STRUCTURE OF EUTECTIC SILUMINS PROCESSED FROM WASTE

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Abstract: *This work aims to be a structure study of an eutectic Al-Si aluminum alloy developed from waste and cast into shapes that provide different rates of solidification due to different solidification speeds. For structural analyzes,there were taken samples from a silumin alloy solidified in different casting processes: sand casting ingot form,; permanent mould(chill) casting and pressure die casting. Although the alloy has an eutectic composition, the obtained structures present a hypoeutectic morphology both due to different cooling terms and to their complex composition. Meanwhile, casting process significantly influences both the main phases granulation and sizes and distribution of intermetallic compounds that arise from the complex composition of waste made alloys.*

Keywords: *silumin, waste, secondary alloy, casting method, metallographic analysis*

1. INTRODUCTION

Most commonly used methods to improve the mechanical properties of casted aluminum alloys are metallurgical processes. The improving structure technologies include liquid alloy treatments for grain refinement and dendrites internal structure and treatments designed to change eutectic morphology.

The hypoeutectic Al-Si alloys are preferred by castings manufacturers, because they present superior mechanical properties and appropriate technological casting characteristics.

This work is intended to be a study of the obtained structure by casting a silicon-aluminum alloy (silumin), only from secondary waste. This silumin, ADC12 type according to Japanese rules (equivalent to AC 1706 on European standard EN 46100 and A384.0 according to ASTM) was produced under different casting conditions. One of pursued objectives in selecting the casting method is to achieve grain refinement in raw castings. This silumin is an eutectic alloy, few hypoeutectic in accordance with the phase diagram in Figure 1; its structure is composed of solid solution dendrites and eutectic, the structure improvement involves both refinement of solid solution as well as the modification of eutectic.

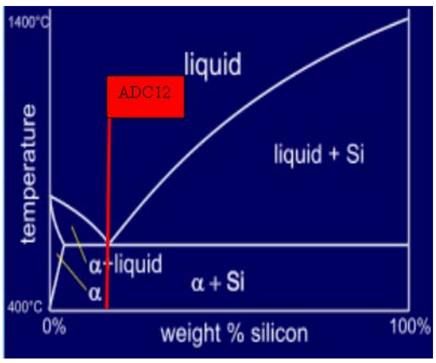

Fig. 1. Phase diagram of Al-Si system

Refinement refers to finishing the dendrites structure in aluminum based alloys and it is done with high melting elements (Ti, B, Zr, Hf, etc.), and the modify operation represents the eutectic morphology changing for Al-Si alloys and it is performed by treating the melt with Na, Sr, Sb, Ca.

Mainly, the structure refinement for the alloys made from remelting waste, also means more refine and homogeneous distribution of intermetallic compounds that are formed in secondary alloys. In this respect, iron compounds shows interest, these can have major influences on the properties of remelting waste made alloys.

Positive results on structure refinement is obtained by raising cooling rate. This way of structural improvement on gravity Al-Si alloy castings in sand moulds or metallic moulds is limited so overall dimensions, local thickness of walls castings and the possibilities of intensifying cooling rates applicable to these processing technologies.

At the same time, the elements used in the technology for aluminum base alloys structure improvement, present a series of problems in them recycling. In this sense, it should be noted sodium, which currently is with predilection used to modify Al-Si eutectic, it is a very harmful for wrought aluminum alloys. Another element, the antimony used to modify Al-Si eutectic is toxic.

A heterogeneous structure decreases the corrosion resistance. Thus, for parts that need corrosion resistance it is required to apply heat treatments for homogenization.

Lately they are undertaken extensive research to achieve alloys with high mechanical properties, close to those of forged products. The trend is not to use heat treatment to castings. This reasoning is primarily bound to economic aspects of costs, reducing castings costs being an important objective to heed.

