeds can be applied, the wear of the deformation tools being lower. The presence of the solid during the filling of the die and the controllable viscosity, that is higher than that of the liquid metals, makes possible to reach parts with low blister cavities, with low macro and micro-segregation and with a fine micro-granulation structure. The gas capitation is also low, and the parts have an excellent surface quality. The materials in semi-liquid state have lower flow resistance than the material in solid state, which is why parts having complicated configuration and thin walls can be produced. The energetic consumption is lowered by approximate 35…40% as comparing to the conventional processing.

2. PROCESSING METHODS IN SEMISOLID STATE

The semisolid state processing as know, generally, two-development route: thixo-forming route and rheo-casting route.

The expression *thixo* comes from the word *thixotropy*, expression used by H. Freundlich in 1935, in order to define the property of the solutions and suspensions to gel formation when being in latent state and to become fluid when being stirred. The phenomenon is a reversible isothermal transformation, the denomination coming from the Greek word *tixis* – touch, contact and *tropos* – change, modification. So, the thixotropy means the capacity of modifying the body by contact, respectively by external mechanical influences: shocks, vibrations, stirring, shaking, etc.[1]

The basic principle of die forging in semi-liquid state is to produce parts within the solidification range of the alloy. Within this range, a part of the material is already liquid, while other parts are totally solid. In order to have a thixo-tropic behavior, the solid phase has to be made of spherical (globular) particles covered in liquid phase. This special microstructure can be reached by a certain stirring (mechanical or electromagnetic) during solidification.

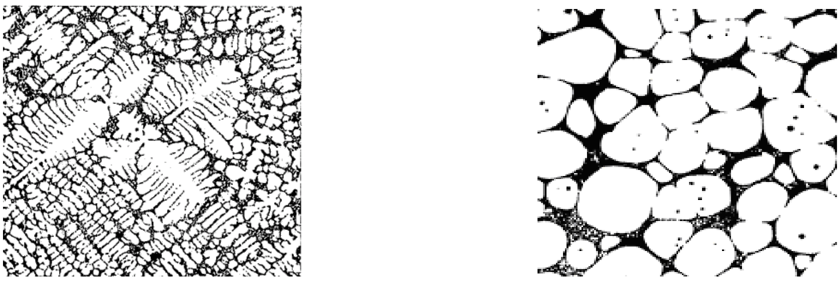

Fig. 1. The microstructures: dendritic (left) and globular (right) of an aluminum alloy [2]

Thixo-forming is the general used term for described of the obtained process of the final parts from the semisolid state materials, with a help of the metallic dies/forms and the top die. If the part is obtained in a metallic closed form, the method is called thixo-casting, and if the part is obtained in a open die, is called thixo-forging.

In figure 2 is presented a scheme of the thixo-forming process, where the processing stages are pointed out: elaboration and casting of the ingots (a), cutting of the ingots in the semi-finished products (b), reheating of the semi-finished products (c) and forming: through die-forging (thixo-forging) (d_1) or through casting (thixo-casting)(d_2).

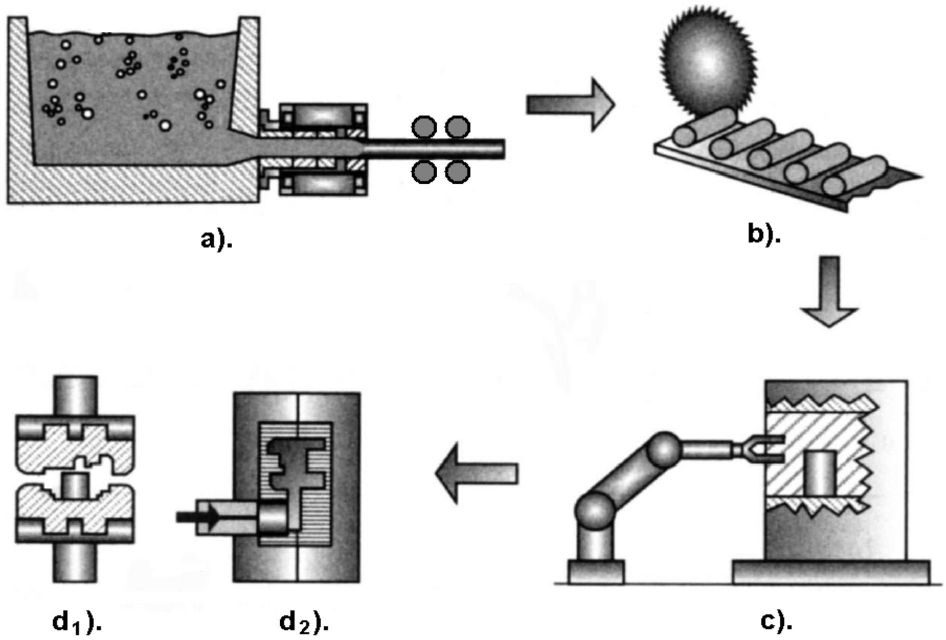

Fig. 2. The scheme of the thixo-forming process [3]

The elaboration and the casting of the ingots is an essential stage that makes the ulterior evolution of the processed material. In this stage is used the specific technologies that permits to obtain the microstructures which determine the thixotropic behavior.

