THE INFLUENCE OF GRAIN REFINER ON DENDRITE ARM SPACING OF ALUMINUM ALLOY ADC 12

Bambang Suharno[1], Is Prima Nanda[2], Sri Harjanto[1] and Erika Lirachandra[1]

[1]Department Metallurgy and Materials, Faculty of Engineering, University of Indonesia
Kampus UI, Depok 16424
[2]Mechanical Engineering Department, University of Andalas
Kampus Limau Manis, Padang 25163

ABSTRACT

THE INFLUENCE OF GRAIN REFINER ON DENDRITE ARM SPACING OF ALUMINUM ALLOY ADC 12. ADC 12 is the common used materials for die casting process in producing automotive components. Grain refiner was added to aluminum ADC 12 to increase mechanical properties by decreasing grain size and improving fine distribution of gas porosity. Grain refiner also give positive effect in aluminum fluidity, where the proper addition of grain refiner will increase the fluidity. The purpose of present research is determining correlation between grain refiner addition and dendrite arm spacing, which also indirectly related to the grain size. 100% scrap of aluminum ADC12 and Al5Ti1B grain refiner were used as raw materials. Melting process has been done in a 1400 gr crucible with cokes and oxygen as the fuming energy. Argon was introduced into crucible at least in 1 minute for degassing. After degassing process accomplished, 0, 0.05, 0.1, 0.15, 0.2 % grain refiner Al5TiB, which have been choosen as experimental variable, were charged into crucible. Vacuum suction machine has been utilized to measure the aluminum fluidity at 680 ^{0}C, the common ADC 12 pouring temperature. Samples for microstructural analysis were tooken at the tip of specimen from vacuum suction test. Measurement of dendrite arm spacing (DAS) was conducted by SIGMA SCAN Pro.5 Software. The result indicated that at 680 ^{0}C, the addition up to 0.15% Al5Ti1B grain refinement reduced 50% dendrite arm spacing from 8.8 ìm (without grain refiner) to 4.5 ìm. Over 0.15% Al5Ti1B, the refinement stopped and DAS increased caused by the complex intermetallic phase (Ti-Al, Ti-B) has nucleated from the excess grain refiner.

Key words : Grain refiner, dendrite arm spacing, fluidity, aluminum alloy ADC 12

ABSTRAK

PENGARUH *GRAIN REFINER* TERHADAP *DENDRITE ARM SPACING* PADUAN ALUMINIUM ADC 12. ADC 12 adalah material yang biasa dipergunakan untuk memproduksi komponen otomotif dengan proses *die casting*. *Grain refiner* ditambahkan pada aluminium ADC 12 untuk meningkatkan sifat mekanik melalui penghalusan ukuran butir dan pendistribusian porositas gas menjadi lebih kecil. *Grain refiner* juga memberi pengaruh positif terhadap fluiditas aluminium. Penambahan sejumlah optimal *grain refiner* akan meningkatkan nilai fluiditas. Tujuan dari penelitian ini adalah untuk menentukan hubungan antara penambahan *grain refiner* terhadap *dendrire arm spacing* (jarak antar lengan struktur *dendrite*), dimana hal ini juga berhubungan erat dengan ukuran butir. Bahan yang digunakan dalam penelitian ini adalah 100% *scrap* aluminium ADC 12 dan *grain refiner* berupa batangan Al5Ti1B. Proses peleburan dilakukan pada *crusible* sebanyak 1400 gram yang dilebur dengan menggunakan pembakaran briket batubara. Proses *degassing* (pengeluaran gas hidrogen) dilakukan dengan cara meniupkan gas argon selama 1 menit kedalam cairan aluminium. Setelah itu *grain refiner* Al5Ti1B sebanyak 0, 0,05 %berat, 0,1 %berat, 0,15 %berat dan 0,2 %berat, dimasukan ke dalam *crusible*. Alat uji fluiditas *vacuum suction* digunakan untuk mengukur fluiditas pada suhu 680 ^{0}C yakni suhu yang biasa digunakan untuk suhu tuang ADC 12. Sampel untuk pengamatan strukturmikro diambil dari spesimen pengujian fluiditas. Pengukuran *dendrite arm spacing* (DAS) dilakukan dengan menggunakan SIGMA SCAN Pro.5 *Software*. Hasil pengujian menunjukkan bahwa pada suhu 680 ^{0}C dan penambahan *grain refiner* hingga 0,15% Al5Ti1B dapat mengurangi 50% ukuran *dendrite arm spacing* yakni dari 8,8 μm (tanpa *grain refiner*) menjadi 4,5 μm (dengan 0,15% *grain refiner*). Diatas 0,15% Al5Ti1B efek penghalusan berhenti, DAS akan meningkat kembali akibat fasa intemetallik (Ti-Al, Ti-B) ini tidak lagi membentuk nukleasi yang aktif yang dapat menghaluskan ukuran butir.

