FILTRATION BEHAVIORS OF INCLUSIONS IN LIQUID ALUMINIUM WITH RIGID MEDIA FILTER

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ABSTRACT

The control of metal cleanliness is one of the most important characteristics affecting the performance of the final products. Filtration is a popular and effective method used for removal of the inclusions from the melts in the cast shop. The filtration efficiency as well as the filtration behaviors of inclusions are, however, not well understood.

The scope of this paper is to clarify the filtration efficiency and the filtration behaviors of some of the inclusions (TiB_2, Al_4C_3, Al_2O_3, and MgO) in liquid Aluminium with rigid media filter(RMF). Effect of filtration conditions on the filtration efficiencies of each inclusions and distribution of the inclusions in the filter after filtration were examined using disk-shape RMFs.

Present paper describes filtration behaviors and filtration efficiencies of each inclusions with the RMF based on the results obtained.

1. INTRODUCTION

A large number of nonmetalic inclusions, such as oxides, carbides, and borides, were found to exist in Aluminium melts[1]. The adverse effects of these inclusions on the product quality of Aluminium and Aluminium alloys are often reported from the customers.

In order to remove the inclusions from the melts, several in-line filtration systems have been developed. Above all, rigid media filter(RMF), deep bed filter(DBF), and ceramic form filter(CFF) are being widely used in the cast shops depending on the quality requested.

On the other hand, several techniques have also been developed to monitor the inclusions in the melts. Metallographic quantification is commonly used after preconcentration of inclusions, because of very low content of inclusions in production melts. Preconcentration was first applied in the PoDFA[2] and later in the LAIS[3]. Filtration efficiencies for CFF[4,5], DBF[5], and RMF[4,5] was investigated with this method.

LiMCA is the most sophisticated and reliable technique to assess the inclusions larger than 20 μm in diameter. Filtration efficiencies for CFF and DBF in the cast shops were evaluated using LiMCA[6,7].

In these experiments, however, What kinds of inclusions the melt contained was not shown, or if shown, metals contained more than one inclusion. Filtration behavior, therefore, filtration efficiency should be different from one inclusion to another. From this reason, it is of great importance to know the filtration behaviors of each inclusions separately.

The scope of this study is to elucidate the filtration behaviors of each inclusions on condition that the melt contains only one spices. As inclusions to be examined, TiB_2, Al_4C_3, Al_2O_3, and MgO, which have been often encountered in daily inspections, were selected.

For this purpose, next two items were investigated with these inclusions.

(1) Effect of filtration conditions; average pore size of the filter, filtration rate, and filter thickness, on the filtration efficiencies of each inclusions.

(2) Distribution of each inclusions from inlet to outlet of the filter.

2. EXPERIMENTAL PROCEDURE

2.1. Preparation of Metals

Metals from a wide range of sources were examined in terms of inclusions with a labo-scale filtration technique. An Al-4% Mg alloy sheet ingot, 99.9% Aluminium ingots and 99.99% Aluminum ingots were found to include mostly Al_4C_3, Al_2O_3, and MgO, respectively, and were subjected to the filtration tests. For preparing the melt which includes TiB_2, an Al-5%Ti-1%B hardener was added to the 99.9% Aluminium which contains other inclusions as little as possible.

2.2. Filtration Procedure

Fig.1 outlines the equipment used for the filtration tests and filtration conditions employed are shown in **Table** 1. Filters used in this experiment are disk-shape alumina RMFs with average pore sizes of 21, 45, 77 and 220 μ m. The 220 μ m-filter corresponds to the RMF which is used in the cast shop.

About 3kg of the metal was melted in the crucible with a disk filter fixed at the bottom and filtered by applying a constant pressure of 1.0 kg/mm2 for 21-μ m-filter or 0.65 for 45-,77- and 220-μ m-filter. The average flow rates under constant pressures are 3 to 40kg/m2/sec depending on the filter pore size used. The pressure was automatically released when the amount of melt remained on the filter reached to about 200g, monitoring the weight of metal passed through the filter by a balance placed under the filter.

