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Researches Concerning PoDFA Method for 5083 Alloys

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The PoDFA (Porous Disk Filtration Analysis) method it is one metallographic analysis for off-line quantitative and qualitative evaluation of melt cleanliness. This Alcan procedure is a good tool for identifying the major types of inclusions present in the molten metal. The most important inclusions which appear during the aluminum melting are aluminum oxides (Al_2O_3) in the shape of disperse particles or oxides films, aluminum carbides (Al_4C_3), magnesium oxides (MgO), spinel($MgAl_2O_4$), titanium boride (TiB_2), aluminum boride (AlB_2) and titanium aluminide($TiAl_3$). The inclusions analysis can be done through the quantitative metallographic, chemical analysis, volumetric tests, non-destructive tests, K-Mold, mechanical testing and PoDFA method.
The aim of this paper is to show the importance of PoDFA method for aluminum industry and estimate the quantity and the nature of inclusions in 5083 alloy.
Also, was estimated the microporosity of the alloy by determining the Density Index (ID). The PoDFA techniques have been introduce by Alcan Company in 1996 like evaluation method of cleaning level for the melting[1].

Keywords: *Porous Disk Filtration Analysis, aluminum alloys, inclusions, melts cleaning.*

1. Introduction

This paper represents a year's cooperation between the biggest Romanian Aluminum Company named VIMETCO ALRO Slatina and University POLITEHNICA of Bucharest[1,2]. The paper target is to distinguish and to evaluate quality cleanliness melts, especially with respect to inclusions. Substantial gains consist in reduction of machining defects, improved surface finish, increased elongation, reduced leakers, and overall scrap reduction and reject castings. Aluminum casting production and process technology is in continuing growing. The higher property requirements of such castings have demanded excellent metal quality and melt treatment processes to provide more stringent controls on metal cleanliness-control of inclusions and hydrogen content to minimize porosity/microporosity. Melt treatments to produce clean metal include fluxing and/or flux injection, degassing and filtration. Filtration processes are now employed in virtually every aluminum shape casting operation. Typical benefits that are expected and achieved include (1) greater metal fluidity and feeding capability during the casting process; (2) higher casting properties; (3) improved mach inability; (4) better surface finish; and (5) overall reduction in scrap and reject castings. There are several means to evaluate molten metal cleanliness that the foundry can employ either in process development or as ongoing production process monitoring. The most common practical and *technical* methodologies are the following: (1) reduced pressure test; (2) actual hydrogen measurement with Alcan, Hyscan, Leco analysis; (3)Qualiflash; (4) Prefil; (5)PodFA or LAIS; (6) mechanical testing; (7) Tatur test; and (8) K-Mold[3].

2. Experimental procedure

The alloys have been melted in one 60 t capacity furnace and with one output by 10 tons/hour. After melting, alloys has been in-line degassed with ($Ar+Cl_2$) mixed gases in Pechiney facilities ALPUR TS 35-24(Fig.1,a) installation and filtered through ceramic foams filters. The slabs of 5083 alloys were cast through Pechiney installation with Epsilon dies. Using aluminum scraps permits to reduce energy costs comparative with the products from primary aluminum. Casting of 5083 alloy has been done at 632^{o}C.

Fig.1, ALPUR degassing facilities (a); Wagstaff vertical casts facilities (b).

Like metallic sample alloys have been used 5083 casting alloys (Al-Mg-Mn). In table 1 it is presented the chemical composition of casting samples. The casting has been done through Wagstaff vertical casting facilities (Fig.1,b). The casting parameters used are: casting rate 45-50 mm/min, cooling water flow rate 679-680 l/min, casting temperature 679-680 ^{o}C, cooling water temperature 9-14^{o}C, metal level in die 50 mm.

