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ANALYSIS OF IMPROVEMENT POSSIBILITIES OF ALUMINUM ALLOY GRANULATION THROUGH MICROALLOYING WITH RARE ELEMENTS

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Abstract: During the past 40 years, materials design has shifted emphasis to pursue light weight, environment friendliness, low cost, quality, and performance. Parallel to this trend, metal-matrix composites (MMCs) have been attracting growing interest. MMCs' attributes include alterations in mechanical behavior (e.g., tensile and compressive properties, creep, notch resistance, and tribology) and physical properties (e.g., intermediate density, thermal expansion, and thermal diffusivity) by the filler phase; the materials' limitations are thermal fatigue, thermochemical compatibility, and low-transverse creep resistance. Matrix composites of aluminum alloy reinforced with particles of TiB2 obtained method alumino-thermic materials are part of the future. Method It may be applied for obtaining in- situ the magnesium matrix composite – material ultralight outstanding physical and mechanical characteristics. In this study and report there have been analyzed the possibilities of achieving, within the contract, certain technological reproducibility conditions of the rare elements micro additions alloy granulation finishing and modifying process.
Keywords: granulation, non-ferrous alloys, aluminum alloys

1. INTRODUCTION

Modification is the process of artificial improvement of the structure of casted alloys. Metallurgic modification achieves structure change with the help of small additions in the liquid alloy. These additions, named modifiers, even in low concentrations, strongly influence the crystallization process, the way the structure is formed and the semi-products and casted specimen's properties.In certain situations, the modifiers increase the number of germs and therefore favor obtaining a fine-grained structure; in other cases they lower the speed of crystal growth, on certain crystallographic directions, and therefore change their shape and dimension.
Using modifiers in the case of non-ferrous alloys is determined by the following two phenomena:

= for most non-ferrous alloys the primary solidification structure is kept;
= metals and non-ferrous alloys have a higher tendency of high granulation crystallization when solidifying.

Pure aluminum and its monophasic alloys have a very high tendency toward forming high granulation structures when solidifying and also toward developing a broad columnar crystal area.
The modifiers used for finishing the structure (primary dendrites granulation) in the aluminum alloys are the substances which form insoluble and non-fusible particles which act as heterogeneous germination inoculants. Such modifiers are: B, Ti, Zr, Ta, V, Mo. Most of these elements give peritectic reactions with aluminum (base metal).

2. PROGRESS OF EXPERIMENTAL WORK

Aluminum is a light metal($r = 2.7$ g/cm^3), it melts at 660°C and crystalizes in CFC network, which provides plasticity and reduced mechanical resistance ($R_m = 8$ daN/mm^2, $A = 35\%$). In pure state it has high electric and thermic conductibility and corrosion resistance through compact Al_2O_3 film formation.
To improve mechanical or casting characteristics it is alloyed with Cu, Si, Mg, Mn, Zn. Aluminum alloys can be binary or complex, deformable (STAS 7608-80) or made by foundry (STAS 201/12-80), curable or not through thermic treatment.Pure technical aluminum (99.8%) has a dendritic casting structure with a reduced eutectic quantity ($Al + Al_3F$) at the limit of grains.
At concentrations of Fe > 0.4% aluminum fragility happens. After lamination the structure is polyhedral without mackles.Aluminum alloys for foundries must have high fluidity, relatively low contraction, low susceptibility for hot cracking and pore forming, properties characteristic to alloys which contain eutectics.From the foundry alloys we mention: Al-Cu, Al-Mg, Al-Si, Al- Zn si Al-Mg-Cu-Ni-Cr. Al-Cu foundry alloys are split between:

= Alloys with 4-6% Cu and low additions of Si, Mg, Ni, Mn, Ti;

- Alloys with 6-8% Cu and additions of Fe, Si, Mn, Cr, Zn siSn;
- Alloys with 10-14% Cu which contain up to 0.4% Mg, 1.5% Fe, 5% Si and low proportions of Ni, Mn, Cr.

Adding alloy elements has a purpose of improving mechanical properties and technological characteristics; Si improves casting properties and in the presence of Mg it makes possible applying hardening thermic treatments, Mg contributes to improving mechanical resistance properties, Ti finishes the granulation raising tenacity, Ni increases resistance to high temperatures, Mn improves mechanical resistance but reduces plasticity. Al-Cu foundry alloys, which contain 4-6% Cu because they lack eutectic, have reduced casting properties, instead alloys with over 10% Cu have very good casting properties, Al-Cu alloys are used to cast specimens which are mechanically stressed, used in building vehicles and airplanes, such as: drum brake, pistons, cylinder head, engine blocks.Al-Mg foundry alloys contain 1% to 13% Mg and some additional alloying elements: Si up to 2%, Mn up to 2%, Zn up to 3%, Li up to 3% and other elements such as: Fe, Cu, Cr, Ni, Ti, B, Be, Zr.

