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A STUDY ON THE QUALITY OF CAST BILLETS OF 6XXX ALUMINIUM ALLOYS

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S-a studiat microsegregarea elementelor de aliere în aliajele 6XXX turnate sub formă de bare, prin analiză chimică, cu un spectrometru de emisie.

S-a efectuat analiza macrostructurală a barelor prin secționarea acestora în diferite zone. S-a observat o distribuție uniformă a grăunților, fără defecte macroscopice; nivelul de porozitate pe scala ZYGLO a fost de 1–2, iar calitatea suprafeței a fost de gradul 5 pe scala SAPA.

În timpul omogenizării (peste 575°C) s-a observat o creştere a grăunților în apropierea suprafeței barelor.

Microsegregation of alloying elements in 6XXX cast billets was studied using chemical analysis by means of an optical emission spectrometer.

Macrostructure analysis was carried out by sectioning the cast billets in different areas. A uniform cellular grain distribution, without macroscopic deffects was observed; the porosity level was of 1–2 degrees on the ZYGLO scale and the surface quality was of 5 degree on SAPA scale.

During homogenization (above 575°C) a grain growth phenomenon was manifest near the surface of billets.

Keywords: microsegregation, diffusion, surface quality, macroporosity

1. Introduction

The 6XXX series aluminium alloys are the most widely used light materials in extrusion due to their high extrudability. These alloys are very attractive in transportation industry due to their high specific resistance.

These alloys contain Si and Mg in a proportion that allows the formation of the Mg_2Si compound. The high content of Mg and Si facilitates the formation of Mg_2Si particles. The optimum ratio required to Mg_2Si formation is Mg/Si=1.73/1.0, but in practice it is impossible to obtain this ratio, so that the alloys have either Mg or Si in excess.

The excess of Mg results in a better corrosion resistance, but decreases the mechanical resistance and plasticity [1]. The excess of Si increases the mechanical

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resistance without diminishing the plasticity and weldability, but favours the intergranular corrosion tendency [2].

The cast rate of aluminium alloys is a function of alloy type and cast part dimensions, ranging in 1 – 3 mm/s [3].

The cooling rate is in direct correlation with the depth of die walls, being $0.5^oC/s$ in the middle of the billet and about $20^oC/s$ at 20mm from surface.

The casting temperature of aluminium alloys varies in the range of 963 – 998K and the temperature gradient is about 0.3 – 5.0 K/mm^{-1}.

Although the DC technology is used for long time there are unsolved problems especially referring to productivity and diminution of defects (cracking, contraction, porosity, inclusions etc.) [4].

The quality and commercial aplicability of cast parts depend in a great measure of macro- and microstructure.

The microstructure variables of interest for aluminium alloys are as follows:

- dendrite arm spacing (DAS),
- grain size,
- type, quantity and morfology of intermetallic phases.

The mechanical properties of cast billets of aluminium alloy depend on each of these variables.

The value of these characteristics depends on the solidification process parameters (cooling rate, solidification rate), alloys compositon and additives (modifiers, grain refiners etc.).

The solidification parameters, which influence the microstructure, are not constant on the whole thickness of the cast billet, so that each volumic element solidifies with a different rate. The differences in solidification rate depend on the cast parameters (melt temperature, cast rate, volume of cooling water). The variation of the solidification rate at cooling causes modification of microstructure and of mechanical properties in different sites of the cast part.

2. Results and Discussion

2.1. The microsegregation of alloying elements

Three type of alloys of 6XXX series was studied, namely 6000, 6063 and 6082. The alloys were industrially cast on a WAGSTAFF casting machine.

Chemical analysis was carried out using GNR METALLAB 75-80J optical emission spectrometer. The chemical composition of the 6XXX billets was determined as furnished in Table 1.

The study of the calibration of the homogenization furnace was performed in the case of billets having the diameter of 203 mm, from 2 charges R 15101476 and R 15101482.

