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Structural evolution of non-dendritic AlSi7Mg alloy during reheating①

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Abstract: The structural evolution of non-dendritic AlSi7Mg alloy during reheating in resistance furnace was studied. The alloy ingots were produced by electromagnetic stirring during solidification. It was found that, the Si phase in eutectic dissolves in a way of diffusion toward α phase, its appearance changes from flake to dot-like, and tends to be fine and spheroidal with increasing reheating temperature. The thinner the flake, the lower the temperature for the occurrence of this process, and the higher the transforming speed. The eutectic melts partially when Si phase dissolves to some extent, and the morphology and size of primary α phase begin to change. The dendrite and rosette α phases tends to sphericize. The size of the former becomes larger, while the size of the latter reduces to be 1/2 ~ 1/4 of the original size. The spheroidal primary α phase has a tendency of grain growth.

Key words: aluminum alloys; reheating; non-dentritic structure; transformation **Document code: A**

1 INTRODUCTION

Metal forming in the semi-solid state is now becoming a new generation metal forming process for its easy to realize near net shape forming, prolonged mold life, reduction in solidification shrinkage, porosity and segregation, as well as its non-dendritic microstructure and finer grain size within the formed parts, when compared with conventional forging and high pressure die casting[1~3]. Semi-solid metal forming is composed of three main processes, that is, semi-solid materials production, partial remelting and thixoforming. Among those, the semi-solid billets production, that is to obtain billets with non-dendritic microstructure which can behave thixotropic characteristic after proper partial remelting treatment, becomes the basis and key to the whole process. The semi-solid billets were produced by electromagnetic stirring and strain induced melt activation (SIMA) commercially[4,5]. It was used to make some important automobile parts mainly with aluminum, magnesium alloys. Semi-solid forming with other materials such as stainless steel, tool steel, copper alloy, aluminum alloy with high silicon content, zinc-aluminum alloy as well as metal matrix composites are also under research and development[6~10].

The transformation behavior of non-dendritic microstructure during reheating and whose microstructure is easy to be reheated to restore good thixotropic characteristic, determine the advantages of the semi-solid metal forming. There is little report about this. In this paper special attention has been focused on the structural evolution of different microstructure during reheating to provide guide for the formulation of reasonable reheating process.

2 EXPERIMENTAL

The non-dendritic AlSi7Mg (Al-7.0%Si-0.6%Mg) alloy billets with the size of d60 mm × 1 600 mm, which was produced on self-devel-

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oped demonstration line for semi-continuous rheocasting through electromagnetic stirring, was cut into pieces with a thickness of 2 mm from cross-section. The furnace for reheating was resistance furnace with a power of 1.5 kW and size of d100 mm × 160 mm. The chamber of the furnace was controlled to be in range of 700 ~ 710 ℃ by a voltage regulator. Then the sample piece was put flatly in the center of the furnace and the temperature rising was recorded by a thermocouple. When the sample reached the designed temperature, it was put out immediately for water quenching, and then was made to be optical metallograph specimens for microstructure observation.

3 RESULTS AND DISCUSSION

Fig.1 shows the optical microstructures of non-dendritic AlSi7Mg alloy. It can be seen that, at the center, the primary α phase is near spheroidal, the α + Si eutectic is fine flake (Fig. 1(a)). In Fig.1(b), the left half is near the center, its primary α phase appears coarse rosette; the right half is near the ingot surface, its primary α phase appears fine equiaxial dendrite.

3.1 Evolution of typical spheroidal grain structure

Fig.2 shows the structural evolution of typical non-dendritic AlSi7Mg alloy after being reheated to 540, 568, and 577 ℃. Compared with the microstructure before reheating (Fig.1(a)), it is found that when reheating temperature is above 540 ℃, the Si phase in the α + Si eutectic dissolves in a way of diffusion toward α phase severely, its morphology changes from flake to dot-like, as shown in Fig.2(a). When the treating temperature increases to about 568 ℃, the eutectic melts on the whole (Fig.2(b)). The treating temperature further increasing to 577 ℃, the primary α phase shows a tendency of grain growth.

3.2 Evolution of rosettelike grain structure

Fig.3 shows the microstructure of rosettelike grain after being reheated to 540, 568, and 577 ℃. The rosettelike grain structure is formed by agglomeration of several primary α particles, the eutectic appears coarse flake. This kind of structure is a non-dendritic structure, which is formed at a lower cooling rate during the production of semi-solid billets[11]. When the billet is reheated to 540 ℃, the coarse flake Si phase has little change (Fig.3(a)). When the temperature is up to 568 ℃, the eutectic melts partially, the rosettelike grains near the melted region begin to separate (Fig.3(b)). The structure transforms to a state that near spheroidal α phase distributes in melted eutectic evenly. The size of the α phase is about 1/2 ~ 1/4 of the rosettelike α phase (Fig.3(c)).