In order to examine the effect of the flow rate, filtration was also carried out at a constant flow rate from 0.4 to 10 kg/m2/sec, which was controlled manually.

To control the flow rate for the filter with a pore size of 220-μ m, an experimental set-up was employed as shown in Fig 2. A 77 μ m-filter was placed below the 220-μ m filter. Otherwise the melt pass through the filter by it's hydrostatic pressure before applying a pressure artificially.

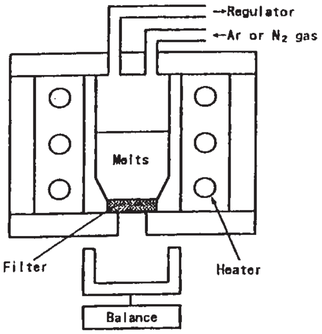

Fig. 1 Filtration Apparatus

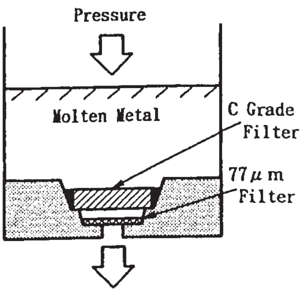

Fig. 2 Experimental Set Up for Filtration tests

Table 1 Filtration Condition Employed

Pore Size (μm)	21	45	77	220
Diameter of Filter (mmφ)	12.5	12.5	12.5	40
Thickness of Filter (mm)	2.5	2.5	2.5	10, 15, 20
Constant Pressure (kg/mm2)	1	0.65	0.65	0.65
Constant Flow Rate (kg/m2/sec)	0.4～11			

2.3. Assessment of Filtration Efficiency

The disk filter with about 200 g of residual metal on top was sectioned after the filtration, mounted using a resin and polished. The quantity (area) of residue present within an area of 1.0×12mm including above and below the surface of the disk was metallographically determined and divided by the amount of melt passed. The amount of the inclusion captured was represented in mm2/kg. In some cases, measurements were carried out from inlet to outlet of the filter to obtain the distribution of the inclusions. To evaluate the filtration efficiency of TiB_2, Boron contents in the metal before and after filtration were determined by optical emission spectroscopy. For determining the filtration efficiency of Al_4C_3, Al_2O_3, and MgO semi-quantitatively, repetitive filtration was conducted. After the first filtration, filtered metal was collected and subjected to the second filteration. This procedure was repeated until almost no inclusion was traced in the filter. The efficiency was calculated from the ratio of the amount of inclusion collected in the fist filtration to the total amount.

3. RESULTS

3.1. Effect of Filter Pore size

Fig.3 shows the effect of the average pore size of the filter on the filtration efficiency of TiB_2. Filtration was carried out at a constant flow rate of 1kg/m2/sec. As can be seen in this picture, the efficiency is little dependent on the pore size. More than 70% of TiB_2 are filtered even by the course filter with the average pore size of 220 μm.

Fig.4 shows the effect of the average pore size of the filter on the filtration efficiency of Al_4C_3. The efficiency decreases steeply with increasing pore size of the filter and almost no Al_4C_3 are captured by the 220 μm-filter.

The effect of pore size on the filtration efficiencies of Al_2O_3 and MgO is shown in **Fig.5**. The efficiencies of Al_2O_3 and MgO also show strong dependence on the pore size. It is apparent that very little amounts of Al_2O_3 and MgO are captured by the 220 μm-filter.