Table 1

Chemical composition of billets of 6XXX alloys

Aloy/state	Element, wt.%									
	Mg	Si	Mn	Fe	Cu	Zn	Ti	Cr	Ca	Na
6060/cast	0.437	0.477	0.016	0.18	0.002	0.006	0.014	-	0.0002	0.0002
6060/ homogenise d	0.397	0.502	0.021	0.19	0.005	0.007	0.014	-	0.0003	0.0002
6063/cast	0.4	0.417	0.017	0.18	0.005	0.006	0.012	-	0.0002	0.0005
6063/ homogenise d	0.437	0,427	0.022	0.19	0.001	0.005	0.012	-	0.0003	0.0003
6082/ cast	1.043	1.11	0.601	0.287	0.03	0.1	0.02	0.019	0.0007	0.0001

In the Fig.1 and Fig.2 are presented the variations of alloying elements content (Mg, Si) of the billets.

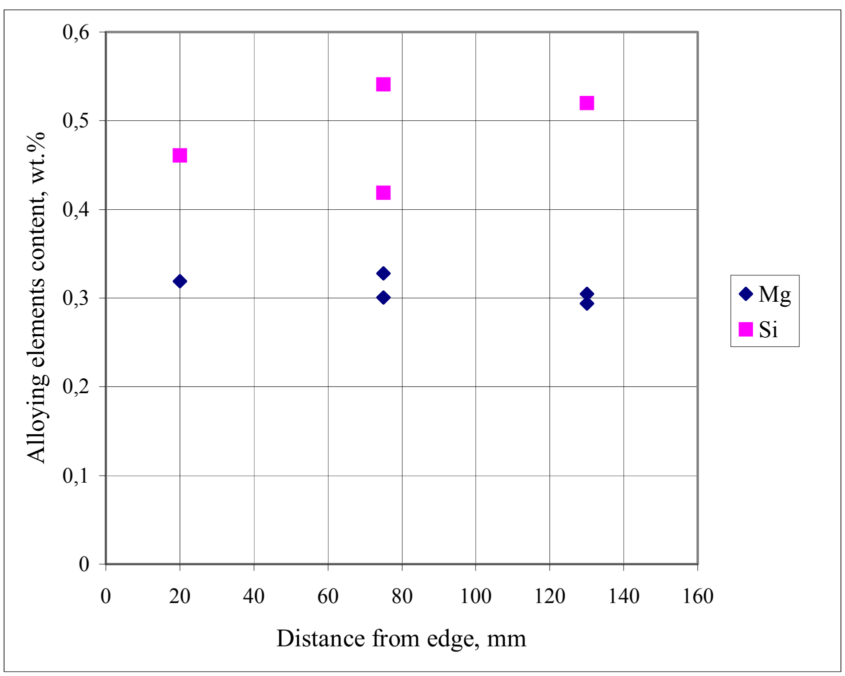


Fig.1. Variation of content of alloying elements (Mg, Si) on

the transversal section of 6060 cast billets.

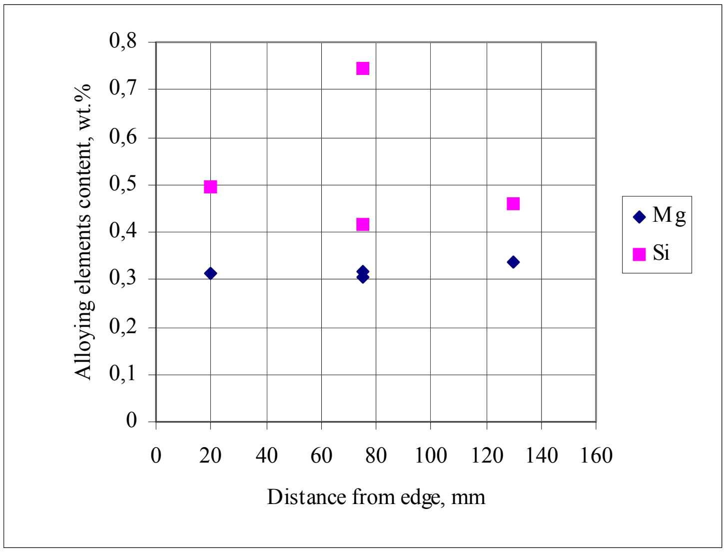


Fig.2. Variation of content of alloying elements (Mg, Si) on the transversal section of 6060 homogenised billets.

