Effect of T6 Treatment on Microstructures and Mechanical Properties of Semi-Solid A356 Alloy

Jun Zhou, Caihua Wang*, Larry Wang
Guangdong Provincial Key Laboratory of Intelligent Molding Equipment Enterprises, Yizumi Holdings Co. Ltd.
*Corresponding address: e-mail: larry.wang@yizumi.com

Abstract: In this work, the semi-solid A356 alloy was prepared by SEED semi-solid pulping process, and effect of T6 treatment on microstructures and mechanical properties were studied by optical microscopy (OM), scanning electron microscopy (SEM), X-ray diffraction (XRD) and other methods. The results indicated that the phase composition of A356 alloy remained unchanged after the T6 treatment, and included α-Al matrix, eutectic Si, and Mg_2Si phases, while, the solid phase fraction (S) of the alloy increased from 66% to 75%, and the shape factor (F) decreased from 0.7 to 0.6, and the mechanical properties significantly improved. The tensile strength (UTS), yield strength (YS), and elongation (EL) of the T6-A356 alloy was 310MPa, 245MPa, and 12.1%, respectively.

Keywords: A356 alloy; rheological forming;microstructure; mechanical properties; high solid faction.

1 Introduction

A356 aluminum alloy is a hypoeutectic alloy with Si and Mg as the main alloying elements, which has good fluidity and a wide temperature range in the two-phase zone, and is commonly prepared by the semi-solid metal forming. Due to its lightweight, excellent mechanical strength, ductility, fatigue performance, compactness and workability, A356 aluminum alloy is becoming more and more attractive in the automotive and aerospace industries [1-2]. The present study prepared the semi-solid A356 alloy by SEED semi-solid die-casting, and studied the influence of T6 treatment on microstructure evolutions and mechanical property changes.

2 Experimental procedure

The A356 commercial alloy ingot was melted at 760 ℃ and kept for 30 minutes. Then, 15 minutes of rotational degassing was performed under argon gas protection. The hydrogen content of aluminum melt was measured, and kept the qualified melt insulated at 630 ℃. The chemical composition of the qualified melt is shown in Table 1.

Pouring the above melt into the SEED crucible by the robotic arm for slurry production. The principle of SEED pulping process is shown in Fig. 1[3]. The LEAP-840T die-casting machine from YIZUMI company was used to cast the slurry. The slow and fast injection speeds was 0.5m/s and 1.5m/s, respectively. The boost pressure was 100MPa. The T6 treatment condition was 540 ℃ × 2h + 170 ℃ × 4h.

Table 1. Composition of Aluminum Melt (wt.%)

Si	Cu	Mg	Mn	Fe	Ti	Al
6.46	< 0.0002	0.34	< 0.0005	0.082	0.09	Bal

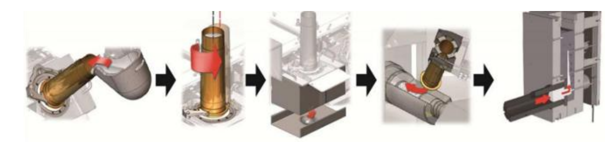

Fig. 1 SEED pulping process principle [3]

The microstructure of the semi-solid A356 alloy were characterized by Zeiss optical microscopy (Smart-zoom 5), field emission electron scanning electron microscopy (S4800), and X-ray diffraction (Smart Lab 9kw XRD). Using Metallographic analysis software to statistic and calculate the primary phase α-Al The solid phase fraction (S) and shape factor (F) of Al are calculated using formulas (1) and (2) [4].

$$S = NA_0/A_S \quad (1)$$

$$F = \left[\Sigma p_0^2 \,/\, (4\pi A_0)\right] / \,N \quad (2)$$

3 Result and discussion

Effect of T6 treatment on Microstructures of A356

Figure 2 shows OM images, SEM-EDS images, and XRD patterns of as-cast and T6-treated A356 alloys. It can be seen that after SEED and semi-solid rheological die-casting, both as-cast and T6-treated A356 alloys have non-dendritic structures with uniform distribution of primary phases, while T6 treatment has minor impact on grain sizes, and the solid phase fraction (S) and shape factor (F) of the T6-treated and as-cast alloys are 75% and 66%, 0.6 and 0.7, respectively.

Among them, the as-cast A356 alloy mainly contains nearly spherical α-Al, black fishbone Mg_2Si eutectic phase (point A) and lath eutectic Si. After T6 treatment, the Mg_2Si phase between the original grains dissolves and enters in the α-Al matrix, the original lath eutectic Si breaks while short rod or near spherical eutectic Si (point B) appears.

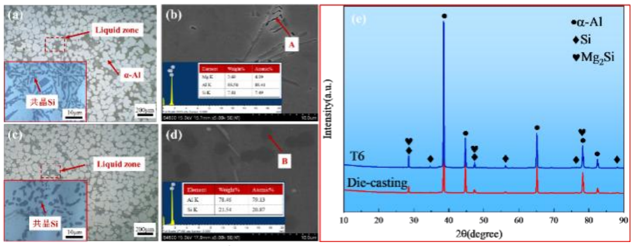

Fig.2 microstructure of A356 alloy: As-cast (a, b); T6 (c, d); XRD patterns (e)

Effect of T6 treatment on Mechanical Properties of A356

Table 2 shows mechanical properties of semi-solid A356 al loys at the room temperature. It can be seen that after T6 tre atment, there's significant increase in the tensile strength (R_m) and yield strength ($R_{p0.2}$) of the alloy, which increases fro m 210 MPa and 115 MPa to 310 MPa and 245 MPa, respec tively, while the elongation (A) decreases from 14.4% to 12. 1%. That is to say, the performance indicators of semi-solid T6-A356 alloy are generally higher than the lower limit of the current standard 《GB/T40809-2021 Casting aluminum alloys-Process specification forsemisolid rheo-diecasting f orming》.

Before T6 heat treatment, fishbone Mg_2Si is mainly distributed between α-Al grains. However, after T6 heat treatment, most of Mg diffuses in the matrix and distributed more uniformly, besides, a small portion of Si dissolves into the α-Al matrix. The above changes formed solid solution strengthening effect, improving the R_m and $R_{p0.2}$ of the alloy significantly. Meanwhile, most of the eutectic Si between Al grains transforms into eutectic Si. It should be noted, the small and dispersed short rod-shaped or nearly spherical eutectic Si in the α-Al matrix, hindering the dislocation movement more seriously, and resulting in a significant increase in the $R_{p0.2}$ of the alloy. This is consistent with the research results of PENG[5].

Table 2 Mechanical Properties of semi-solid A356

Alloys	UTS/MPa	YS/MPa	EL%
A356	210	115	14.4
T6-A356	310	245	12.1

4 Conclusion

(1) Microstructures of both as-cast and T6-treated A356 alloys are composed of α-Al matrix, eutectic Si, and Mg_2Si phases. The solid phase ratio and shape factor of α-Al is 66% and 75%, 0.7 and 0.6, respectively.

(2) T6-treated A356 alloy exhibits superior mechanical properties with R_m, $R_{p0.2}$, and A of 310MPa, 245MPa and 12.1%, which is overall higher than the lower limit values specified by the national standard for semi-solid rheological die castings.

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