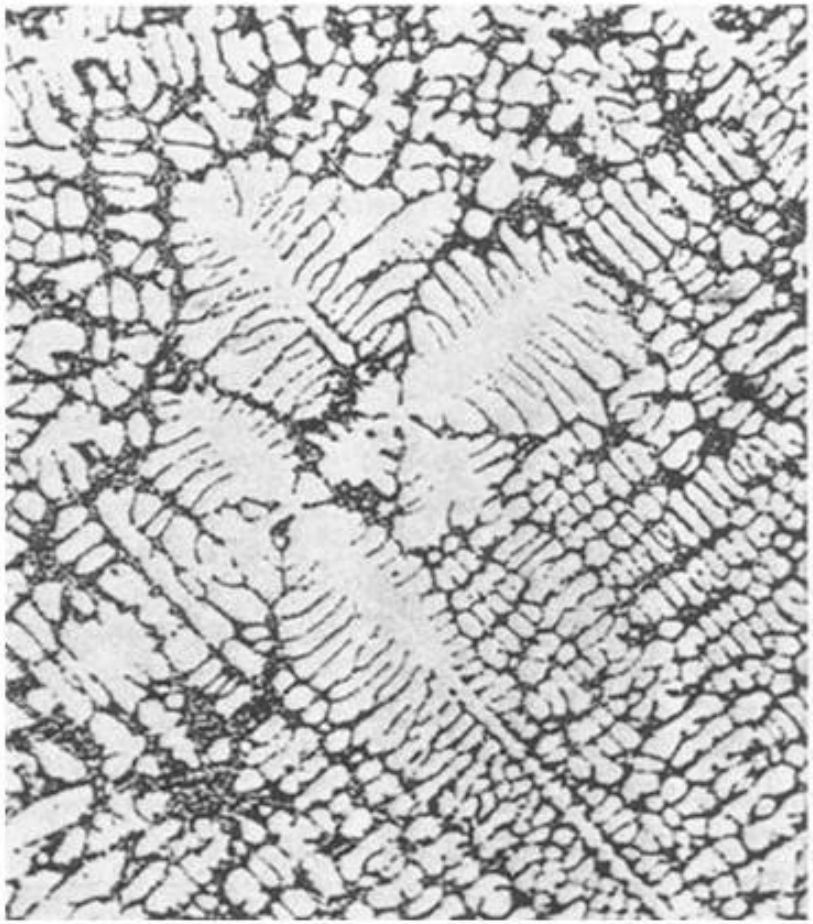
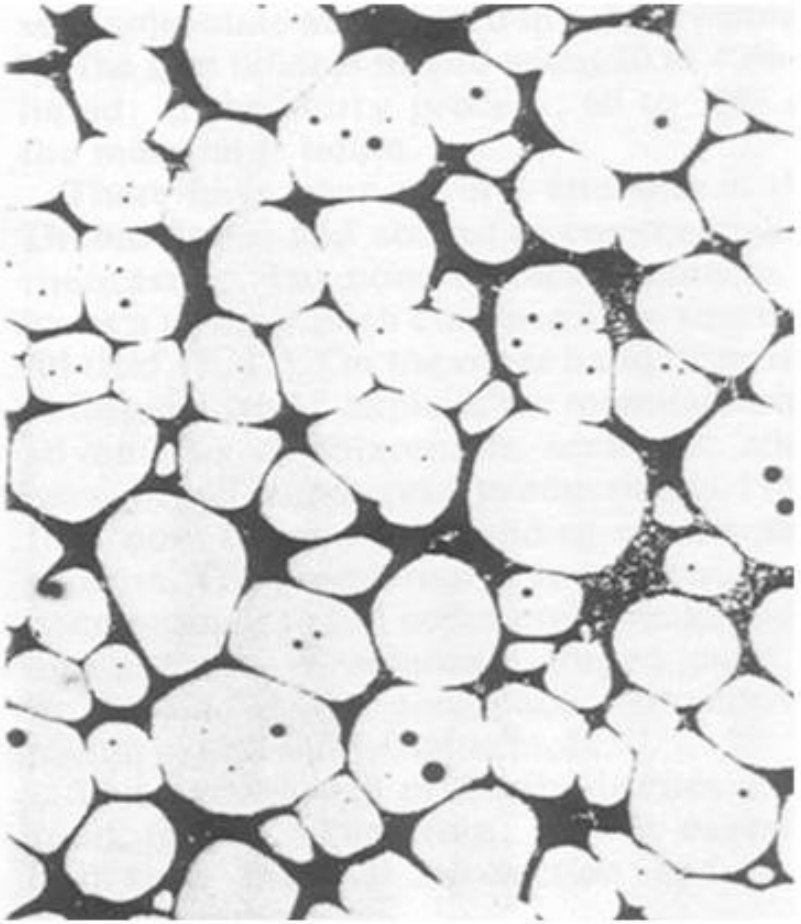
# Semi Solid Metal Casting