Tabel 1. Chemical composition of ADC12 alloy taken from samples (in %)

No		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Sn	Ni	V	Al
Standard limits	min	9. 600	-	1. 500	-	-	-	-	-	-	-	-	-	Rem.
	max	12. 000	0. 900	3. 500	0. 500	0. 300	-	1. 000	-	-	0. 200	0. 500	-	
1	ADC 12	11. 464	0. 657	1. 532	0. 143	0. 058	0. 020	0. 913	0. 036	0. 041	0. 025	0. 036	0. 007	85. 068

As known the processing of casting aluminum alloys are used more secondary materials (waste, old metals). The use of these is becoming more frequent particularly after waste recycling campaigns.

2. EXPERIMENTAL DETERMINATION

In the experimental determinations it was studied the structure evolution of ADC12, the aluminum alloy developed from secondary raw material (waste), with the chemical composition shown in Table 1 and it was produced by various casting methods. For choosing the casting method, one of the aims pursued is to achieve the refine of grain size in castings

The alloy's processing was done in a tilting furnace with a graphite crucible, heated by marsh gas, in accordance with processing and casting technology for aluminum alloys cast in ingot. It can be mentioned that after degassing and deoxidizing by fluxes the melt was not liable to any operation intended to improve the structure (modifying or refining).

For samples processing, from the same melt we obtained products cast: into ingot (L), in sand casting (AdF); permanent mould (chill) casting (C) and pressure die casting (TSP), Figure 2.

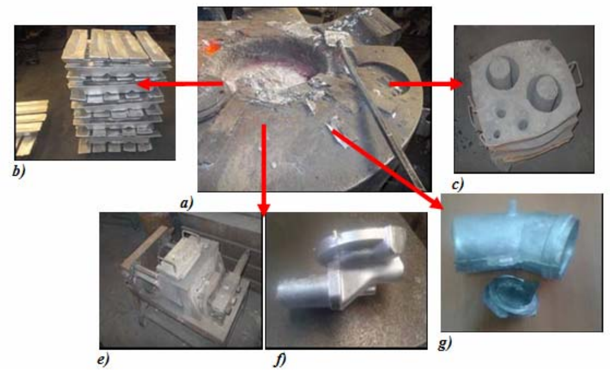

Fig. 2. ADC12 alloy a) in the liquid state into furnace; b) casted ingots; c) sand casting; e), f) casting in chill – permanent mould and its foundry product; g) pressure die casting.

Samples were taken from the same alloy casted in different conditions; they were incorporated in self-strengthening dentacrylic solution, for metallographic examinations. The preparation was done by polishing with different sizes emery paper and sleeking on thick cloth with water + aluminum oxide emulsion.

Structure analyzing on aluminum alloy samples was performed on a metallographic microscope, at magnifications of 25 to 1000. Phase identification was based on data from specialized literature [2,4,5,7].

The most significant structures on the four casting processes are presented in Figures 3-6. Qualitative analysis of structures obtained allow to formulate the major importance observations for the practice of siluminurilor processing on secondary raw materials (waste).

The structure on AdF casting confirms the eutectic composition of alloy. It consist in eutectic, with long silicon eutectic acicular particles. It can be noticed iron presence as Al_3Fe acicular particle. For casted ingot, due to higher cooling rate, it is observed the moving of structure in the hypoeutectic area, through the apparition of alpha solid solution dendrites. Meanwhile, the acicular eutectic silicon particles have lengths lower than alloy casted in AdF. Due to higher cooling rate iron appears as polygonal particles and it is present as $Al_6(MnFe)$ (lighter shade than silicon primary particles). In TSP casted sample, the alloy structure clearly presents a hypoeutectic morphology. Both silicon eutectic particles, as well as those based on intermetallic compounds have globular shape (the ratio length / width tends to 1) and there are uniformly distributed to the limits of alpha solid solution dendrites.

Fig. 3. Microstructure of sand casting sample

Fig. 4.Microstructure of ingot casted alloy

For sand casting the cooling rate is slow and in structure it is precipitated both primary and acicular silicon crystal.