Kata kunci : Penghalus butir, *dendrite arm spacing*, fluiditas, paduan aluminium ADC 12

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INTRODUCTION

ADC 12 is the common used material for die casting process in producing automotive components. Grain refiner was added to aluminum ADC 12 to increase mechanical properties by decreasing grain size and improving fine distribution of gas porosity [1,2]. Grain refiner also give positive effect in aluminum fluidity, where the proper addition of grain refiner will increase the fluidity [3,4,5]. The purpose of present research is determining correlation between grain refiner addition and dendrite arm spacing (DAS), which also indirectly related to the grain size.

Controversial result on the effect grain refiner on dendrite arm spacing have been reported in litterature. A.M Glenn [6] showed that the relationship between dendrite arm spacing and local solidification time was also found to be independent of grain refining TiB_2 on material aluminum AA5182. John E. Gruzleski [2] also stated same correlation between DAS and the grain refiner without an materials explaination. On the other hand, John Campbell [7] in his research found that grain refiner effected the refinement of dendrite arm spacing as concequences to the refinement of the grain size.

EXPERIMENTAL METHOD

100% scrap of aluminum ADC12 and Al5Ti1B grain refiner were used as raw materials. Melting process has been done in a 1400 g crucible with cokes and oxygen as the fuming energy. Flux was added to the liquid aluminum to prevent hydrogen adsorbtion. Argon was introduced into crucible at least in 1 minute for degassing. After degassing process accomplished, 0%, 0.05%, 0.1%, 0.15%, 0.2% grain refiner Al5TiB, which have been choosen as experimental variable, were charged into crucible. Vacuum suction machine has been utilized to measure the aluminum fluidity at 680 ^{0}C, the common ADC 12 pouring temperature. The main parts of vacuum suction test apparatus is depicted in Figure.1. Samples for microstructural analysis were tooken at the tip of specimen from vacuum suction test. Dendrite arm spacing was measured by SIGMA SCAN Pro.5 Software.

RESULTS AND DISCUSSION

Microstructure Observations

Figures 2 – 6 shows the microstructure of ADC 12 without and with 0.05% - 0.2% grain refiner Al5Ti1B addition

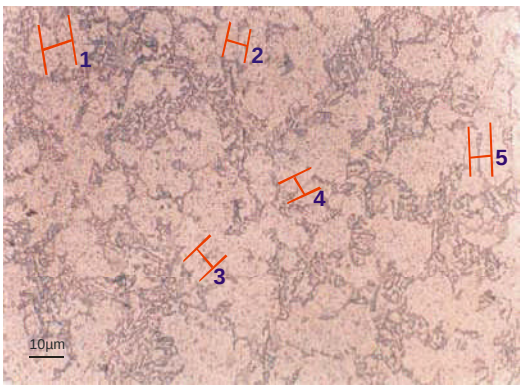
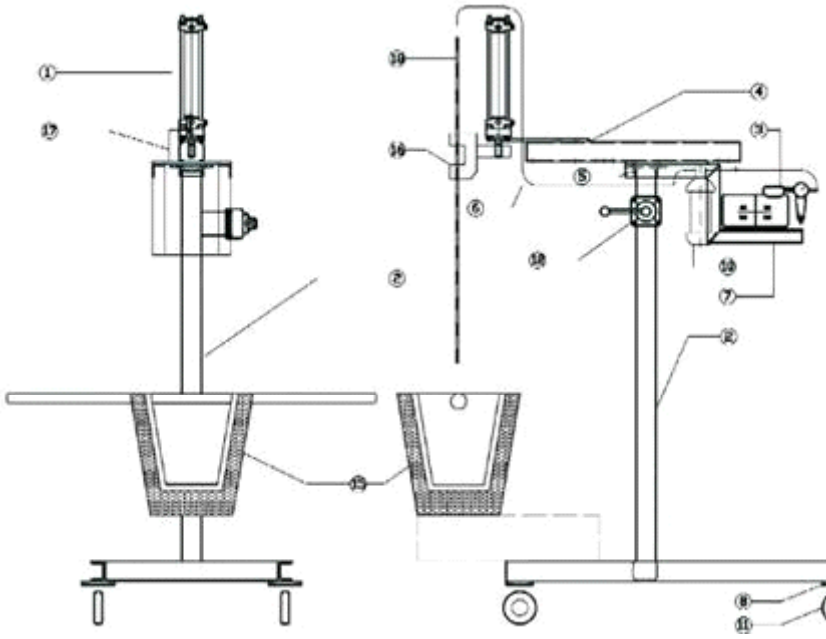