Table 1, Chemical composition of 5083 alloys:

Sample	Composition in wt. %						
	Mg	Mn	Fe	Si	Cr	Ti	Al
1	4.38	0.5	0.32	0.08	0.08	0.015	rest
2	4.30	0.41	0.36	0.11	0.09	0.014	rest
3	4.25	0.61	0.30	0.10	0.10	0.008	rest
4	4.25	0.51	0.35	0.14	0.11	0.015	rest
5	4.68	0.42	0.32	0.21	0.07	0.015	rest
6	4.27	0.40	0.41	0.14	0.07	0.014	rest
7	4.67	0.60	0.27	0.27	0.11	0.033	rest
8	4.58	0.52	0.26	0.26	0.078	0.025	rest
9	4.53	0.57	0.25	0.16	0.093	0.031	rest
10	4.62	0.53	0.27	0.14	0.10	0.025	rest
11	4.38	0.54	0.26	0.10	0.084	0.035	rest
12	4.7	0.51	0.15	0.04	0.09	0.022	rest
13	4.32	0.58	0.21	0.15	0.08	0.030	rest
14	4.50	0.52	0.23	0.14	0.08	0.030	rest
15	4.40	0.50	0.39	0.17	0.09	0.035	rest
16	4.53	0.50	0.14	0.06	0.08	0.037	rest
17	4.58	0.45	0.14	0.06	0.07	0.035	rest
18	4.63	0.66	0.27	0.37	0.067	0.022	rest
19	4.50	0.65	0.25	0.17	0.095	0.030	rest
20	4.70	0.70	0.20	0.21	0.092	0.038	rest

3.1 Metallographic analysis of inclusions, which are present in the sample

Metallographic analysis consists of examining the residue of unfiltered metal at the surface of the PoDFA filter. Thanks of this method can be determined all kind of inclusions from melt. Using a grid method based on the PoDFA technique the total inclusion area is obtained and then divided by the weight of the metal that has passed through the filter[4]. The most important inclusions in 5083 alloy are titanium diboride TiB_2 (Fig 2.a), aluminum carbide-Al_4C_3(Fig2.b), aluminum oxide-αAl_2O_3

(Fig 2.c), magnesium oxide-MgO(Fig2.d), and spinel-$MgAl_2O_4$ (Fig 2.e). Metallographic preparation and chemical etching are done in concordance with ASTM E 3 and ASTM E 407.