3.3 Evolution of equiaxial dendritic grain structure

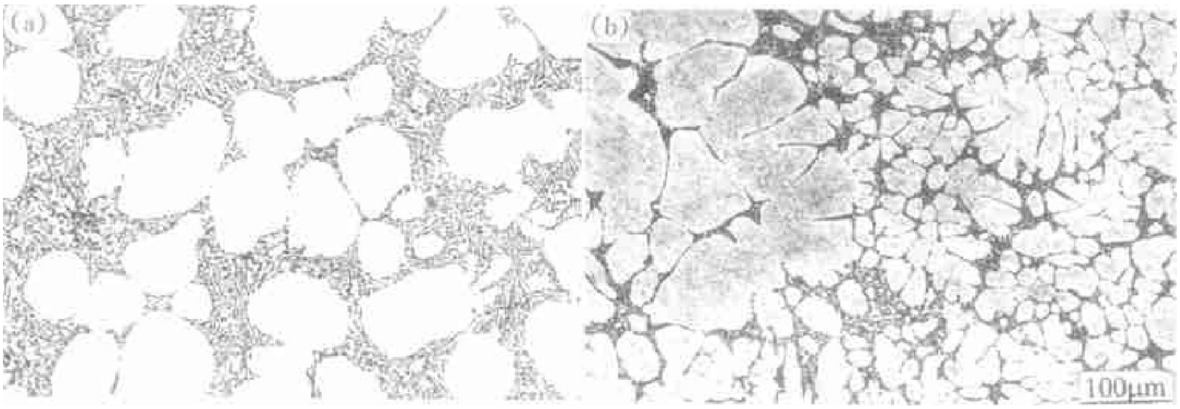

Fig.1 Three kinds of microstructure in ingots produced by electromagnetic stirring
(a) —At center; (b) —Near ingot surface

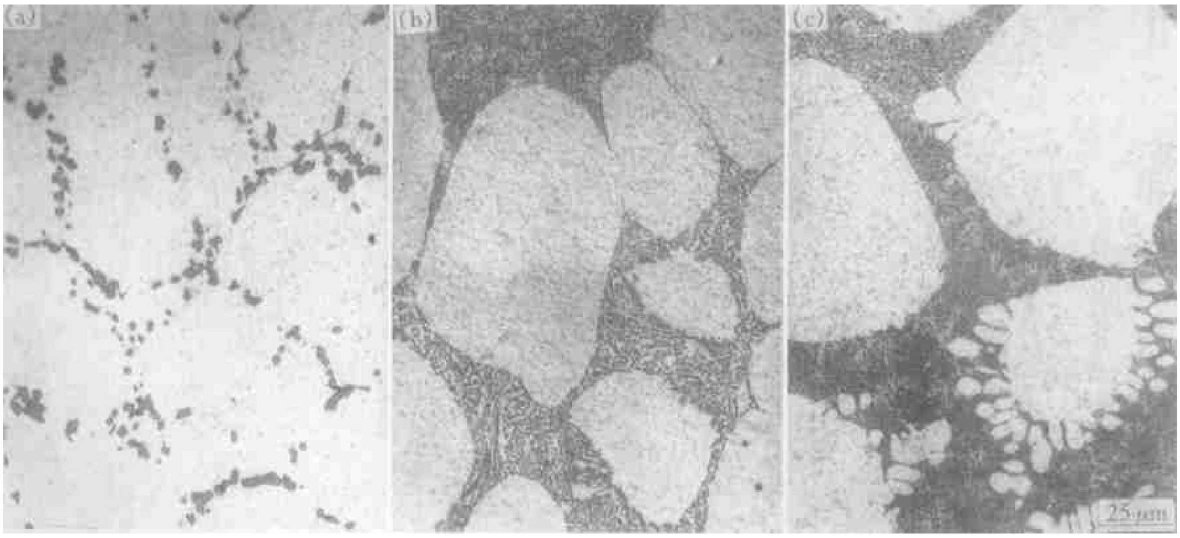

Fig.2 Microstructures of samples with typical semi-solid morphology quenched in water after being reheated to different temperatures