Figure 2. ADC 12 microstructure (500x) without grain refiner Al5Ti1B addition



1. *Air cylinder*
2. *Frame*
3. *Vacuum pump*
4. *Adjustable support*
5. *Rotary support*
6. *Hose*
7. *Mounting table*
8. *Wheel bracket*
9. *Hand valves bracket*
10. *Vacuum chamber*
11. *Wheels*
12. *Hand valves 4/3 way*
13. *Togle valve 3/2 way*
14. *Limits valve 3/2 way*
15. *Crusible set*
16. *Clamping pipe*
17. *Clamping support*
18. *Tubing test*

Figure 1. Vacuum suction test apparatus

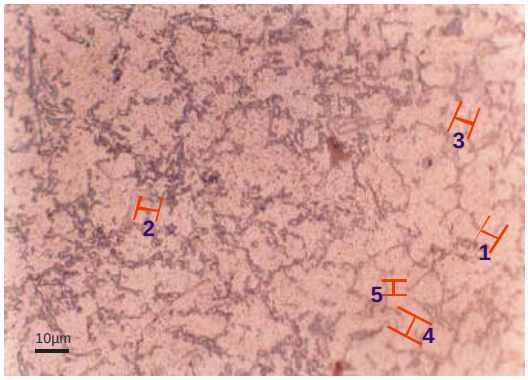


Figure 3. ADC 12 microstructure (500x) with 0.05% grain refiner AL5TI1B addition

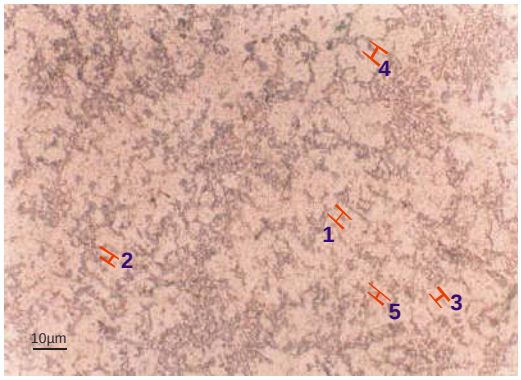


Figure 5. ADC 12 microstructure (500x) with 0.15% grain refiner AL5TI1B addition

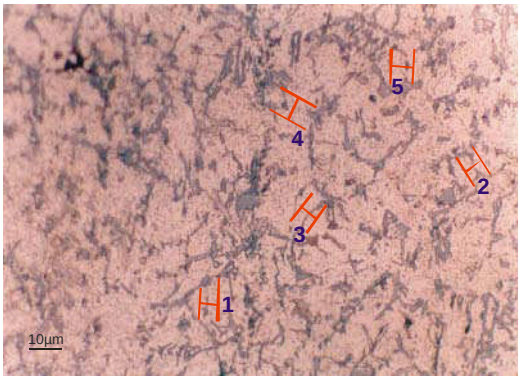


Figure 4. ADC 12 microstructure (500x) with 0.1% grain refiner AL5TI1B addition

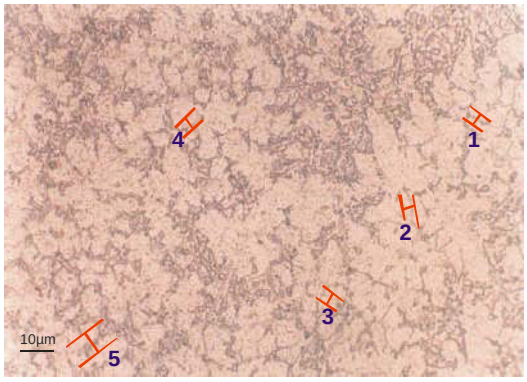


Figure 6. ADC 12 microstructure (500x) with 0.2% grain refiner AL5TI1B addition

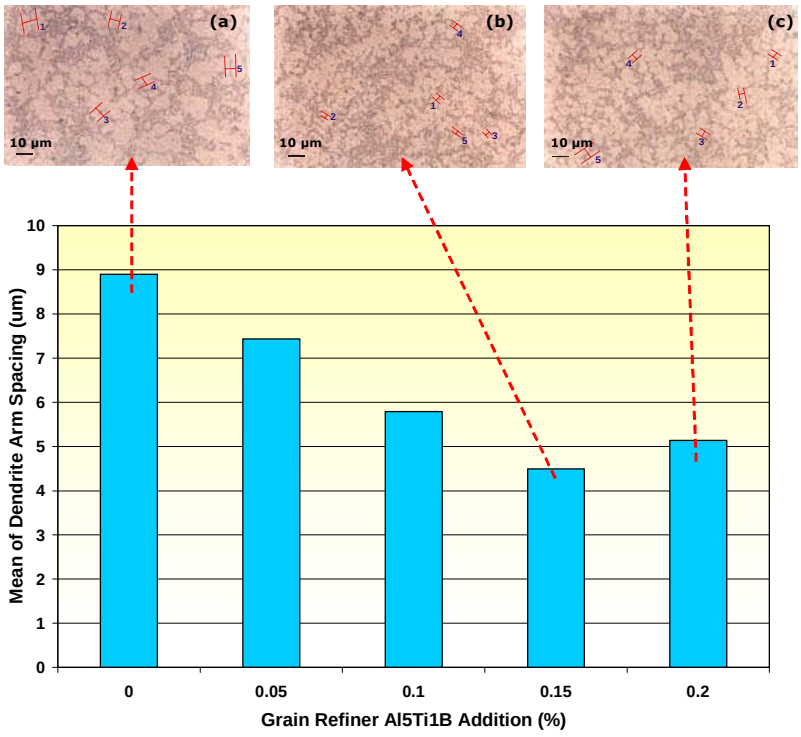


Figure 7. The rellationship between grain refiner addition and dendrite arm spacing.

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Dendrite Arm Spacing Measurement

The measurement of dendrite arm spacing can be shown in Table 1.

Tabel 1. Dendrite Arm Spacing (DAS) measurement.

	0% AlTiB (A)	0.05% AlTiB (B)	0.1% AlTiB (C)	0.15% AlTiB (D)	0.2 % AlTiB (E)
Point 1	11.080	7.913	7.162	4.194	3.825
Point 2	8.865	7.008	5.817	3.324	5.102
Point 3	9.003	7.747	6.388	5.442	4.244
Point 4	7.544	8.660	4.774	5.738	5.312
Point 5	7.957	5.835	4.774	3.751	7.216
Mean of DAS	8.890	7.433	5.783	4.490	5.140

Discussion

Based on the function, addition of Al5Ti1B grain refiner has a significant effect to grain refinement process. It is possible that the size of grain can be considerably larger than the dendrite arm spacing but, of course, the reverse is not possible. The grain also correlated directly to DAS, where the small grain size will also have a small dendrite arm spacing [7].