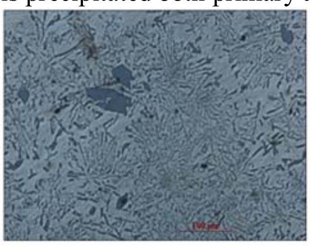

Fig. 5. Microstructure of permanent mould sample

Fig. 6. Microstructure of pressure die casting sample

Table 2. Phases dimensions for ADC12 alloy's structure in different solidified conditions(μm)

Casting type	$Al_9Fe_2Si_2$		Al_3Fe		Al6(MnFe)			Al_2Cu		eutectic Si		α.s.s. dendrites	
	L	d	L	d	L	d	A	L	d	L	d	L	d
Sand casting	70	50	40	6	20	20	400	4	4	49	4	-	-
	80	60	50	4	26	16	416	6	6	75	6	-	-
	120	80	55	8	36	24	864	8	8	128	3	-	-
Ingotting	100	50	30	4	28	28	784	6	6	34	3.5	-	-
	120	40	40	4	32	24	768	8	8	57	4	-	-
	180	80	60	6	40	20	800	8	8	83	3	-	-
Permanent mould	30	10	24	4	6	6	36	6	6	26	2	24	36
	50	24	30	4	10	12	120	10	10	45	7	27	40
	60	20	36	6	12	16	192	8	8	71	4	29	64
Pressure die casting	20	20	12	2	6	7	42	6	6	7	1	12	17
	28	20	24	3	8	8	64	7	7	10	1	16	21
	40	12	30	6	10	11	110	8	8	13	1.5	17	18

Note: L- length, d- width of analyed phase, A- area surface of $Al_6(MnFe)$ particles

The iron in silumins forms intermetallic compounds like $Al_9Fe_2Si_2$ and $Al_{12}Fe_3Si$ which decreases plasticity. Binary or complex eutectic silumins are used for pressure die casting . High speed solidification ensures the decreasing of iron negative effect especially for its larger amounts when the casting is on secondary waste.