**Prof. Dr. Kerem Altuğ GÜLER**

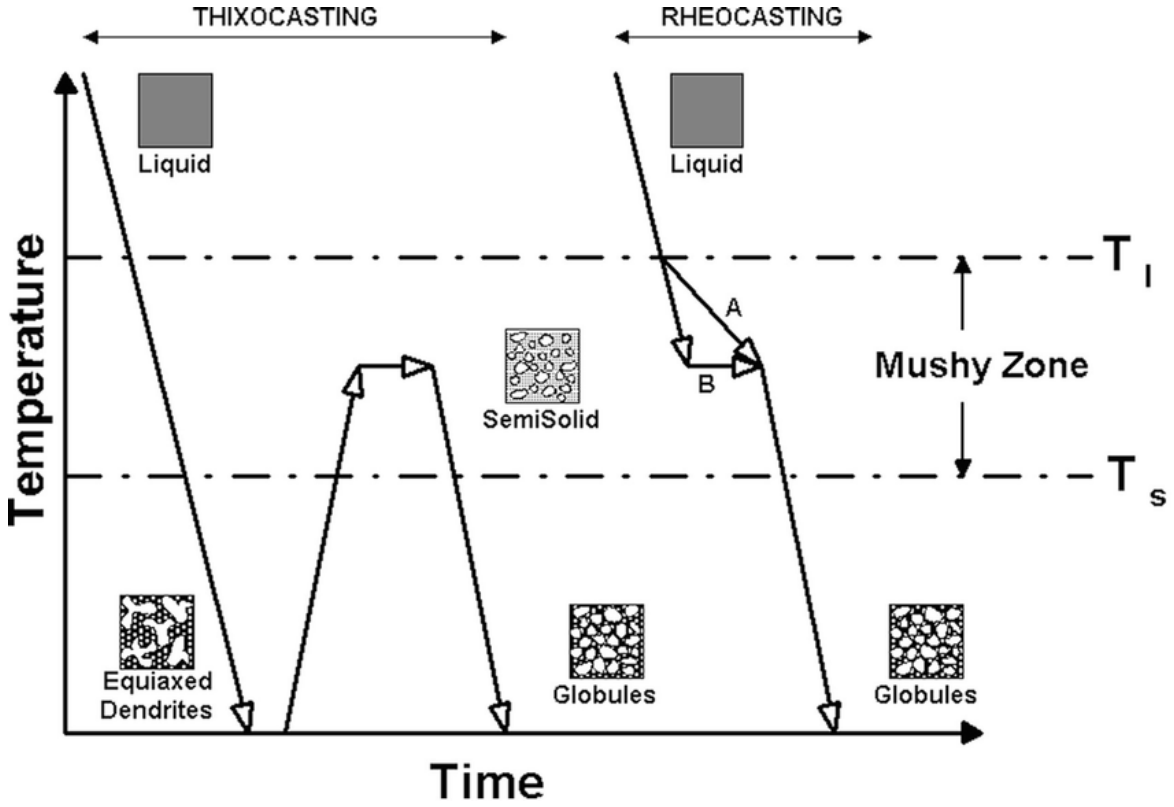
Semisolid metalworking, also known as semisolid forming, is a hybrid manufacturing method that incorporates elements of both casting and forging. It was based on a discovery made at the Massachusetts Institute of Technology (MIT) in the early 1970s. Processes based on the discovery were identified by MIT as rheocasting, thixocasting, or stir casting . Today it is a two-step process for the near-net shape forming of metal parts using a semisolid raw material that incorporates a unique nondendritic microstructure.