They have high mechanical properties, low density and corrosion resistance in saline atmosphere.The casting properties of these alloys depend on their Mn content. Manganese improves mechanical resistance and removes the negative effect of Fe over the corrosion resistance, Zn improves casting properties, Cu, Fe, Ni lower corrosion resistance and plasticity, raise refractory, Ti, Zr, B finish the granulation increasing tenacity, Be lowers oxidation susceptibility of melted alloys.Al-Mg alloys are used in the vehicle building industry, for casting specimens resistant to corrosion in the atmosphere, salt water and alkaline solutions, with the right mechanical resistance properties.

Based on primary structure characteristics which can be changed through the modifying process we can mention three modifying types or methods (technologies):

- Type I modification, consists of reducing primary grains dimension;
- Type II modification, consists of changing the internal structure of the primary dendritic grains, in the sense of ramification emphasis and increasing dendrites thickness. In this situation, even the secondary phase's distribution in alloy microstructure is affected, towards a more uniform repartition in between the dendrites;
- Type III modification, leads to a change of the morphology and finesse of the eutectic in the whole alloy microstructure.

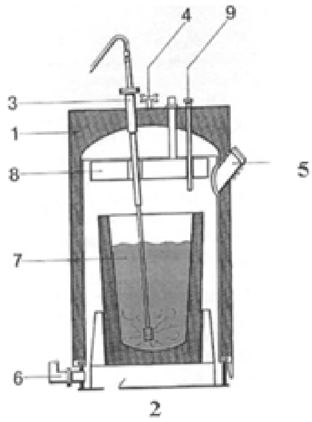


Figure 1. Melting and elaboration aggregate

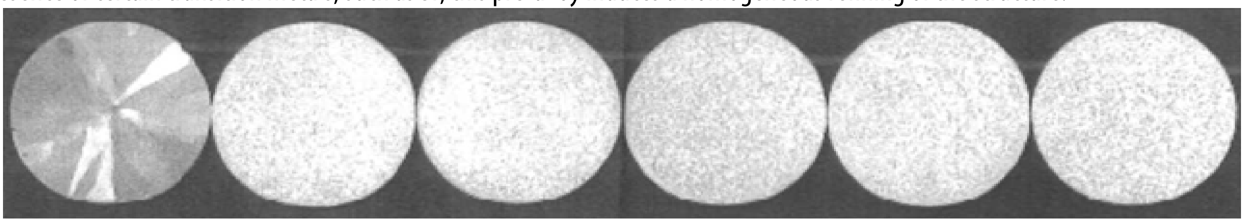
Melting and elaboration aggregate for the studied alloys and the following pre-alloys: Al-Si, Al-Ti, Al-Ni, Al-Sr, Al-Ti-B, is represented by the medium frequency induction furnace with graphite crucible. The inside of the furnace presents the possibility of being relatively watertight by adding a metallic housing pos.1 on a mobile base pos.2 with the possibility of firm attachment and manipulation of the crucible. With auxiliary equipment it is recommended to have a deoxidation gas insufflation rod or a rod for the mechanical mixer pos.3. A manipulation system for the furnace mantle pos.4, a system for gas absorption pos.5 and a watertight system pos.6.

The aluminum alloy metallic melt pos.7 can be refined by adding protection and refining salts or modifiers by using a standard device pos.8. The temperature of the metallic bath can be controlled through the immersion thermocouple from pos.9.

There can be various technological versions for this type of aggregate which can allow the elaboration of both the pre-alloy and also Al-Si-Mg based alloys.

3. RESULTS AND CONCLUSIONS

A real impact over the quality (physical and mechanical properties) which aluminum alloys have is revealed when taking into consideration the types of pre-alloys used for modifying silicon magnesium alloys. In this sense, a great deal of attention is given to understanding the modification mechanism which AlTiB uses. Very susceptible to the inhibition phenomenon of the modification, in presence of certain transition metals, such as Sr, this pre-alloy induces a homogeneous refining of the structure.



1 (before alloying) 2 3 4 5 6

Figure 2. TP1 Standard Test Procedure for Aluminium Alloy Grain Refiners

Minutes after the modification: 1 - zero minutes (before alloying); 2 - two minutes; 3 - four minutes; 4 - ten minutes; 5 - fifteen minutes; 6 - thirty minutes.

Adding various contents of Sr, up to 1%, in the Al-Ti-B pre-alloy has led to obtaining a complex pre-alloy which has to simultaneously modify and refine the aluminum alloy. 1% Sr additions in the aluminum leads to forming interface products and Al_4Sr dispersoid.

The necessity of obtaining an excellent fatigue, corrosion and friction behavior, has led to a worldwide plan of making aluminum alloys with Sr, Ti and B. The new tendency of associating modifiers with elements for finishing the granulation offers aluminum alloys a new approach in developing the technological industry of aluminum.

For aluminum, alloying pursues obtaining certain solid solutions and intermetallic compounds with superior mechanical properties. Introducing dispersoids will lead to obtaining adequate properties for metallurgic processes further to obtaining ingots (semi-products). The used alloying elements form with aluminum limited solid solution domains, and also eutectic domains.