(a) —540 ℃; (b) —568 ℃; (c) —577 ℃

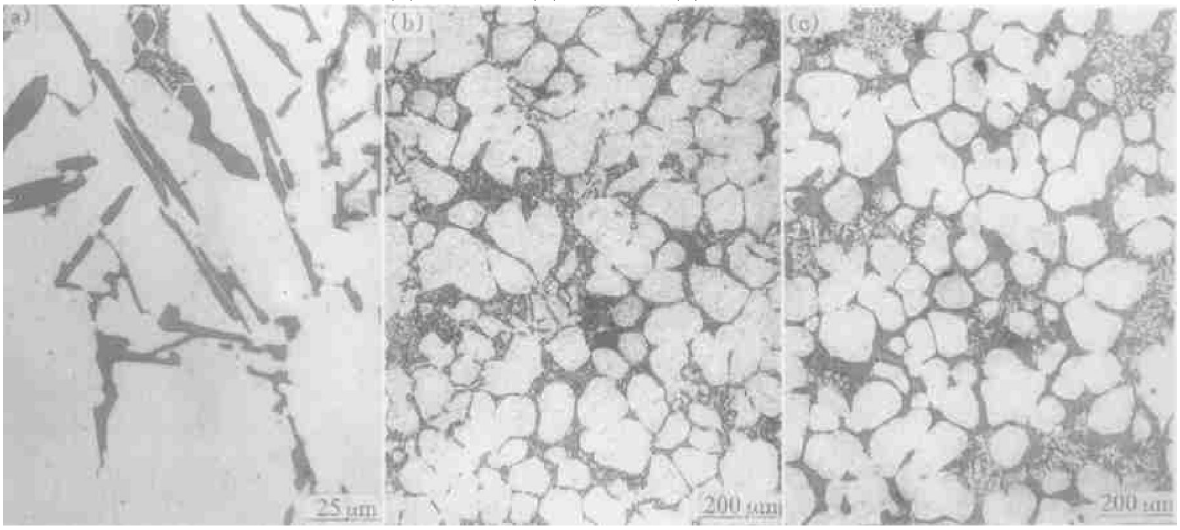

Fig.3 Microstructures of samples with rosette morphology quenched in water after being reheated to different temperatures

(a) —540 ℃; (b) —568 ℃; (c) —577 ℃

Fig.4 shows the microstructure of equiaxial dendritic grain structure quenched in water after being reheated to 540, 568 and 577 ℃. It is found that the flake Si eutectic changes to be particles when reheated to 540 ℃ (Fig.4(a)). The dendritic primary α phase sphercizes obviously when reheated to 568 ℃, and there is little change occurred to the rosettelike α phase nearby. When reheated to 577 ℃, both dendritic α phase and rosettelike α phase sphercize rapidly. At the surface layer, the coalescence of dendrite arm with preferred matching crystallographic orientation causes the existence of intragranular liquid[12] (Fig.4(b) and (c)).

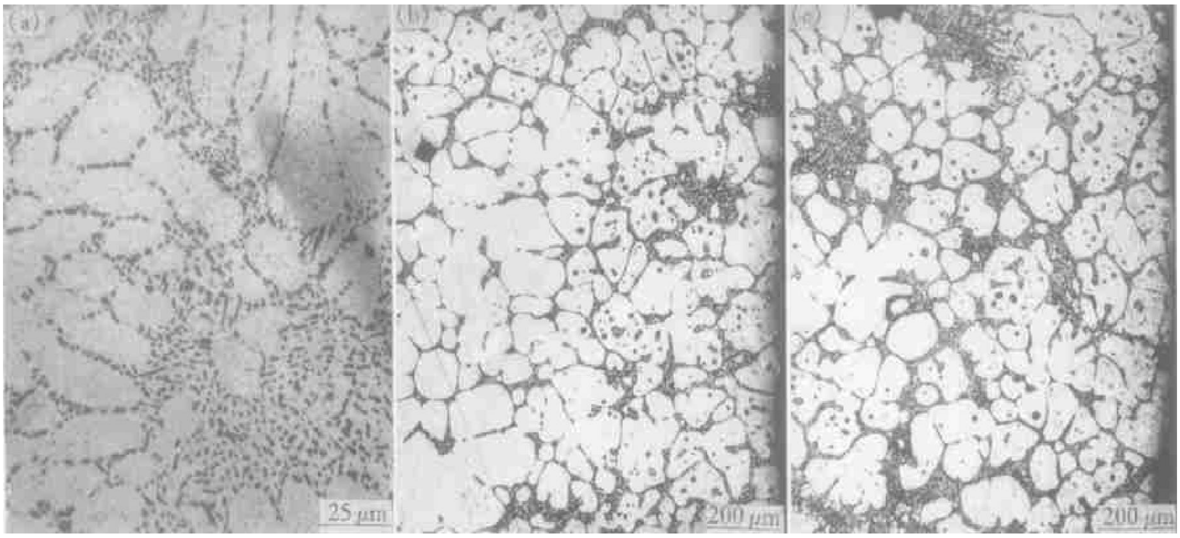

Fig.4 Microstructures of samples with equiaxial dendritic morphology quenched in water after being reheated to different temperature
(a) —540 ℃; (b) —568 ℃; (c) —577 ℃

4 CONCLUSIONS

(1) The Si phase in the eutectic dissolves in a way of diffusion toward α phase, when reheating the non-dendritic AlSi7Mg alloy. Its morphology changes from flake to dot-like and tends to be fine and spheroidal with increasing temperature. The thinner the flake, the lower the temperature for the occurrence of this process, and the higher the transforming speed. The fine flake eutectic in equiaxial dendritic and spheroidal structure sphercizes when reheated to 540 ℃, while the Si eutectic with rosettelike structure changes little.

(2) The original eutectic begins to melt when Si phase dissolves to some extent, and the dissolving speed is determined by the thickness of the flake Si phase. The eutectic in dendritic structure melts completely at 568 ℃. The meltting of eutectic in rosettelike grain structure needs longer processing at 577 ℃.

(3) The morphology and size of the primary α phase change obviously only after melted. The dendritic α phase tends to be spheroidal and somewhat coarse. The rosettelike α phase tends to be fine through separation of α phase, its size is about 1/2 ~ 1/4 of the original size. The near spheroidal α phase has a tendency of grain growth.

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