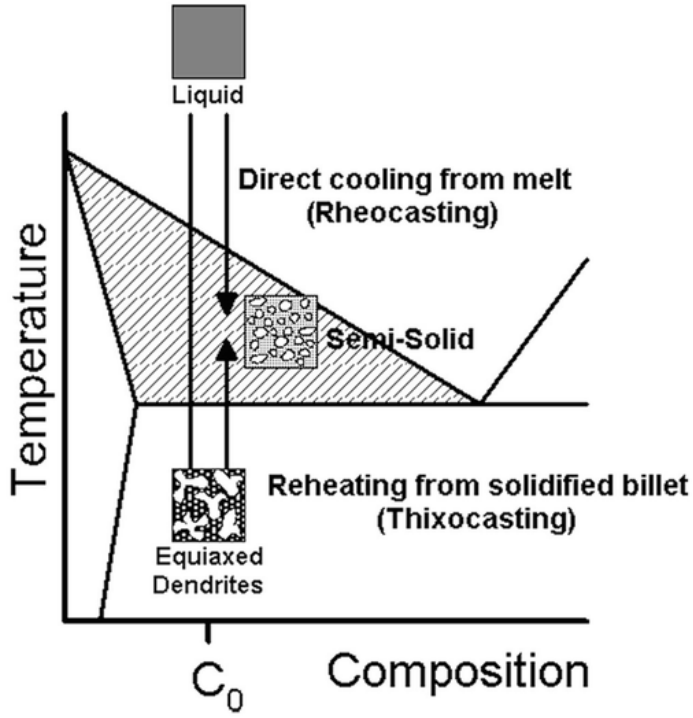


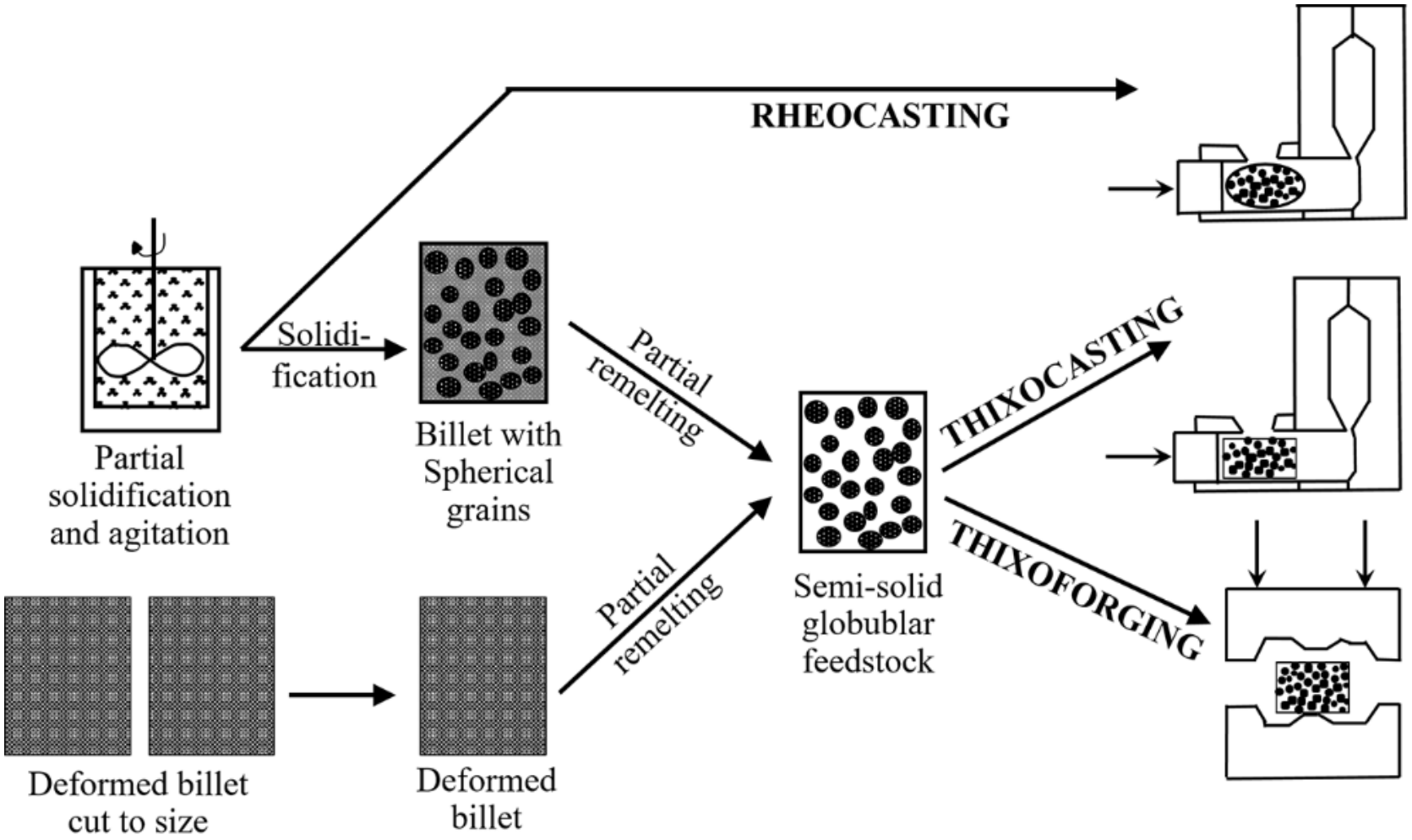
**(a)** Dendrite structure



**(b)** Globular structure


THIXOCASTING
RHEOCASTING
Liquid
Liquid
Temperature
$T_l$
$T_s$
A
B
Mushy Zone
SemiSolid
Equiaxed
Dendrites
Globules
Globules
Time


Liquid
Direct cooling from melt
(Rheocasting)
Semi-Solid
Temperature
Reheating from solidified billet
(Thixocasting)
Equiaxed
Dendrites
$C_0$
Composition