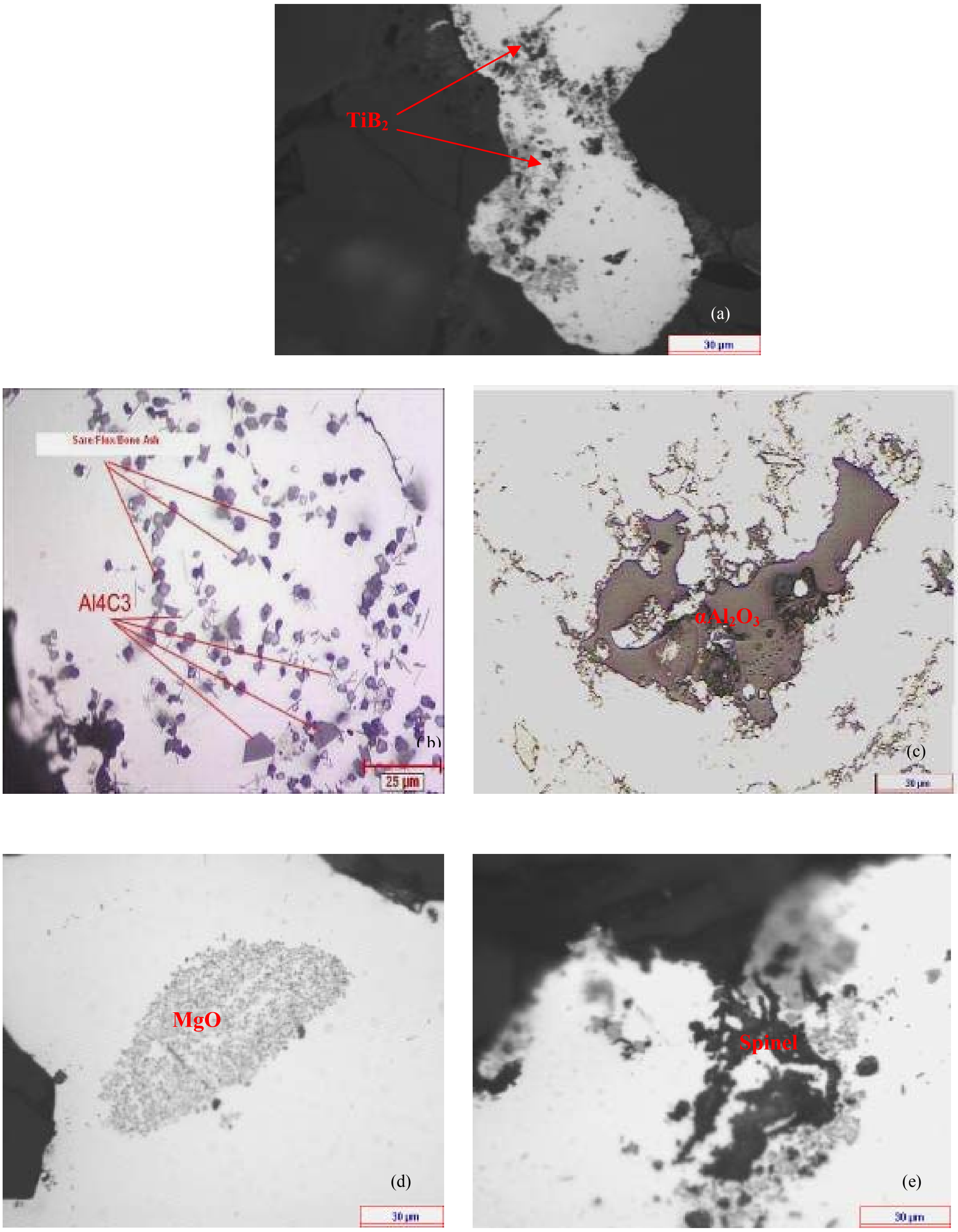


Fig.2, Non metallic inclusions: TiB_2 (a), Al_4C_3 (b), αAl_2O_3(c), MgO(d), Spinel (e).

PoDFA techniques imply two different lies operations: a) to takes samples from liquid metal and filtration processing; b) preparation and estimation of samples in metallographic laboratory. Each inclusion is identified about the measure, color, morphology, hardness. The kind of inclusions depend by alloy nature: γ-Al_2O_3, Al_4C_3, MgO, $MgAl_2O_4$, refractory materials, like-spinels, α-Al_2O_3, C(graphite), $MgCl_2$, NaCl, $CaCl_2$, bone ash[$Ca_2(PO_4)$], (Ti,V)B_2, and so on. Technical principles of PoDFA process are the followings: a) filtration of liquid melting by 1-1,5 kg through one porous disk, which will collect each solid inclusion which is in suspension in liquid melting, oxides films or another's big particles (it will remain over the filter and in the filter); b)Continue checking of filtrate metal. Through PoDFA testing a small quantity of metal is caused to flow under pressure through a fine-grade test filter (Fig.3). The inclusion content concentrated on the surface of the test filter is then examined metallographically. Inclusions are classified about the class and content (in mm^2/kg), (Table 2) [5].