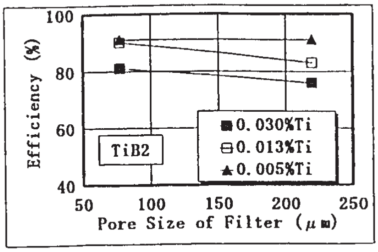

Fig.3 Effect of the Average Pore Size of the Filter on the Filtration Efficiency of TiB2

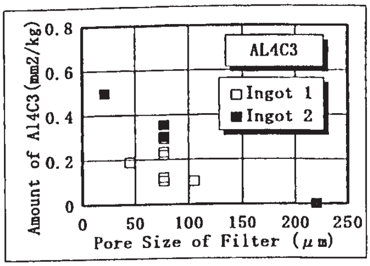

Fig.4 Effect of the Average Pore Size of the Filter on the Amount of Al4C3 Filtered

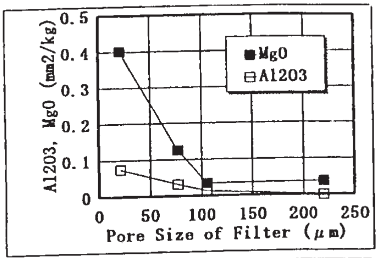

Fig.5 Effect of Average Pore Size of the Filter on the Amount of Al203 and MgO Filtered

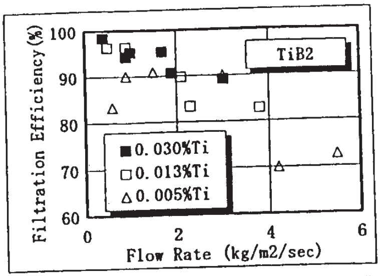

Fig.6 Effect og Flow Rate on the Filtration Efficiency of TiB2

3.2. Effect of Filtration flow rate

Fig. 6 shows the effect of flow rate on the filtration efficiency of TiB_2. The filtration is highly dependent on the flow rate. The efficiency decreases steeply with increasing flow rate. At the rate of 1 kg/m2/sec which is about the size of flow rate at the cast shop, more than 90% of TiB_2 is captured by 220 μ m-filter depending on the amount of TiB_2 added.

The effect of flow rate on the filtration efficiency of Al_4C_3 is shown in **Fig.7** and that of Al_2O_3 and MgO in **Fig.8**.The efficiencies of Al_4C_3, Al_2O_3, and MgO are little dependent on the flow rate not as in the case of TiB_2.

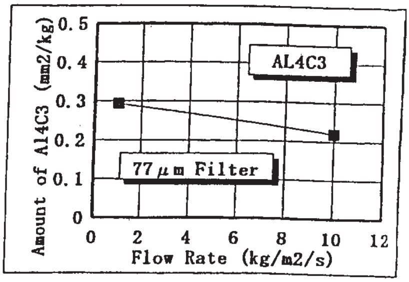

Fig.7 Effect of the Flow Rate on the Amount of Al4C3 Filtered

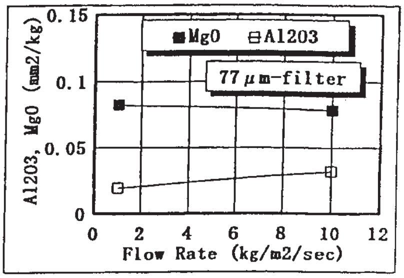

Fig.8 Effect of Flow Rate on the Amount of Al203 and MgO Filtered

3.3.Effect of filter thickness

The effect of filter thickness on the efficiency of TiB_2 is shown in **Fig 9**. The thicker the filter, the higher the efficiency.

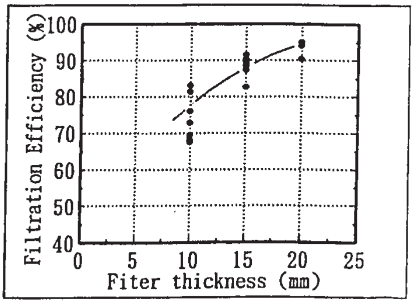

Fig 9. Effect of Filtration rate on the Filtration Efficieny

3.4. Distribution of Inclusions in the Filters

Photo.1 and **Photo.2** show the TiB_2 trapped on the surface of the filter and in the filter, respectively. The distribution of TiB_2 determined metallographically is shown in **Fig.10**. It is apparent from Photo. 1 , 2 and Fig.10 that TiB_2 are captured both on the surface and in the filter.

