논 문

The Effect of Solid Fraction on the Casting Formability in Vertical Type Squeeze Casting Process

Pan-Ki Seo, Sung-Man Sohn*, and Chung-Gil Kang**†

NSC Ind., Jinhae-si, Kyungsangnam-do 645-480, Korea
*SUNGWOO HITECH, Kijang-gun, Busan 940-15, Korea
**School of Mechanical Engineering, Pusan National University, Busan 609-735, Korea

Abstract

레오다이캐스팅 공정은 용탕상태의 원소재로부터 최종형상에 가장 가까운 정형제품 (near-net shape) 을 원하는 기계적 성질과 동시에 경제적으로 생산할 수 있는 제조방법으로 개발되어 왔다. 본 논문에서는 전자교반 시스템을 이용하여 결정립이 제어된 반용융 상태의 소재를 수직형 다이캐스팅기를 사용하여 리어파트 (rear parts) 자동차 부품을 성형실험 하였다. 성형된 시제품들은 성형조건에 따른 조직 및 인장강도를 관찰하였으며, 시효경화 시간에 따른 T6 최적 열처리 조건을 조사하였다.

Key words : Rheo-diecasting, Electromagnetic Stirring

(Received April 3, 2007 ; Accepted January 20, 2008)

1. Introduction

Electromagnetic stirring is a forming process which, by strongly stirring the molten metal at the initial stage of solidification, transforms the dendritic microstructure to fine spherical particles close to globules [1-3]. Due to good rheological fluidity and low deformation resistance of the semi-solid material during processing, it is possible to form a near-net shape production of engineering parts in complicated shapes [4,5]. A study of a vertical-type squeeze casting process has not been reported so far, although a study of the rheological processing technique and horizontal die casting process using rheology materials has been reported [6,7]. Thus, in this study, the solid fraction of rheological materials is controlled by using EMS, and the manufacture and the performance of the vertical-type squeeze casting process is demonstrated by fabricating automobile components using the rheological materials.

2. Experimental

A356 alloy was adapted for the experiment because it, Si series cast material, is widely used in casting and forging because it has good fluidity and a wide range between solidus and liquidus line. Figure 1 shows the experimental sequence for EMS. The material was melted in the furnace for the stirring experiment. The degassing treatment was performed by using nitrogen gas after reached a pre-determined temperature was reached. After an electrical current was applied to the cup as the melt was poured into it. The parameters of the experiment, to form the rheological materials, were performed by varying the stirring time, stirring current, and initial temperature of the melt. The manufacture of rheological material was manufactured based on the author's extensive experience in rheology study. Rheological diecasting was performed using a stirring current of 80 A, a stirring time of 60 sec, and pre-determined temperature of 715°C [8,9].

3. Results and Discussion

3.1 Rheocasted Rear Parts of A356 Alloy

Figure 2 shows the photographs of the microstructures of the rear part fabricated by rheocasting with A356 alloy, and Figure 3 shows the photographs of microstructures of rear part fabricated by squeeze casting. Figure 2 C and E compare the microstructures of the products produced by squeeze casting and rheocasting. As can be seen, there is less dendrictic globular microstructure in the rheocasting products than in the squeeze cast product. The fine and spherical primary microstructure can be obtained because the dendtritic microstructure is destroyed by EMS and the viscosity of solid-liquid phase is higher than that of liquid phase [10].

†E-mail : cgkang@pusan.ac.kr

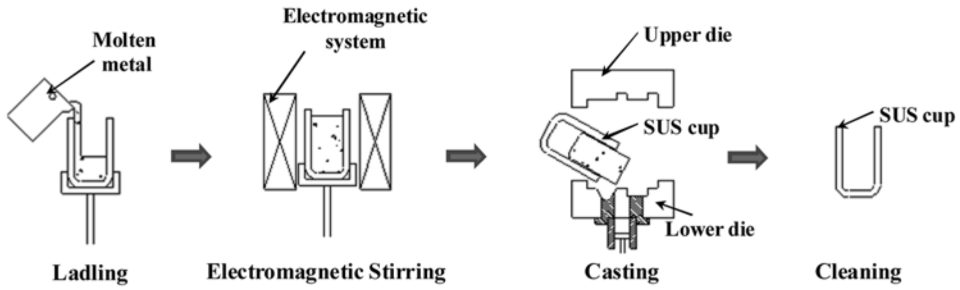

Fig. 1. The Progress of the experimental for electromagnetic stirrer.