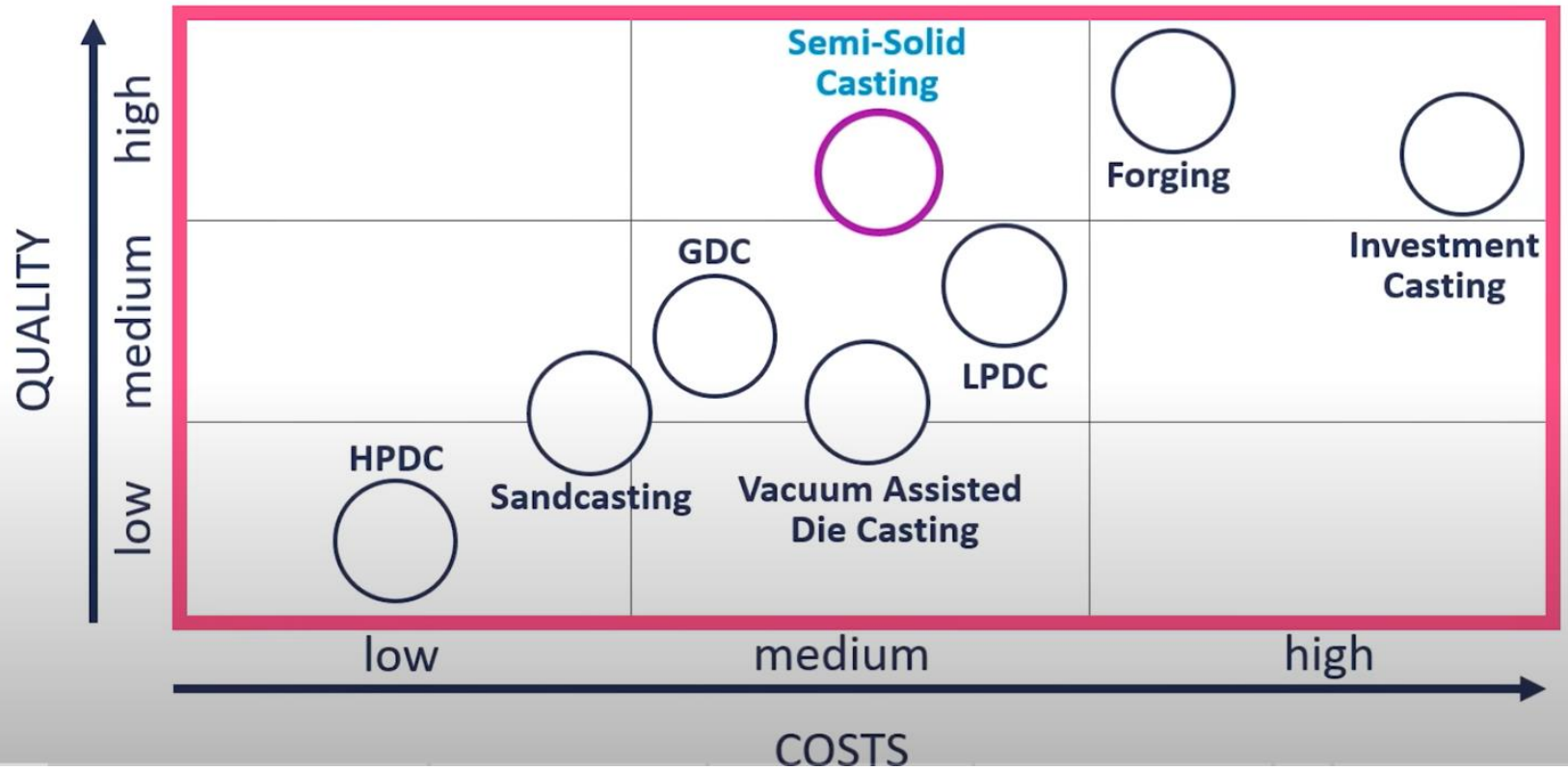

RHEOCASTING
Solidi-
fication
Partial
solidification
and agitation
Billet with
Spherical
grains
Partial
remelting
THIXOCASTING
THIXOFORGING
Semi-solid
globublar
feedstock
Partial
remelting
Deformed billet
cut to size
Deformed
billet

## Differences of semi-solid metal casting from conventional die casting

- Laminar or mixed flow, no turbulence
- Much longer tool life
- Lower metal temperature
- Less shrinkage
- Shorter cycle time
- Less porosity
- Higher mechanical properties
- Some alloys with a melting temperature above the limits of die casting can be used.

- Ability to work with lower capacity machines for parts of equal size and weight.
- Possibility of casting thin section parts with Al alloys with lower Si content (It is important to increase thermal conductivity).
- Possibility to use sand core due to low compression pressure.
- Problem-free heat treatment and ageing of the produced parts.

