Chapter 4
Recent Developments in Slurry Formation

Despite the proven improvement in the quality of products formed by semisolid processing, providing both better surface finish and mechanical properties after heat treatment, the main obstacle to progress in the industrial use of thixoforming are due to the additional costs involved in.

1. The production of *solid* billets having the correct internal structure, e.g., by the MHD process
2. The reheating, melting, and soaking of the billet to reform the semisolid structure
3. The scrap produced by each thixoformed article, which must be returned to the billet manufacturer for reconstitution as appropriate billets

These cost problems have led back in recent years to a reconsideration of the rheoforming route (the production of semisolid alloy slurry on site followed by immediate injection of slurry into the die), that was originally used at MIT, thus bypassing casting of solid by MHD.

The UBE process [35] has been developed whereby rapid cooling of the aluminum alloy in a cylindrical steel crucible forms a semisolid billet. The semisolid billet and crucible are then transferred to the die casting machine by robot arm, where the billet is dropped into the shot sleeve for immediate injection. The scrap from the operation is collected ready for remelting in the holding furnace on site for further casting. This route clearly obviates the need for MHD stirring to produce a nondendritic structure, and the heating and partial melting of billets prior to injection.

A more recent process has been developed at MIT (the SSR®process) [35], which is claimed to have added advantages. A spinning cold rod is introduced into the molten alloy just above the liquidus to generate very fine spherical particles (Fig. 4.1).

As the liquid cools rapidly to a temperature a few degrees below the liquidus, nucleation occurs on the cold rod with solid growing into the undercooled melt. Given the rapid heat removal and therefore rapid growth of solid into the melt, it is likely that the solid grows as a fine dendritic structure. In this thermal and flowing environment, the dendrite arms will rapidly coarsen and melt off, providing large quantities of fine spheroidal solid particles that are detected in quenched samples (Figs. 4.2 and 4.3).

David H. Kirkwood et al., *Semi-solid Processing of Alloys*,
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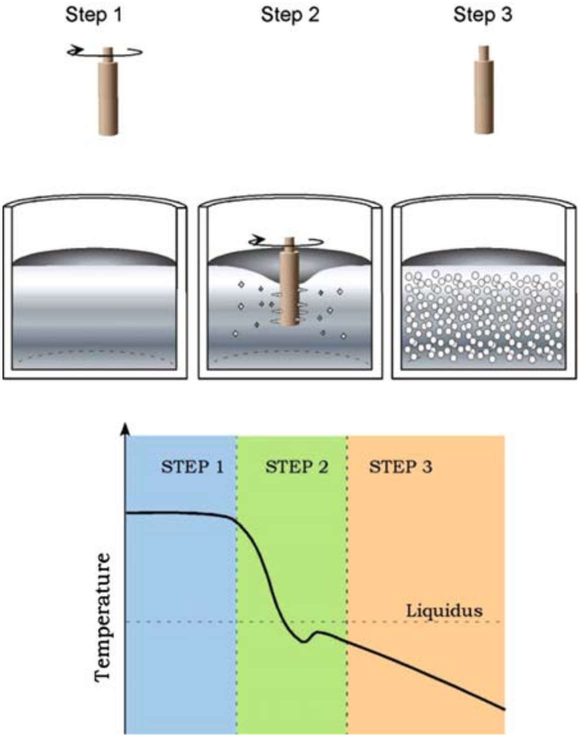


Fig. 4.1 Schematic of the SSR process

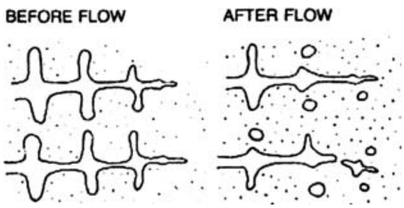


Fig. 4.2 Schematic of dendrite multiplication

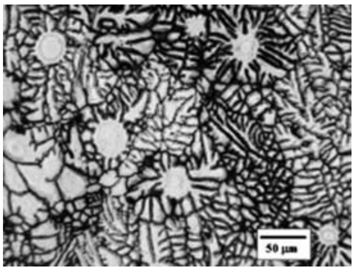
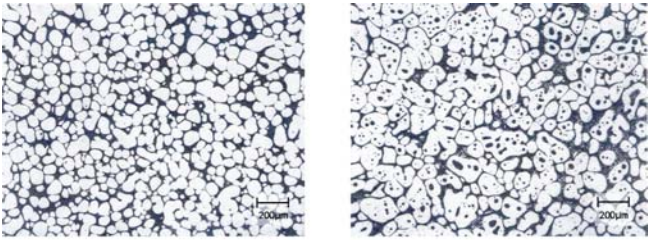


Fig. 4.3 Micrograph of Al–Cu alloy rheocast with SSR and then immediately quenched. Spheroidal primary grains are evident that formed during the initial period of solidification with subsequent dendritic microstructure that formed during the quench



(a) (b)

Fig. 4.4 Microstructures of reheated and quenched Al–Si alloy produced by **(a)** SSR and **(b)** electromagnetically stirred MHD continuous cast billet [35]

A few degrees below the liquidus, where $f \cong 0.1$, the spinning rod is removed and the melt allowed to solidify more slowly in quiescent conditions. The spherical nuclei continue to grow as spheres to produce a fine grain structure of particle size of around 70 μm. This structure may be remelted, as in normal thixoforging practice, to produce a semisolid billet containing $f_s = 0.5$ for die injection, and given the fine grain size and lack of entrapped liquid within the solid particles, this slurry will flow easily to provide a casting of good mechanical properties (Fig. 4.4).

Alternatively, the solidification process may be halted at a higher temperature corresponding to $f_s = 0.3$; at this low fraction solid, the slurry flows almost like the liquid melt and may be poured into the small shot hole of a conventional die casting machine. This approach combines the advantages of thixoforming producing a fine structure and avoiding air entrapment that allows heat treatment, with the convenience of conventional die casting and also allowing scrap recycling in-house.