There is a difference between the content of Mg and Si from edges and middle of the cast billets. This difference flattens after homogenisation in the case of Mg, and increases to middle of the billet in case of Si.

This behaviour can be explained by the difference in diffusion coefficients of the magnesium and silicon (Fig.3) [8].

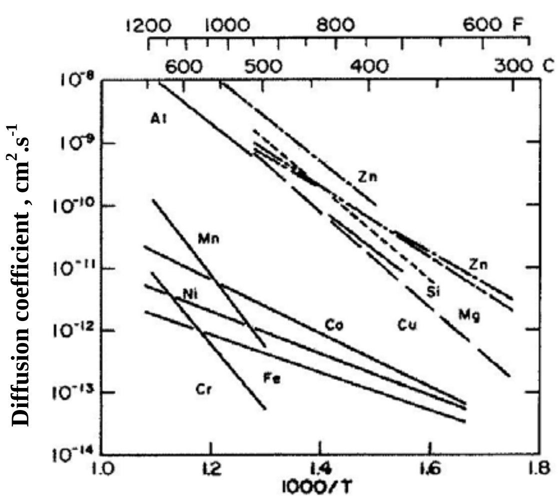


Fig.3. The diffusion coefficients vs. temperature, for alloying elements in aluminium.

2.2. The study of outside area of the billets

The surface of the billets was examined visually and also according to SAPA scale presented in Fig.4.

Examination of the billets has shown that the surface is fine, smooth, being of 5 degree of SAPA scale (Fig.5).

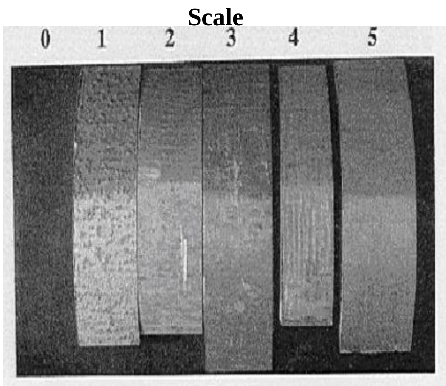


Fig.4. SAPA scale of surface quality of billets.

Fig.5. Surface of cast billets (level 5 on SAPA scale).

2.3. The study of the macrostructure of the billets

Macro-examination was carried out by sectioning the specimen folowed by grinding on 320, 400 and 600 Grit SiC emery papers and fine polishing with 3 μm and 1 μm diamond abrasive and final polishing with colloidal SiO_2.

Macrostructures of cast billets of 6063 alloy with two different diameters are shown in Fig.6 and Fig.7.

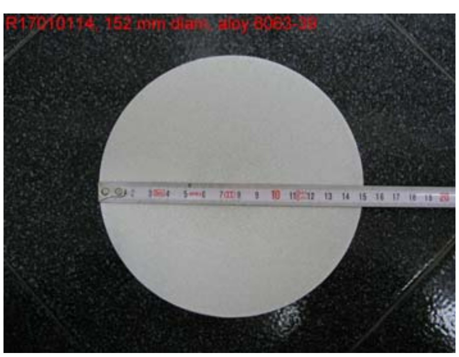


Fig.6. Macrostructure of the cast billet of 6063 alloy, with diameter of 152 mm.