# Price-performance-ratio of semi-solid casting



Semisolid metallic alloys were discovered by Spencer in 1972 at MIT while investigated viscosity of Sn-15%Pb and found out during the experiment, semisolid state without stirring produce dendritic while the continuously stirred material was spheroidal. Since then, extensive research regarding semisolid metal processing (SSMP) leads to various processes development. SSMP were applied in the industry due to the final product has less defect such as porosity, shrinkage, gas entrapment and macrosegration SSMP can be categorized into two routes, namely rheocasting and thixoforming.

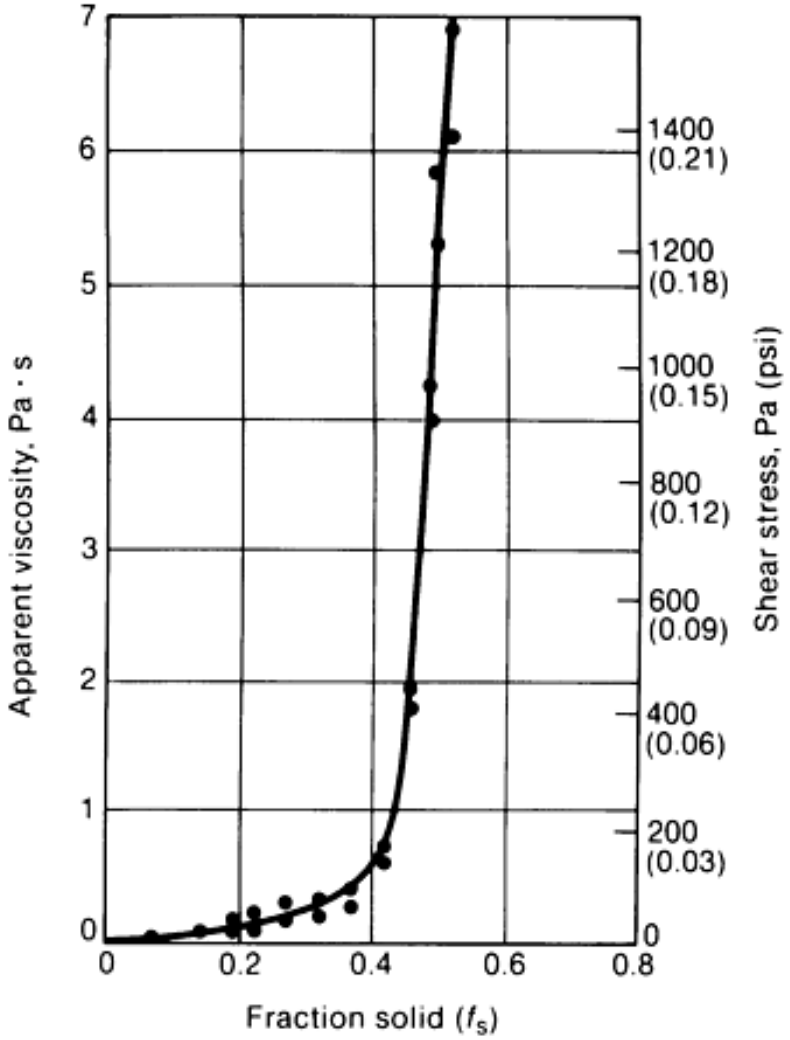
Rheocasting is a forming process start from liquid alloy, directly introduced into a die without any intermediate solidification step. The semisolid slurry in this route produced from an entirely liquid regular alloy. While thixoforming is a route consists of reheating and forming process. Thixoforming steps are feedstock billet with globular microstructure specially prepared, cut to length, reheated into solid-liquid temperature to achieve suitable solid fraction, then final product formed by various methods

In the early years of SSMP research, scientists mainly focus on thixotropic material development because it was essential in both routes. The material in thixotropic condition was described as the ability of material to flow when shear force was given and it will thicken again when shear force was released. Thixotropic condition happened due to globular microstructure in the material.