Pre-alloys foreseen to be used in experiments are substances which form insoluble and hard fusible particles, which act work as heterogeneous germination inoculants. As modifiers and refining elements will be used a series of Al pre-alloys with additions of transition metals with high chemical reactivity, such as Ti, and compounds based on Sr and B. Industrial usage of titan and strontium pre-alloys usually require 0.015% up to 0.050% Sr. For the modification pre-alloy based on Al and Sr will be used metallic melts which have a minimum purity of 99.7% Al. In practice, the modification duration with Al-Sr is much higher in comparison with sodium usage.

Table 1. Sr pre-alloy type

Element	Al-Sr5	Al-Sr 10
Al	remainder	remainder
Sr	4.5-5.5%	9-11%,
Fe	0.15-0.30%,	< 0.30%,
Ca	< 0.02%,	<0.03%,
Si	< 0.20%,	< 0.20%,
Mg	< 0.05%,	< 0.10%,
P	<0.01%,	<0.01%,
Other elements	<0.01%,	< 0.01%,

Table 2. Al-Ti-Sr or Al-Ti-B pre-alloy type

Prealloy	Required (estimated minimum) alloy for refining (kg/t Al alloy)	Casting temperature/mixing duration (°C/min)
Al-6Ti-Sr	4.25	730/2
A1-10TÌ-0.4B	1.50	730/2
A1-5TÌ-1B	1.40	730/2
A1-5TÌ-0.2B	1.80	730/2
A1-3TÌ-1B	1.50	730/2

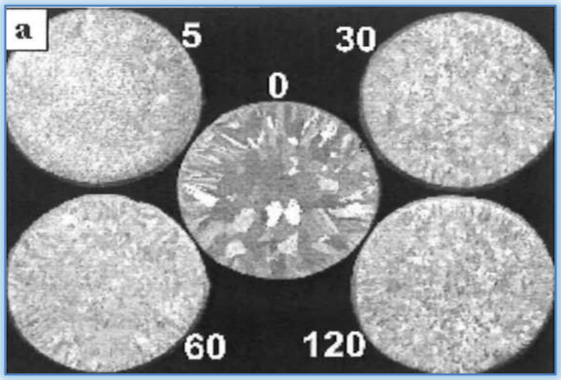


Figure 3. Standard structures (Al-Ti-B-Sr modifiers). 0.2% complex modifier usage. Time elapsed from modification between 0 and 120 minutes. Microstructures highlighted at 0, 5, 30, 60,120 minutes

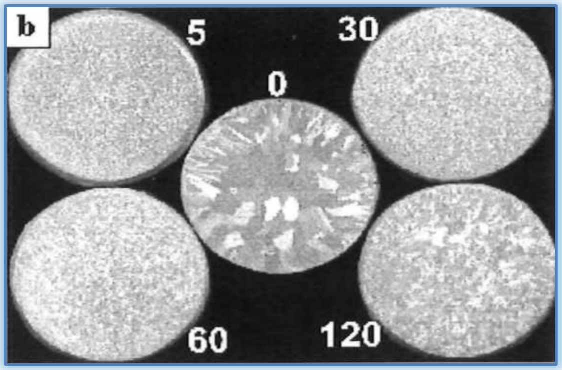


Figure 4. Standard structures modified for Al-Si-Mg and Al-Mg-Si alloys.0.5% complex modifier usage. Time elapsed from modification between 0 and 120 minutes. Microstructures highlighted at 0, 5, 30, 60,120 minutes

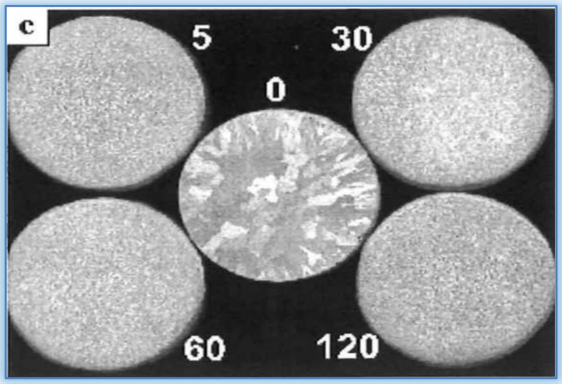


Figure 5. Usage of complex modifier MODIFINER Al-Ti-B-Sr (ISRS 2004 macrography).1% complex modifier usage. Time elapsed from modification between 0 and 120 minutes. Microstructures highlighted at 0, 5, 30, 60,120 minutes

4. CONCLUSIONS

For a fast evaluation of grain size after casting and solidification there have been developed specific series of tests and specimens. One of the fastest evaluation tests certificated in many industrial procedures consists of using a cast iron shell in which we insert the cavity of a circular specimen with the diameter of 75mm, height of 25mm and wall thickness of 6mm. After casting the sample is detached from the shell, cleaned and attacked in order to highlight the grain size on both sides of the ring.

Therefore, using modifiers to control the structure of non-ferrous alloys has allowed great improvements in mechanical properties as a result of structure finishing and smoothing on the whole section of the casted product and has also allowed improving technological properties, the probability of forming fissures in the casted pieces has been eliminated and favorable conditions for intensifying the casting processes have been created.

Modifying additions have allowed developing several new aluminum alloy qualities with superior mechanical and technological properties and at the same time have made possible better usage of lower quality raw materials.

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