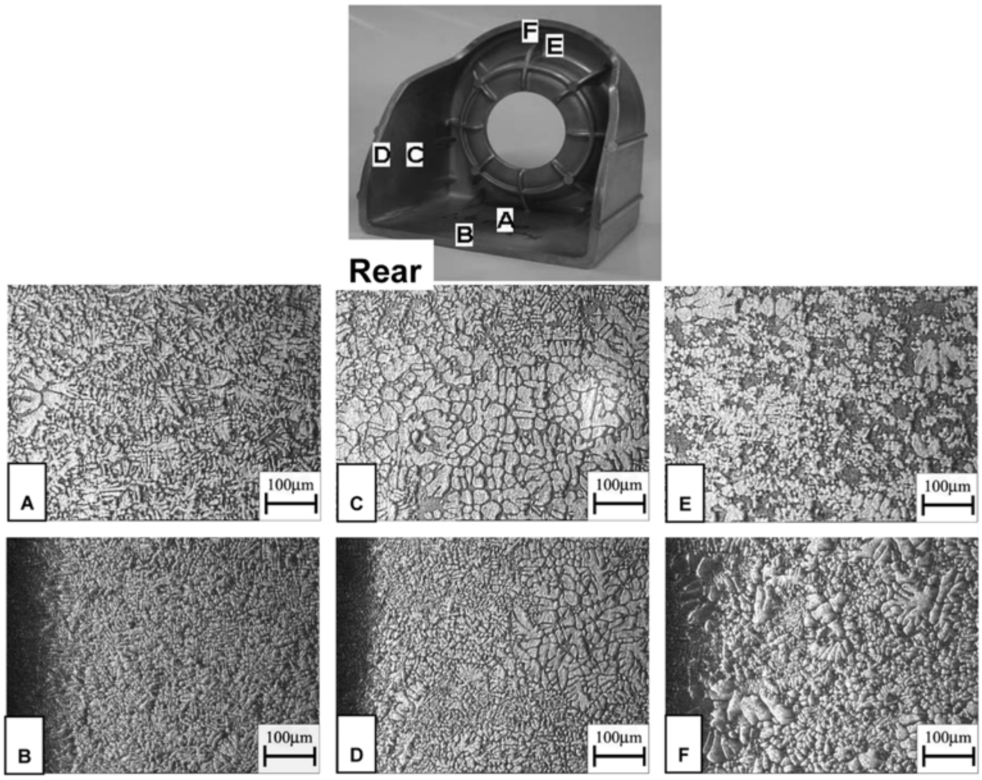

Fig. 2. Microstructures of rear part fabricated by rheocasting with A356 alloy.