Metallography observation had been revealed that general structure of ADC 12 aluminum consisted of two phases. The dark region are eutectic silicon and the other are eutectic aluminum phases. Dendrites can be also observed in final microstructure which indicated that this materials are casting products.

Based on Figure. 2-6, it is clearly shown that DAS decreased with the proper addition of grain refiner Al5Ti1B, 0.15%. Over that amount, the refinement stoped and DAS grew larger.

The refinement mechanism of DAS can be quantitative found by measuring its distance in the microstrucure [8]. In this reseach, SIGMA SCAN Pro.5 Software was used to calculate DAS by drawing an upright line between two dendrite arm equal devide lines. From the calculation, a graphic can be made, as can be seen in Figure. 7. It is depicted that the addition of 0.15% Al5Ti1B grain refinement reduced 50% dendrite arm spacing from 8.8 ìm (without grain refiner) to 4.5 ìm at 100% scrap of ADC 12 aluminum.

Dendrite arm spacing refinement phonomena has a correlation with grain refinement mechanism. The addition of grain refiner increased the number of nucleant for homogeneous nucleation thus, it reduced the grain size after solidification process accomplished. As the result, addition a proper amount of grain refiner will lead to a small DAS

The optimalization of the grain refiner capabillity to reduce dendrite arm spacing was achieved when the amount of nucleant $TiAl_3$ and TiB_2 in liquid aluminum enough for nucleation. Over those amount, nucleants in liquid aluminum are not capable anymore to be activated because the interfacial energy become lower [2], thus, complex intermetallic phase which has nucleated from the excess grain refiner will lead into increasing Dendrite Arm Spacing [2,9,10].

CONCLUSIONS

Based on this experiment, the result indicated that addition of Al5Ti1B grain refinement until 0.15% reduced 50% dendrite arm spacing from 8.8 ìm (without grain refiner) to 4.5 ìm, at 680 ^{0}C. Excessive addtion of grain refiner was followed by halting refinement effect and increasing dendrite arm spacing which caused by nucleation of complex intermetallic phase from the excess grain refiner.

ACKNOWLEDMENTS

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