The reheating of the semi-finished products up to the semisolid state is done, currently, with the induction furnaces, that guarantee a uniform heating, rapidly and exactly, necessarily for the material processed in the semisolid state.

Depending on the processed method, the temperature of the semi-finished material is adjusted for a liquid fraction between 30…60%. When the desired temperature is reached, the semi-finished products still remain inside the furnace in order to homogenize the temperature; in this time the solid particles will grow and the melting process takes place.

Depending on the homogenization time, the solid particles shall build a more or less coherent skeleton, resulting in a flow behavior that is a strong variable of the strength of the skeleton. This strength depends strongly on the concentration of the globular solid particles.

Is important to retain: the semi-finished material in the semisolid state keeps its shape during the homogenization period, although about half of the material is liquid. This shape stability is even robust enough to permit a transfer of the semi-finished material into forming tool (figure 3). When shear forces are applied to the semi-finished material does the solid behavior change to a viscous suspension flow. This structural viscosity, or pseudo-plasticity, is the main principle of the thixo-forming process; when sheared, the robust skeleton of solid particles is disrupted and the now isolated globular particles float in the viscous melt, resulting in much lower viscosities than the solid skeleton [4]. When rested after shearing, the inter-particle networks builds-up again, forming a skeleton what is comported as a solid.

Fig. 3. Material in the semisolid state, cuted whit the knife [2]

At present, thixo-casting through horizontal cold chamber die-casting is the dominant process. A robot arm transfers the semisolid semi-finished material into the shot chamber and the plunger injects the materials into the die cavity by a hydraulic ram.

The *Rheo-casting* is other route for development of the semisolid processing in the semisolid state. He is used, still from beginning of the researches like as the technology for obtaining of the material with non-dendrite microstructure for ulterior processing through thixo-forming. In 1996, is developed a new rheo-casting (NRC) process, which was patented by UBE Industries Ltd. In November 2000, the authors H. Kaufmann, M. Nakamura, H. Wabussey and P. J. Uggowitzer mention this new method in the *Diecasting World* magazine.

In the NRC process, as shown schematically in Figure 4, a slightly overheated melt liquid alloy (a) is poured into specially designed steel crucibles (b), which are placed on a carousel next to a vertical SQC machine. By controlling the material temperature (therefore solid fraction), a stable skeleton of the solid phase is formed within a few minutes after pouring. The solid-like slug of cylindrical shape is then heated by induction heating to homogenize the slug temperature (c) is inverted (d) and is transferred into the casting machine (e), where it is cast into its final shape.

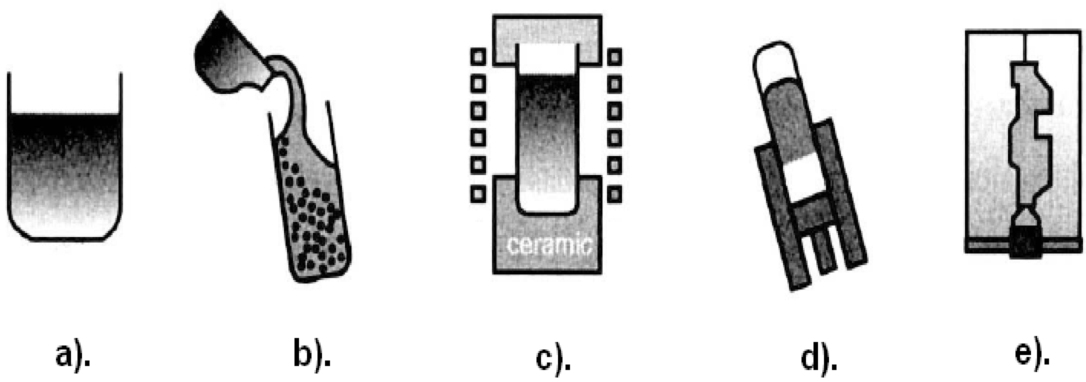

Fig. 4. The scheme of the New Rheo-casing Process (NRC) [5]

3. A NEW METHOD OF PROCESSING IN THE SEMISOLID STATE

Another method of the rheo-casting process is presented in scientific papers [6] and [7]. This method is proposed and studious of a collective from Faculty of Engineering Hunedoara. This method, whit **NRC-p** symbolization, is composed from the next stages: elaboration of alloy, alimentation of the mould with alloy and the mechanical agitation through vibrations and the forming in presence of the vibrations. Figure 5 presents a scheme of this method, where the processing stages are pointed out. With red arrows is symbolized the mechanical agitation of the material and the die.