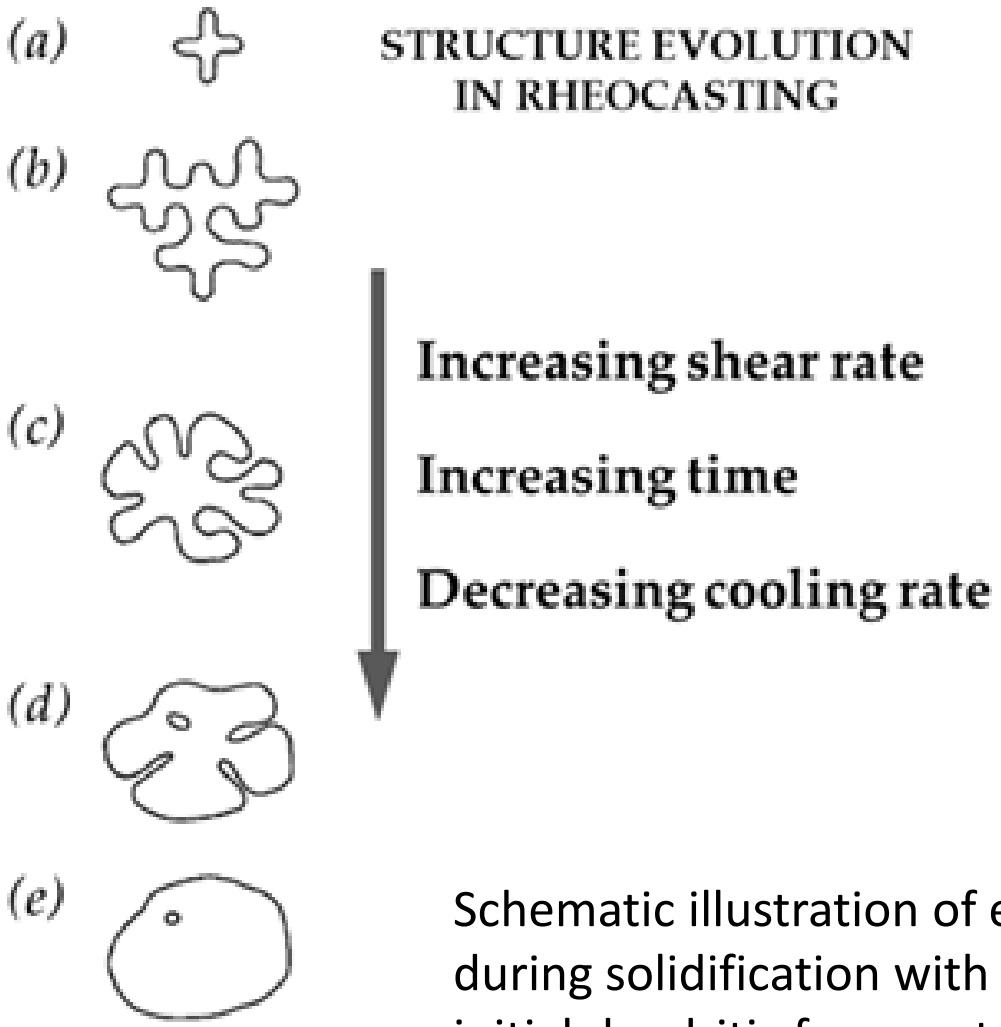
Methods to gain fine globular microstructure such as Magnetohydrodynamic stirring, Strain Induced Melt Activated (SIMA), Mechanical stirring, Cooling slope and Direct Thermal Method are widely used either for scientific research or industry application.

Thixoforming particularly needs feedstock billet which prepared by special method because solidification step is essential compared to rheocasting. Thixoforming also described as near net shape forming due to billet reheated into solid-liquid temperature and partially melted non-dendritic slug into a metal die. In industry application, thixoforming was considered high-cost manufacturing because of raw material was not supplied widely. However, this method offers broader ranges of design option which attract people in this area improves it continuously.