Distribution of Al_4C_3 in the filters are shown in **Photo.3** and in **Fig.11**. Most Al_4C_3 were captured near the surface of the filter and little were found in the filter.

Fig.12 shows the distribution of Al_2O_3 and MgO. The same distribution pattern as Al_4C_3 was obtained for Al_2O_3 and MgO.

3.5. Repetitive Filtration

Results of repetitive filtration test obtained for Al_4C_3 is shown in **Fig.13**. The amount of Al_4C_3 collected decreases drastically in the second filtration compare to that in the first filtration and almost no Al_4C_3 is found in the third filtration. The filtration efficiency of the first filtration was estimated to be 95%. The filtration efficiencies estimated for Al_2O_3 and MgO in the same way were 97% and 94%, respectively.

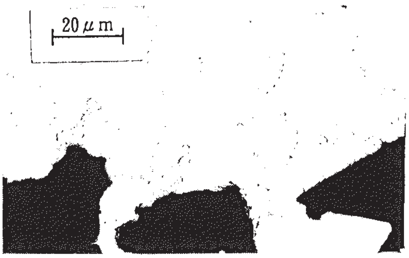

Photo.1 TiB2 Captured near the Surface of the Filter

4. DISCUSSIONS

4.1. Filtration Behavior

Results obtained on the filtration behaviors of the inclusions in this experiment are summarized in **Table 2**.

Table 2 Summery of the Filtration Behavior

Kind of Incl.	Effect of Filtration Condition			Distribution of Inclusion	
	Pore Size	Filtration Rate	Filter Thickness	Surface	inside
TiB2	small	big	big	○	○
Al4C3	big	small	small?	○	△
Al2O3	big	small	small?	○	△
MgO	big	small	small?	○	△

○ ; Considerable amount of inclusions was found.
△ ; Very little amount of inclusions was found.

The behaviors of Al_4C_3, Al_2O_3, and MgO are resemble each other, but quite different from that of TiB_2. The efficiency of TiB_2 is highly affected by the flow rate, but not much by the pore size. The efficiency of Al_4C_3, Al_2O_3, and MgO are, on the contrary, affected to a degree by the pore size, but little by the flow rate. Distribution of TiB_2 is also different from those of other three inclusions. TiB2 was trapped on the surface to form a cake and at the same time in the filter. Other inclusions deposit mostly on the surface.

It is apparent that a deeper filter is favorable for removing TiB_2 efficiently from the melts as shown in Fig 7. This is simply because TiB_2 are captured not only on the surface of the filter but also in the filter. Most of TiB_2 was found near the filter media as can be seen in Photo.2. It is probable that TiB2 was trapped by adsoaption on the surface of the filter media.

This might also explain the effect of flow rate on the filtration efficiency of TiB_2. Higher flow rate would generate a force to rip TiB_2 off the surface of the filter media

Although it hasn't been examined yet, the effect of filter depth on the filtration efficiencies of Al_4C_3, Al_2O_3, and MgO is supposed to be small, because they are trapped mostly on the surface of the filter.

4.2 Filtration Efficiency

Filtration efficiencies obtained for each inclusions are shown in **Table 3**. It was confirmed from the chemical analysis of acid insoluble Titanium (TiB2) before and after filtration that the efficiency of TiB_2 was reliable. More than 70% of TiB_2