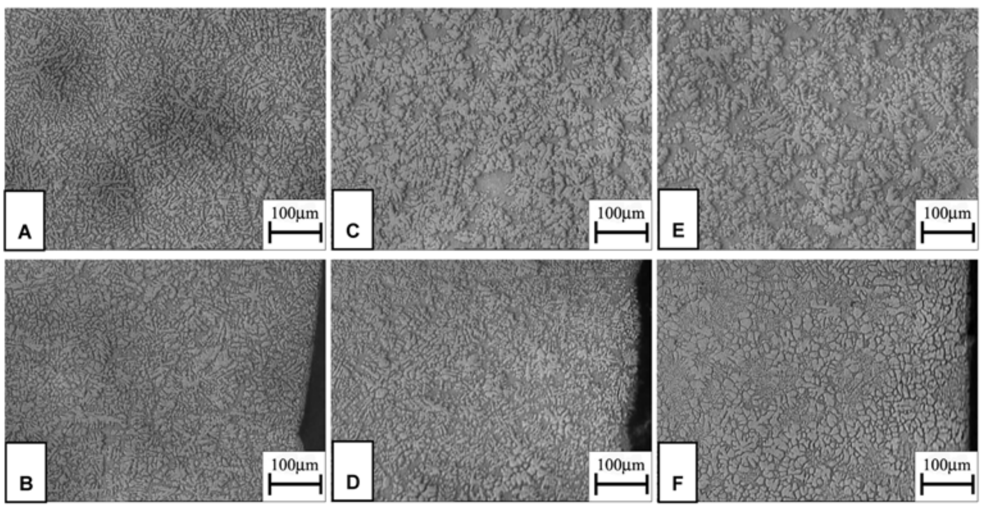

Fig. 3. Microstructures of rear part fabricated by squeeze casting with A356 alloy.

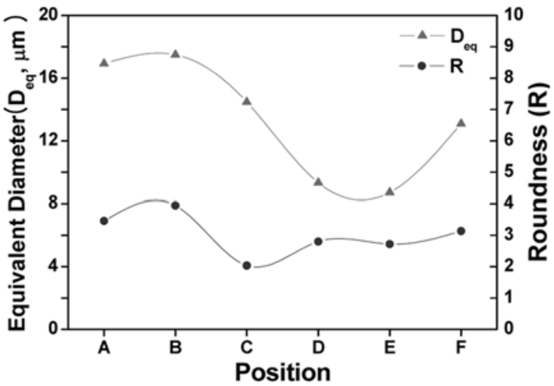

Fig. 4. The comparison of mean roundness and primary α phase size at each position in rheocasting rear part.

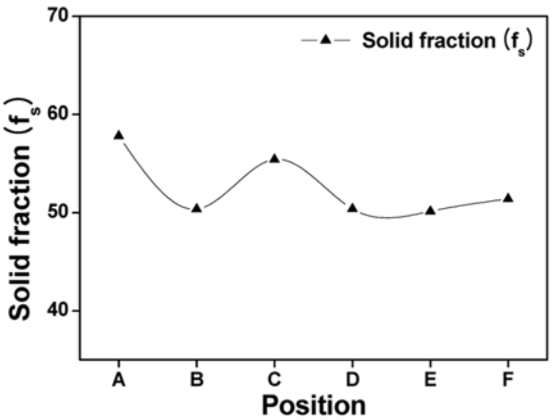

Fig. 5. The comparison of solid fraction at each position in rheocasting rear part.

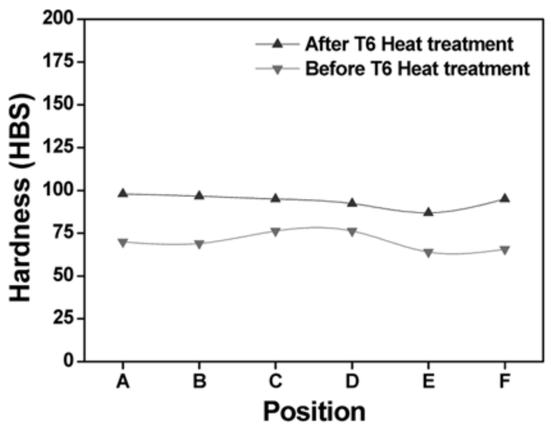

Fig. 6. Hardness of rear part fabricated by rheocasting at each position.

3.2 Image Analysis

The microstructures of rheocast materials were observed by optical microscopy (OLYMPUS BX60M) and then the photographs were taken by Leica MW S/W. The mean equivalent diameter, mean roundness, and solid fraction were investigated using the results of the optical microscopy. Figure 4 compares the mean roundness and primary a phase size at each position in A356 rheocasting rear part. The mean roundness and primary a phase size decreases in proportion to the distance with which the melt is filled. The longer the distance the more rapid the solidification will be, and thus the growth time for the primary a phase is decreased. Consequently, the primary α phase size decreases. In addition, there is little difference by position of the sample in the spheroidization intensity of primary a phase. Figure 5 shows the variation of the solid fraction at each position in A356 rheocasting rear part. Eutectic segregation increases at positions B, D, E, and F which have a comparatively long flow distance and a late cavity filling in comparison with positions A and C for which the flow into the die cavity is relatively smooth and easy. Therefore, if the solid fraction increases as much as it can, an increase of uniform and fine microstructure evolution and decrease of segregation phenomena can be expected.

