Chapter 9
Introduction to Industrial Applications of Semisolid Processing

Semisolid metal (SSM) processing is a hybrid technology combining features of both casting and forging that enables the production of near net-shape components of superior properties and surface finish. It was developed, from a discovery made at the Massachusetts Institute of Technology in the early 1970s, by Spencer et al. [1] that stirring of alloys during solidification led to a change in the solidifying microstructure resulting not only in a dramatic lowering of the apparent viscosity of the semisolid slurry, but also facilitating two-phase homogeneous flow at quite high fractions solid. More detail of this discovery and the effects of shear rate cooling rate and fraction solid can be found in Part II.

The process of stirring alloys during solidification to produce non-dendritic solid within a slurry, and then injecting this slurry directly into a die as in liquid metal die casting, was called "rheocasting" by the MIT researchers and that name has largely stuck. Rheocasting started out as the preferred process route for industrial production and a new company formed by MIT and a group of industrial partners "Rheocast Corp." designed and built several large-scale rheocasters for production of both aluminium and copper-base alloys. The first major customer of the technology and for the large-scale rheocasters produced by Rheocast Corp. was International Telephone and Telegraph (ITT) Corp.

Initial commercial production at ITT Corp. focussed on copper alloy electrical connector hardware, but soon after commercial production began, lightweight automotives became a focus of attention due to the energy crises, and intense commercial interest began to turn toward aluminium alloys. Almost immediately, questions regarding the process reliability and consistency of rheocasting structural aluminium alloy parts were raised both regarding the viability of large-scale rheocasters in an aluminium cast-house and because rheocast aluminium parts evidenced internal flaws. This spurred development by the ITT corporation of the second alternative process route proposed by MIT, which comprised producing rheocast billet and allowing it to completely cool before re-heating back into the semisolid temperature range for forming or casting.

This alternative process, whereby the slurry is first cast as a fully solid billet, cut into appropriately sized slugs, and subsequently reheated back to the semisolid condition before injecting into a closed die was termed "thixocasting" by the same MIT team. The thixocasting name has endured better in Europe than in the USA

David H. Kirkwood et al., *Semi-solid Processing of Alloys*, 109
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and a similar process of shaping between closed dies was termed “thixoforging”. Over the years, proprietary interests have created a wide range of alternative process nomenclature, such as “soft” or “viscous” forging, but primarily the terms semisolid casting or processing are most commonly used. For the purpose of this chapter, all these variants for shaping alloys are collectively referred to as “semisolid metal forming processes”.

Although the original MIT research had pioneered the concept of using semisolid material (either rheocast or thixocast) as feedstock for horizontal die-casting machines, the early commercial operations were based around unique, vertical downward stroke, forging machines in an attempt to minimize the use of the specialized raw material. The very first commercial applications of the technology for both copper alloy and aluminium alloy parts were in fact, direct closed die semisolid forging processes, in which effectively 100% of the charge material was converted to the final part. However, while attractive from a material yield/cost point of view, this approach proved troublesome from a quality perspective creating intense segregation beneath the forging ram and incorporating oxides from the charge material surface within the interior of the part among other things.

As more companies became involved in the technology, once that the MIT protective patents ran out, the conventional wisdom of marrying available horizontal die-casting technology with this new raw material won the day. A typical horizontal semisolid metal casting cell is shown in Fig. 9.1.

The last vertical downward forging operations expired in the early 2000s, when AEMP Corporation, the final licensor/custodian of the original MIT technology, filed for bankruptcy. By that time, even the proponents of that approach had converted their technology to utilize gates and runners much like die-casting although

Fig. 9.1 Example of a modern 400 ton horizontal semisolid metal casting machine, and carousel induction heater

in a vertical orientation. Not only was this technology fraught with technical issues like those cited above, but it also suffered from the absence of available infrastructure (who could build tooling for example) and competitive bidding on the very specialized machinery.

In the beginning of commercial operations, both the rheocast and the thixocast process routes were actively pursued, but over a time, the thixocasting process won out for a variety of reasons. For many years, the “thixocasting” process route has dominated the commercial scene. Lately, however, commercial pressure to achieve the lowest possible cost has seen a resurgence of the rheocast approach, since it avoids the need to acquire specially processed billet and allows free purchase of ingot on the open market.

The term “semisolid metal processing” is used here to cover both the operations of producing the raw feedstock and shaping the alloy.