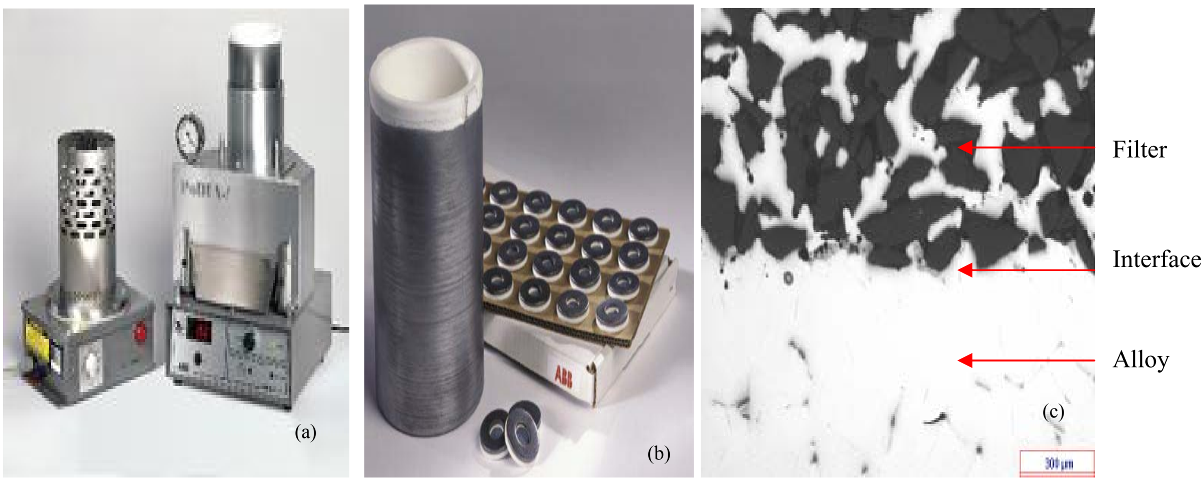
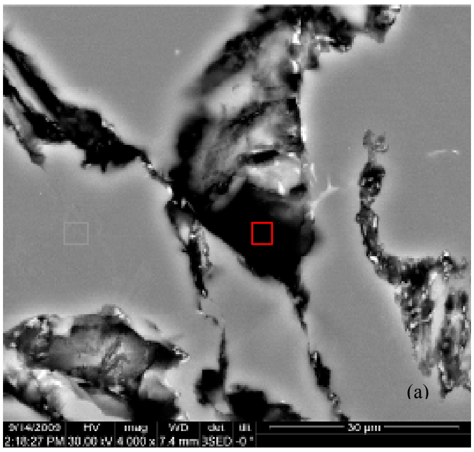


Fig.3, The PoDFA facilities (a), crucibles and filter (b) and interface aspect on PoDFA sample (c).

Table 2, Inclusions classifications.

Class	**Inclusions content, mm^2/kg**
Very small –(1)	0,0-0,05
Small-(2)	0,5-0,1
Medium-(3)	0,1-0,4
Big-(4)	0,4-1,2
Very big-(5)	≥1,2

It was established that the inclusion content is between 0.011 mm^2/kg and 0.025 mm^2/kg. The results of SEM and energy dispersive X-rays analysis of samples are done in Fig.4. It can be observed Al_2O_3 and SiO_2 oxides from filter material, and also TiB_2, graphite (c) and Na, K from fluxes utilized in the process. Using a grid method based on the PoDFA technique, the total inclusion area is obtained and then divided by the weight of the metal that has passed through the filter. Generally, the metallographic examination of solidified melt samples, searching for inclusions and their characterization, much less providing quantifiable data, can often be characterized as 'searching for a needle in a haystack'. Best results at PodFA determination when filtration takes place after flux injection[6]. Using filtration mean to eliminate hardspots caused by sludge, corundum particles, oxides and refractory erosion with point-of-cast bonded particle filters in the dipwells[7].



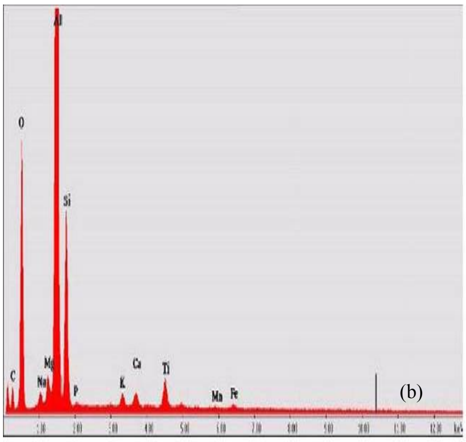


Fig.4, Results of SEM evaluation (a) and energy-dispersive X-rays of some inclusions (b).

3.2 The Density Index (ID)

The Density Index (ID) has been determinate through VAC TEST SYSTEM EQUIPMENT VT 622P model (The Reduced Pressure Test). Are presented the estimations concerning the microporosities presence in DC cast slabs. The Density Index is given by the following relation:

$$ID = (D_{alloy} - D_{vacum}) / D_{alloy} \text{ x } 100 \qquad (1)$$

where: D_{alloy} – 5083 alloy density 5083 solidificated in air,

D_{vacuum} – 5083 alloy density solidificated in vacuum (80 mbar) and presented in table 2.