3.3 Hardness Measurement

Figure 6 shows the hardness distribution various position of the rear part fabricated by rheocasting of A356 alloy. The mean value of measured hardness is evaluated by 70 (HBS). The hardness value is relatively high at position D because the eutectic phase is uniformly distributed compared to that of the other positions. At positions E and F, the hardness value tends to decrease, although the eutectic phase increases. It is possible that porosity will occur in the final filling positions and the hardness value appears to decrease due to the irregular distribution of the eutectic phase. The hardness values of A356 alloy after and before T6 heat treatment were measured under for 3 hrs at 520°C and 6 hrs at 170°C, and the results are found to be 70 (HBS) and 94 (HBS), respectively.

4. Conclusions

The following conclusions were made regarding parts design, prototype fabrication, and phase analysis during rheocasting to fabricate a sprocket tower rear which had been fabricated by conventional steel specification:

(1) Forming parameters such as stirring time, stirring current, and stirring temperature are derived to form the slurry by EMS for the rheocasting process.

(2) Using the designed and fabricated front and rear die, rear parts of A356 alloy was fabricated through squeeze casting and rheocasting, and the engineering basis for mass production were established.

Acknowledgement

This work was supported for two years by Pusan National University Research Grant.

References

[1] Charles Vives: J. of Crystal Growth, “Crystallization of Semi-solid Magnesium Alloys and Composites in the Presence of Magnetohydrodynamic Shear Flows”, 137, 1994, 653-662.

[2] Charles Vives: Metall. Trans. B, “Elaboration of Metal Matrix Composites from Thixotropic Alloy Slurries Using a New Magnetohydrodynamic Caster”, 24B, 1993, 493-510.

[3] B. Niedermann: the 6th Int. Conf. on Semi-Solid Proc. of Alloys Composites, “The Semi-Solid Metal (SSM) Casting Process”, eds. G.L. Chairmetta and M. Rosso, Turin, Italy, 2000, 641-647.

[4] S. B. Brown and M. C. Flemings: Adv. Mater. & Proc., “Net Shape Forming via Semi-Solid Processing”, 143, 1993, 36-40.

[5] Y. B. Yu, P. Y. Song, S. S. Kim and J. H. Lee: Scripta Mater., “Possibility of improving tensile strength of semi-solid processed A356 alloy by a post heat treatment at an extremely high temperature”, 41(7), 1999, 767-771.

[6] Z. Fan, X. Fang and S. Ji: Mater. Sci. & Eng. A, “Microstructure and mechanical properties of rheo-diecast (RDC) aluminium alloys”, 412(1-2), 2005, 298-306.

[7] M. Adachi and S. Sato: SAE 2000 World Congress, “Advanced Rheocasting Process Improves Quality and Competitiveness”, Michigan, 2000, 21-25.

[8] J. W. Bae, T. W. Kim and C. G. Kang: J. of Mater. Proc. Tech., “Experimental investigation for rheology forming process of Al-7% Si aluminum alloy with electromagnetic system”, 191, 2007, 251-255.

[9] C. G. Kang, J. W. Bae and B. M. Kim: J. of Mater. Proc. Tech., “The grain size control of A356 aluminum alloy by horizontal electromagnetic stirring for rheology forging”, 187-188, 2007, 344-348.

[10] D. H. Rho, S. M. Lee and C. P. Hong: J. of Korea Foundrymen’s Soc., “Solidification Characteristics of an Al-7wt%Si Alloy Produced by Pressurization in the Semi-Solid State After Stirring”, 19(2), 1999, 123-133.