Discussion

Discussion of "Effects of Melt Thermal-Rate Treatment on Fe-Containing Phases in Hypereutectic Al-Si Alloy"*

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The authors[1] describe how thermal treatment of the liquid alloy appears to affect the structure of the subsequently solidified alloy. They attribute the refinement of Si particles to the "heredity of the melt structure," the action of the superheating being to dissolve Si-Si atomic clusters. This writer is concerned that there does not seem to be any evidence for such a mechanism. The refinement of the iron-rich phases, particularly the β-Fe phase, Al_5FeSi, is attributed partly to an increased cooling rate and partly to the transformation of γ to α-alumina "clusters" which are less good initiation sites for β-Fe. However, the detailed mechanisms are not clear and are not explained.

An explanation arises easily and naturally from the recognition that aluminum oxide bifilms are a common constituent of liquid aluminum melts. The bifilm are doubled-over oxide films, introduced by the turbulence of pouring, which act as cracks in suspension in the liquid. However, in addition to their role as cracks, they also form favored substrates for practically all intermetallics studied so far.

The oxide "clusters" reported by the authors would be expected to be, and do appear to be, oxide bifilms, convoluted into tangled compact masses by the turbulence during the casting and stirring of the melt. Whereas it is known that γ-alumina bifilms form favored substrates (*via* a prior nucleation of AlP on the bifilm) for the formation of both Si and β-Fe particles, it is not known whether α-alumina will behave similarly. From the results of the authors and similar confirmatory research, it seems that at least Si may not favor deposition on α-alumina, but the behavior of β-Fe appears unchanged.

An explanation of the observations by the authors would seem to be consistent with the following scenario.

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After first melting and casting, the Si and β-Fe precipitate on bifilms in suspension. Initially the bifilms are compact and convoluted. However, the growth of these phases naturally straightens the bifilms, evolving the relatively harmless convoluted and compact cracks into planar engineering cracks which have a strongly deleterious effect on properties. The severely deleterious effect of Fe as an impurity in Al alloys arises simply as a result of this straightening action of bifilms. The bifilm crack is often seen along the center of β-Fe plates (unhelpfully referred to as "needles" in this paper).

On heating the liquid metal to a high temperature the conversion of the aluminum oxide from its α to its γ form it appears to become unfavorable as a substrate for Si. On cooling, the Si now precipitates and grows at a lower temperature as a classical coupled eutectic of Al and Si, with a fine spacing controlled in the normal way by diffusion and interfacial energy.

The refinement of the β-Fe particles appears to be somewhat different. The particles appear to still form on bifilms even though they have now changed their crystal structure to α-alumina. The refinement may be the result of the fragmentation of the bifilms. However, the most effective refinement is observed by the authors for rapid cooling and freezing. In this case it seems highly likely that the bifilms pose a restraint to the rate of growth of the β-Fe because the flimsy and fragile films are attempting to open and straighten against the inertial drag of the surrounding liquid aluminum. Naturally, the faster the particle attempts to straighten the bifilm as it grows, the greater will be the viscous drag restraining the rate of growth. Thus in general the size of the iron-rich particles attained within a given time will be smaller.

The presence of the central bifilm crack in the Si and β-Fe particles can occasionally be seen in the authors' work in Figures d1 and e1. Similarly the large planar facets on fracture surfaces in Figure 6 are expected to be result of the fracture surface following the opening of bifilms along the central planes of Si and β-Fe particles (although no chemical analysis is supplied to confirm this).

The benefits in refinement of the structure by the high temperature treatment are thereby explicable, as are also the improvement in abrasion resistance (reduced precipitation of iron-rich compounds hence more iron in solution strengthening the matrix) and improved corrosion resistance (the bifilm cracks allow the ingress of corrodants into the interior of the alloy; the effect being enhanced by the iron and silicon precipitates on the bifilms which act as corrosion couples).

This writer apologizes, but feels obliged to recommend his book "Complete Casting Handbook" published by Elsevier, Oxford, UK in 2011, which gives much of the background to bifilms and their profound effect on metallurgy in general.

REFERENCE

1. Q. Wang, H. Geng, S. Zhang, H. Jiang, and M. Zuo: *Metall. Mater. Trans. A*, 2014, vol. 45A, pp. 1621–30.