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Microstructural Optimisation of Chill Cast Al-Si Eutectic Alloys

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One of the most used alloys of the Al-Si binary system is the eutectic composition. Their properties are influenced by the development of non-equilibrium microstructures under industrial processing conditions whose main features are: the grain size and volume fraction of the primary α-Al phase [1]; the particle diameter and geometry of the primary silicon phase; the morphology of the eutectic [2-4], notably the shape of the Si cuboids, as well as the morphology of second-phase Fe based intermetallics present as contaminants in the commercial alloys. In general, the mechanical properties can be improved markedly by the addition of modifier elements that change the morphology of the eutectic Si varying it from acicular platelets seen as needles in the plane of polish, to granular Si particles [2, 5]. By adding refiner elements, it is possible to reduce the size, increase the volume fraction and disperse the tougher α-Al dendrites.

Two objectives were pursued in the present investigation: the first one aimed at determining the effectiveness of modification by Sr and refinement with Ti added separately to a standard commercial alloy (Table 1 and 2). The second objective was to verify the usefulness of these elements in modifying the microstructure when the addition of Sr and Ti is simultaneous, using two different alloying levels (Table 2).

After adding Ti, it was observed that this element is capable of removing any trace of the columnar structure, giving rise to a clustered-cellular morphology (Fig. 1). The addition of Sr enhances the formation of large highly branched, basaltic dendrites. Both Ti and Sr helped to increase the volume fraction of primary α-Al illustrating their α-forming nature (Table 2). On adding Ti and Sr at 0.05%Sr and two different levels of Ti, the α-forming nature prevails although a loss in effectiveness is noted. As for the analysis conducted on Si particles, a reduction of its diameter was detected with Ti and with Sr. A synergistic effect was observed when Ti and Sr were added together leading to additional further refinement. The volume fraction of cuboids remained unaltered with the addition of Sr to the commercial alloy, but increased somewhat with Ti additions. The combined addition of Ti and Sr resulted in higher volume fractions of Si cuboids denoting the prevailing effect of Ti. The morphological changes of the eutectic can be followed in Fig.1(d)-(f) at higher magnification. As a summary, the addition of Ti alone was irrelevant, but Sr additions change the eutectic from acicular to granular. The interest, however, centers on the simultaneous addition of Ti and Sr: Ti has a tendency to coarsen the Si granules and also to dilute the eutectic, a matter that can be resolved at about 600×.

References

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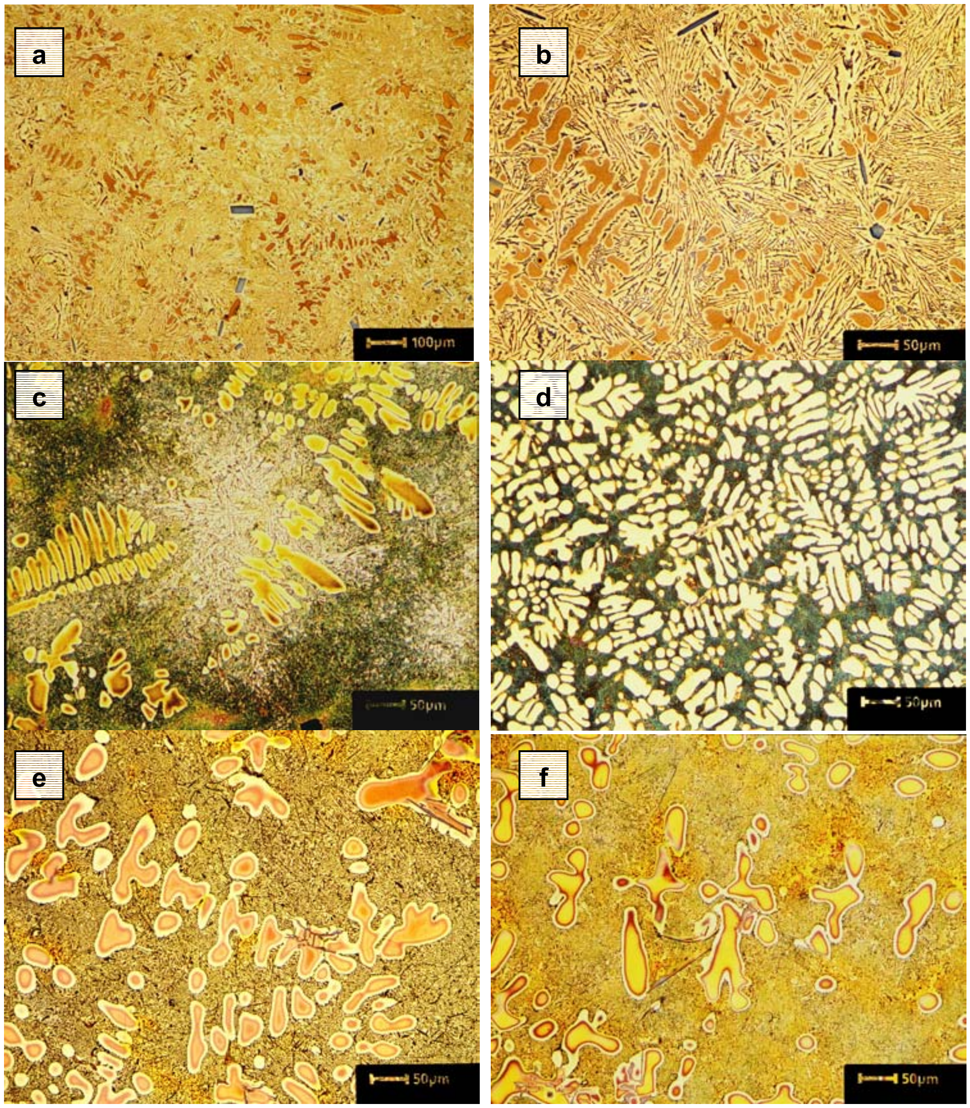

Fig. 1. Optical micrographs of studied compositions: (a)-(b) Al-12Si commercial alloy; (c) with 0.03 wt.% Ti; (d) with 0.04 wt.% Sr; (e) with 0.03 wt.% Ti and 0.05 wt.% Sr; and (f) with 0.05 wt.% Ti and 0.05 wt.% Sr .(scale bars = 50 μm, except for Fig.1(a) = 100 μm).

Table 1 Chemical composition of the Al-12Si base commercial alloy.

Elements	Si	Fe	Cu	Mn	Mg	Ni	Zn	Pb	Ti	Cr	Other
Content	12.90	0.8	0.0	0.2	0.01	0.006	0.03	0.02	0.008	0.013	0.023

Table 2. Details of Sr and Ti additions and relevant quantitative features measured.

Sample no.	Basic Chemistry		α-Al		Si-cuboids	
	Ti (wt.%)	Sr (wt.%)	f_v (vol.%)	$\overline{A}_{\alpha\text{-}Al}$ (μm^2)	f_v (vol.%)	$\overline{d}_p$ (μm)
1	-----	-----	21.87	11296	0.51	36.9
2	0.03	-----	36.82	1085	2.40	11.5
3	-----	0.04	28.84	1639	0.50	7.6
4	0.03	0.05	30.73	1455	3.07	7.2
5	0.05	0.05	31.71	1302	3.32	6.7

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