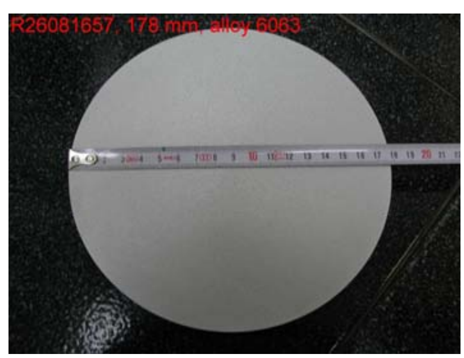


Fig.7. Macrostructure of the cast billet of 6063 alloy, with diameter of 178 mm.

In both cases an uniform cellular grain distribution, without macroscopic defects such as inclusions is observed.

During homogenization (prior to the extrusion process) if the billets are overheated grain growth near the surface of billets (Fig.8) may appear.

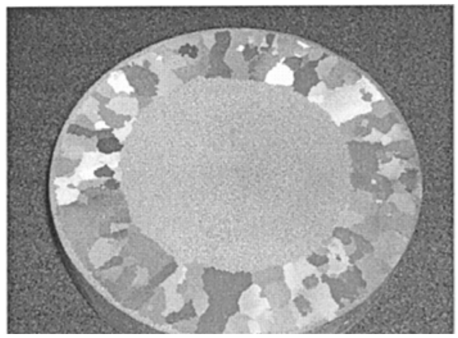
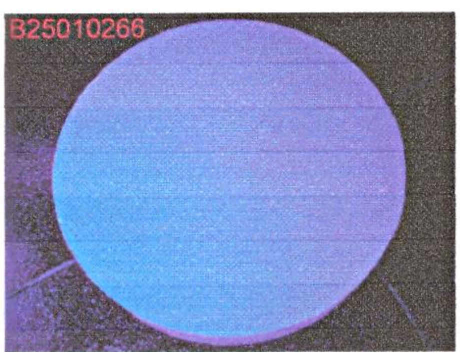


Fig.8. Macrostructure of 6063 homogenized billet, above 575°C.

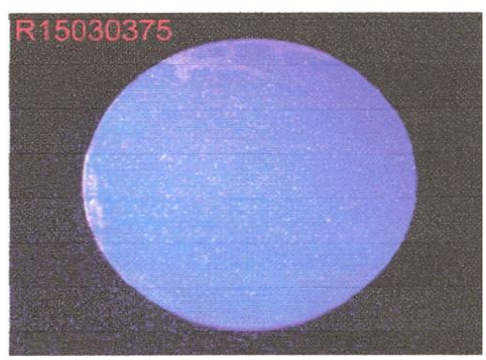
Macroporosity of the billets was performed by the ZYGLO method, with penetrating liquids.

There are 7 levels on the ZYGLO macroporosity scale (Fig.9).

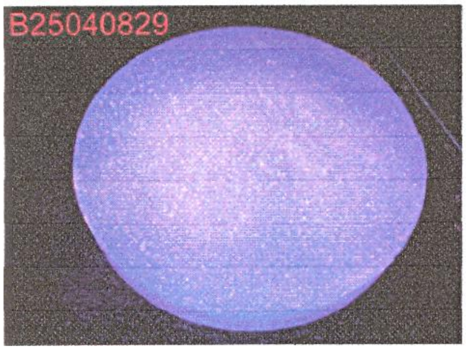
The billet is accepted if its macroporosity is situated in the levels 1 – 2, the billet are rejected from 3 to 7 level.