Density Index determination taken from 5083 slab was done on the samples A-D (fig.5).

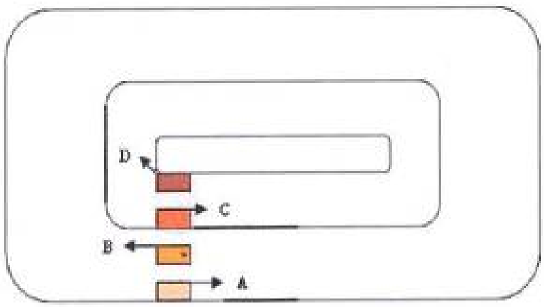


Fig.5. Transversal section through 5083 casting slabs alloys: A, B-areas without microporosities, C and D areas with microporosities.

The A area represent side area (cortical area), B position represent quarter area, C position represent middle area between quarter and middle, and D position represent center area. A part of samples was heat treated (homogenizing) at 483- 524 ^{o}C; holding time was by 48 hours. In figure 6 it is represented the correlation between density and density index for 5083 cast alloys. The microporosity decrease on the sample 5 with density in air by 2588 kg/m^3 and in vacuum (at 80 mbar) it is 2542 kg/m^3, that is represented in figure 6. For it the manganese ratio is 0.28.

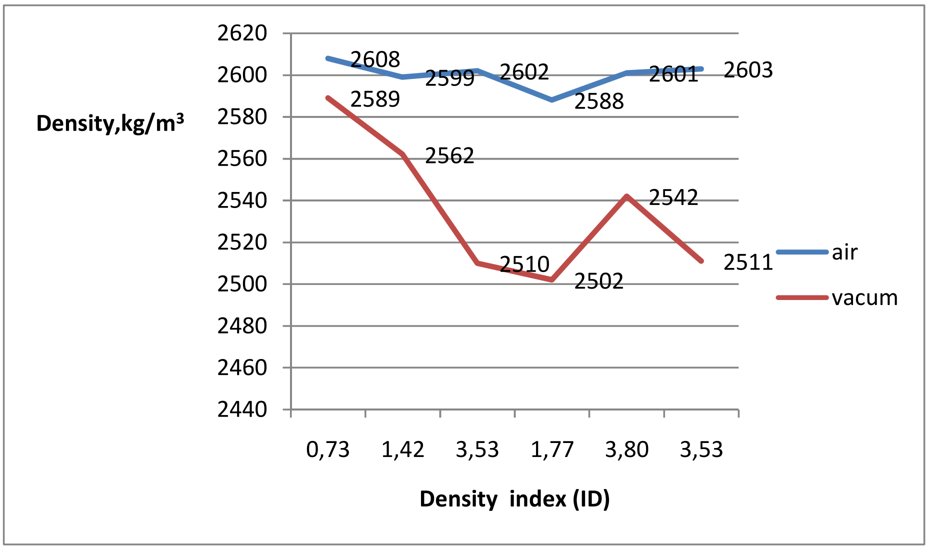


Fig.6, Correlation between density index (ID) and density for 5083 alloy.

Also, the microporosity decreases from 3.53(ID) to 1.77 (ID) with increasing of Mn/Fe ratio from 2.44 to 3.5. The mean dimension of pores, also, decreases from ~30 µm to ~22 µm.

3. Conclusions

Microporosity was evaluated by Density Index(ID) slabs at 5083 alloys. Density index has been measured on different lies areas of 5085 slabs. Like facilities has been used Vac Test System with a standard deviation by ±10%. Through PoDFA method has been identified the followings inclusions:TiB_2 ,Al_4C_3, MgO, Al_2MgO_4 and αAl_2O_3, FeO. The micropores are well interconnected with iron and manganese intermetallic phases. The PodFA analysis, concentrates the inclusions present, albeit still from a rather small sample, but still gives a reliable, industry-recognized-technique result.

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