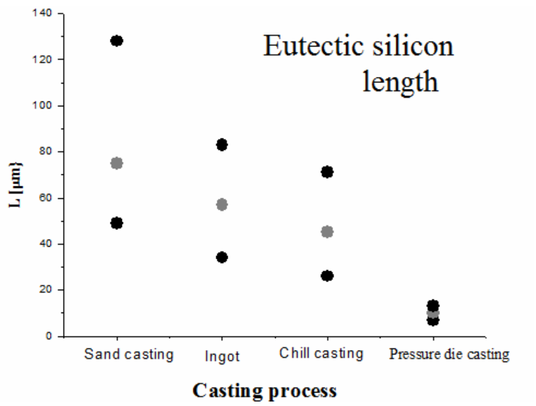

Fig. 7. Length of eutectic silicon particles according to casting processes

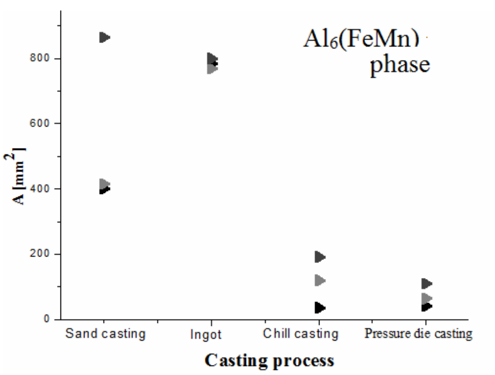

Fig.8. Area of $Al_6(FeMn)$ phase according to casting processes

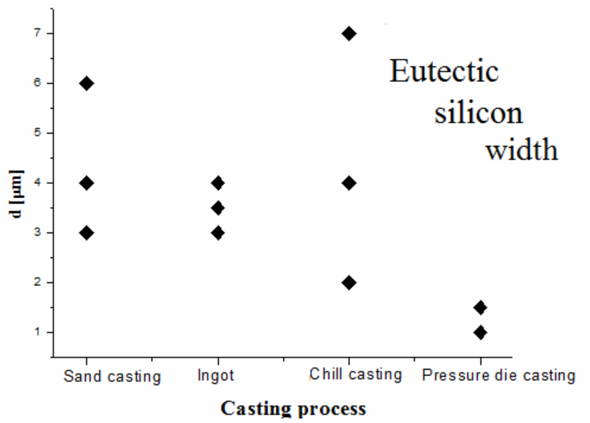

Fig. 9. Width of eutectic silicon particles according to casting processes

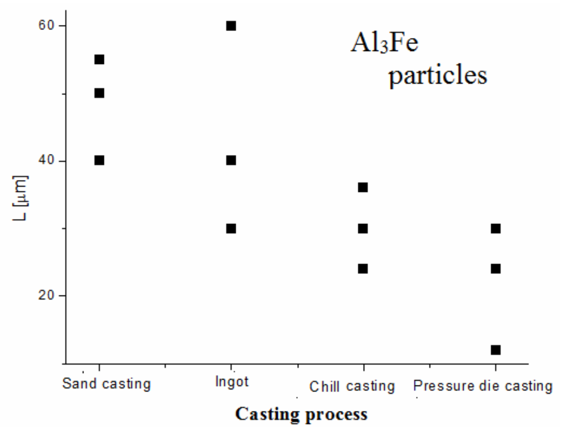

Fig.10. Length of Al_3Fe particles according to casting processes

In order to illustrate the influence of casting technology (cooling rate) in structure of silumins processed on secondary raw materials, there are presented in Figures 7, 8, 9 and 10 the variations of phases dimensions with significant influence on alloy's properties, depending of casting technology. It can be mentioned that based on using literature data [6,8] and the own observations it is considered that cooling rate increases from sand casting processes, in ingot, in permanent mould and pressure die casting.

Referring to permanent mould (chill) casting and pressure die casting, higher cooling rate first of all determines the reducing of size eutectic silicon particles and intermetallic compounds, both length and width.

For pressure die casting the eutectic percent in structure decreased, while eutectic silicon particles was reducing them size from 75 µm to 10 µm.

On ADC12, an eutectic alloy, both casting in permanent mould and pressure die casting structural changes caused by high cooling rate of the melt are obvious.

It is observed the structure modification trend in permanent mould casting by decreasing the size of intermetallic compounds, from 26 µm to 10 µm.

In Figure 8 is illustrated the length of eutectic silicon particles that by increasing cooling rate from sand casting to pressure die casting technology decreases four times, and in accordance with Figure 9 particles area calculated by Al_6(FeMn) decreases twice while cooling rate is increasing. Under the same conditions, as shown in Figure 10 the length of Al_3Fe particles reduces twice.

3. CONCLUSION

Based on the comments performed on the same charge could be highlighted significant structural differences that occur in different casting procedures.

The cooling rate for eutectic composition alloy determines the movement in hypoeutectic area of structure morphology. Maximum effect is on pressure die casting.

If, for various reasons, it is not done the metallurgical structure modify, the modification of eutectic silicon shape can be achieved only by casting technologies that provide high cooling rate**.**

The negative influence of iron on alloy properties may decline by form compaction of iron containing particles through the application of increased cooling rates during solidification or by alloying with manganese.

Besides phases finishing, the pressure die casting process ensures maximum structural homogeneity.

Increasing the cooling rate from casting in chill to pressure die casting technology determines both growing percent of alpha solid solution dendrites and their refinement.

The merit of the work is that it makes quantitative argumentation of cooling rate influence specific to different casting technologies on phases dimensions that have major influence on properties for silumin castings.

4. ACKNOWLEDGMENTS

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