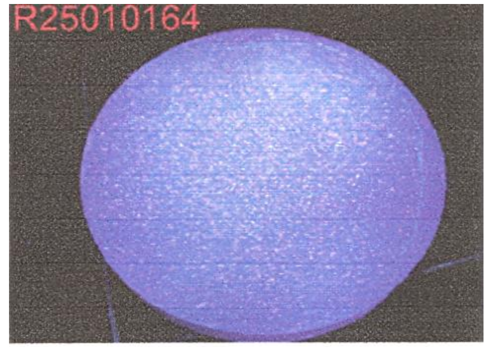
(a) 1 – 2 porosity level



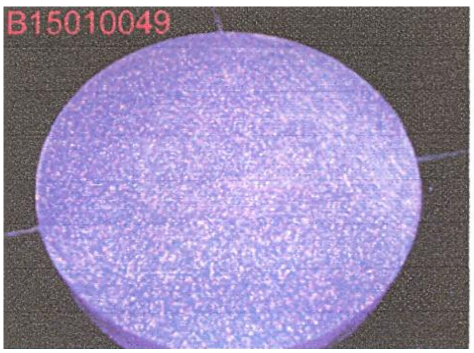
(b) 3 porosity level



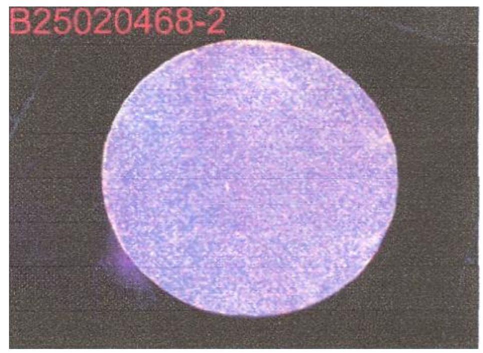
(c) 4 porosity level



(d) 5 porosity level



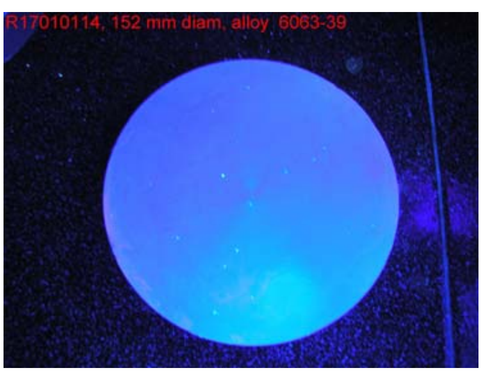
(e) 6 porosity level



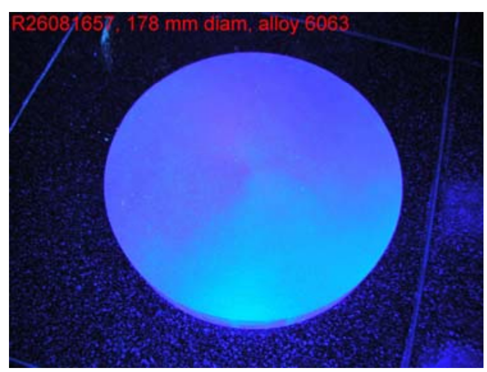
(f) 7 porosity level

Fig.9. ZYGLO porosity scale.

The macrostructure of the 6063 billets showed a 1 –2 porosity level, therefore the billets are accepted (Fig.10).



(a)



(b)

Fig.10. Macrostructure of 6063 cast billet with diameter of 152 mm (a) respectively 178 mm (b).

3. Conclusions

- The microsegregation of the alloying elements in 6XXX cast billets was determined, and it was explained by the difference in diffusion coeficients of magnesium and silicon in aluminium.
- Examination of 6063 billets has shown that the surface is fine and smooth, of 5 degree of SAPA scale.
- Macro-examination of billets has shown an uniform cellular grain distribution without microscopic defects ; porosity level was of 1- 2 level on ZYGLO porosity scale.

R E F E R E N C E S

[1] *R.A.P.Fielding*, Recent Developments in Grain Refining Technology and Standardization, Light Metal, June 1997, pp.66-80
[2] *S.M.Hirth and al*., Materials Science Eng., A, **vol.319-321**, pp.452-456
[3] *I.Fara, N.Panait, P.Moldovan s.a.,* Aluminiul de la materia primă la produse finite, Editura Tehnică, Bucureşti, 2000.
[4] *G.Switkes*, Foiling the Aluminum Industry, Int.Rivers, Network, Aug. 2005.