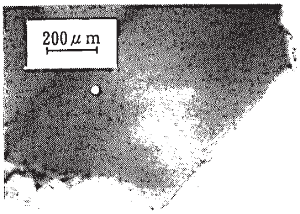

Photo.2 TiB2 Captured in the Filter

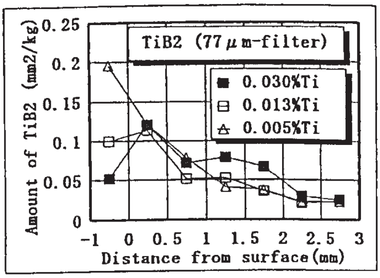

Fig. 10 Distribution of TiB2 in the Disk Filters

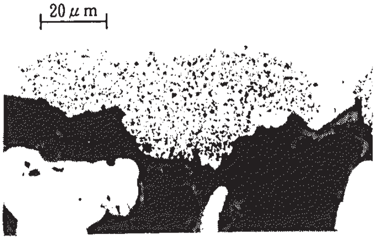

Photo.3 Al4C3 Captured near the Surface of the Filter

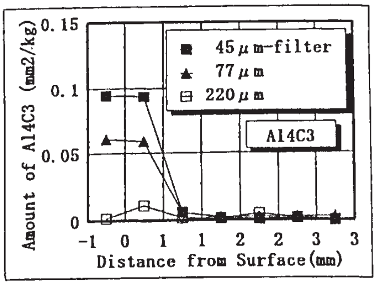

Fig. 11 Distribution of Al4C3 in the Disk Filters

which is added as a grain refiner are captured by RMF.

Table 3 Filtration Efficiencies Estimated

(%)

Pore Size	TiB2	Al4C3	Al2O3	MgO
(μm)	1 kg/m2/sec	1~40 kg/m2/sec		
21	–	95	97	92
77	80~90	43	43	25
220	75~91	0.2	0	8

The efficiencies of Al_4C_3, Al_2O_3, and MgO are estimated from the inclusion area on the filter, based on the efficiency obtained with the repetitive filtration. It is to be noted that most of Al_4C_3 and Al_2O_3 particles pass through the 220 μm-RMF, which is commonly used in the cast shop. Removal of MgO with 220 μm-RMF is also relatively low. In order to reduce these inclusions more efficiently from the melts, it is necessary to use a filter with a finer pore size. If more than one inclusion exist in the melt, the filtration efficiencies would be higher than those shown in Table 3.

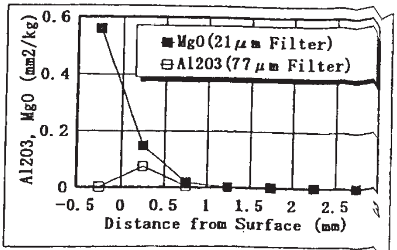

Fig. 12 Distribution of Al203 and MgO in the Disk Filters

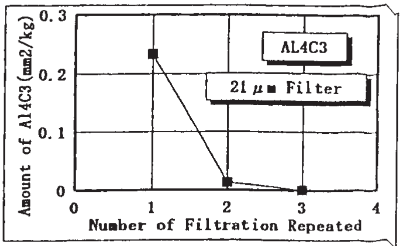

Fig. 13 Change in the Amount of Al4C3 Trapped with the Number of Filtration Repeated

Estimation of the efficiency from the repetitive filtration tests might not be completely reliable. Finer inclusions could pass through the filter even after the third filtration. If so, the filtration efficiency would be over estimated. And removal of these inclusions with RMF must be lower than those shown in Table 3.

4. CONCLUSIONS

(1) TiB2 was captured both on the surface and in the filter, whereas Al_4C_3, Al_2O_3, and MgO deposited mainly near the surface of the filter and very little in the filter.

(2) Filtration efficiency of TiB_2 with RMF was strongly affected by the flow rate, but little by the average pore size of the filter.

(3) Filtration efficiency of Al_4C_3, Al_2O_3, and MgO were, on the contrary, strongly influenced by the pore size, but little by the flow rate.

(4) As far as the melts contains only one spices of inclusion, RMF(220 μm) was found to be relatively inefficient for the filtration of Al_4C_3, Al_2O_3, and MgO.

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