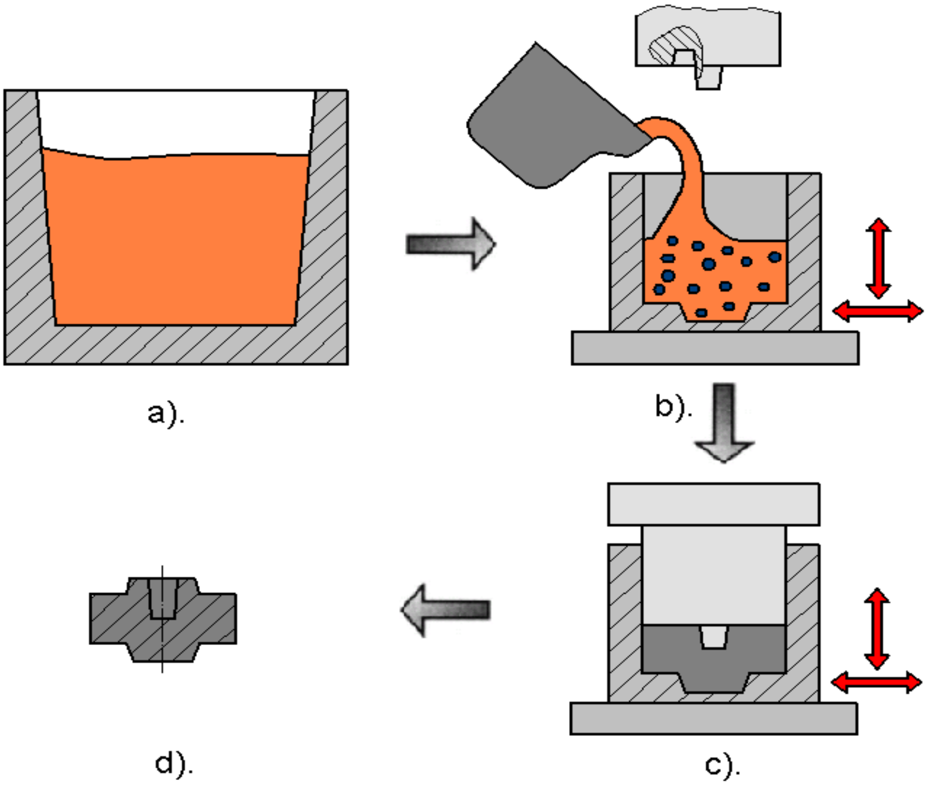

Fig. 5. The scheme of the new Rheo-casting method (NRC-p)
a) alloy elaboration, b) alimentation of the mould with alloy and the mechanical agitation through vibrations; c) forming in presence of the vibrations; d) finite part

Through this method (**NRC-p**) is eliminated the operations of pouring into the crucible and reheating for the homogenization of the temperature of the ingot, operations that consumes much energy and time.

Also, this method exploitation the advantages of plastic deformation in presence of vibration, because the vibrations influences, in the positive sense, the flow geometry, the friction between material and work tools and the physical – mechanical characteristics of the pieces.

The forming consist in apply of the mechanical pressure, with a punch or top die, that determine the filling of the die cavity and plastic deformation of the material.

4. REFERENCES/BIBLIOGRAPHY

[1.] FLOREA, J., s.a., *Dinamica fluidelor polifazice si aplicatiile ei tehnice*, Ed. Tehnica, Bucuresti, 1987, p. 62-64
[2.] SPENCER, S. B., *Rheological behavior of Sn-15 Pct Pb in the cristallization range*, Metallurgical Transactions 3, 1972, p. 1925-1932
[3.] GULLO, G. C., *Thixotrope Formgebung von Leichtmetallen - Neue Legierungen und Konzepte*, Diss. ETH-Zürich, 2001
[4.] KENNY, M. P., s.a., *Metals Handbook*, volum 15, American Society for Metals, 1988, p. 327-338
[5.] FLEMINGS, M. C., s.a., *Behavior of metal alloys in the semi-solid state*, Metallurgical Transaction A, 22A, 1991, p. 957-981
[6.] ILCA, I., CIOATA, V. G., *Cerere de brevet cu nr. A/00529/2004 pentru inventia cu titlul "Procedeu si instalatie de obtinere a pieselor prin matritare din materiale metalice semilichide"*, 2004
[7.] CIOATA, V. G., *Studii si cercetari privind matritarea metalelor si aliajelor in stare semilichida*, Teza de doctorat, Universitatea Politehnica Timisoara, 2004