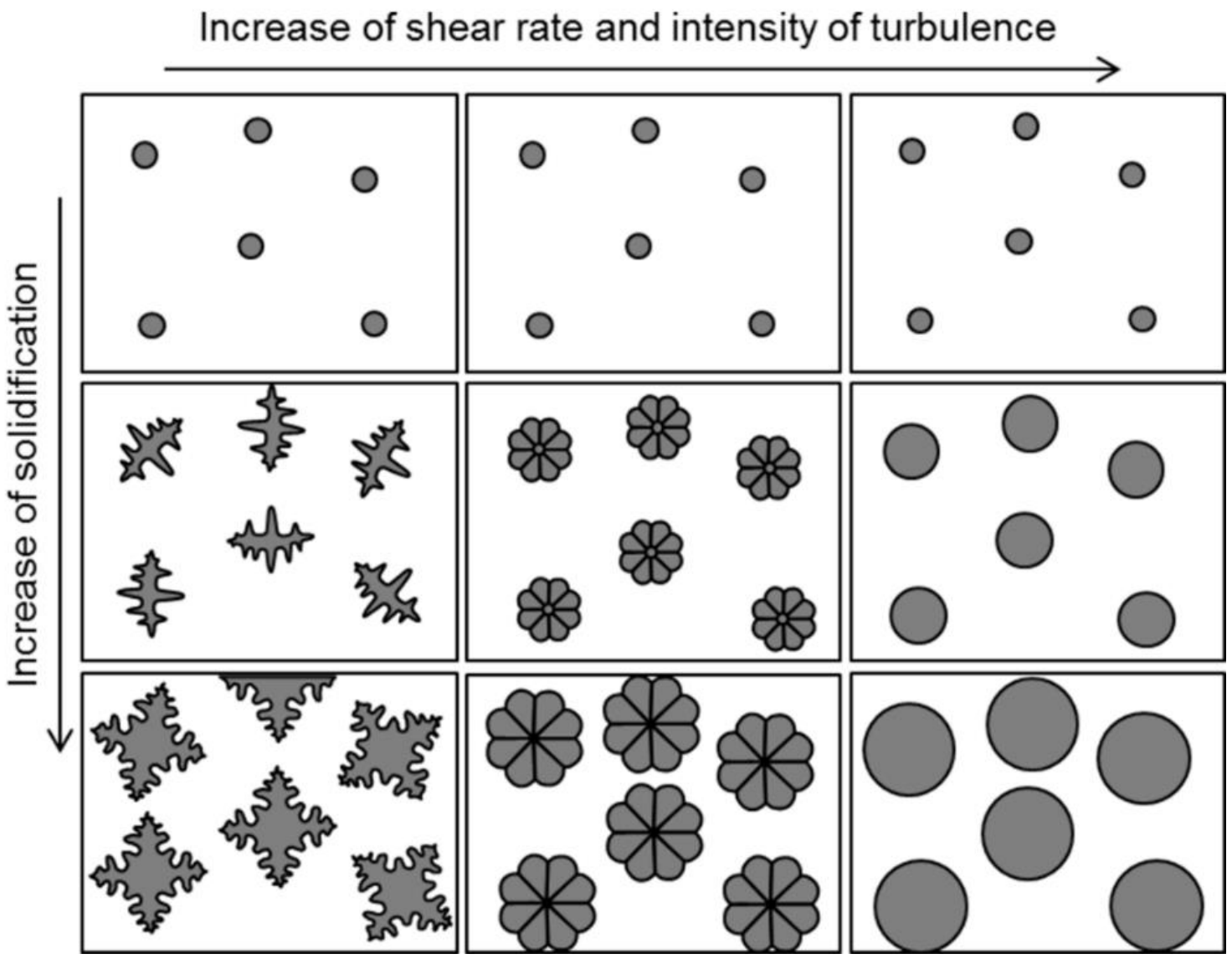
Semi solid aluminium billet being cut by a spatula

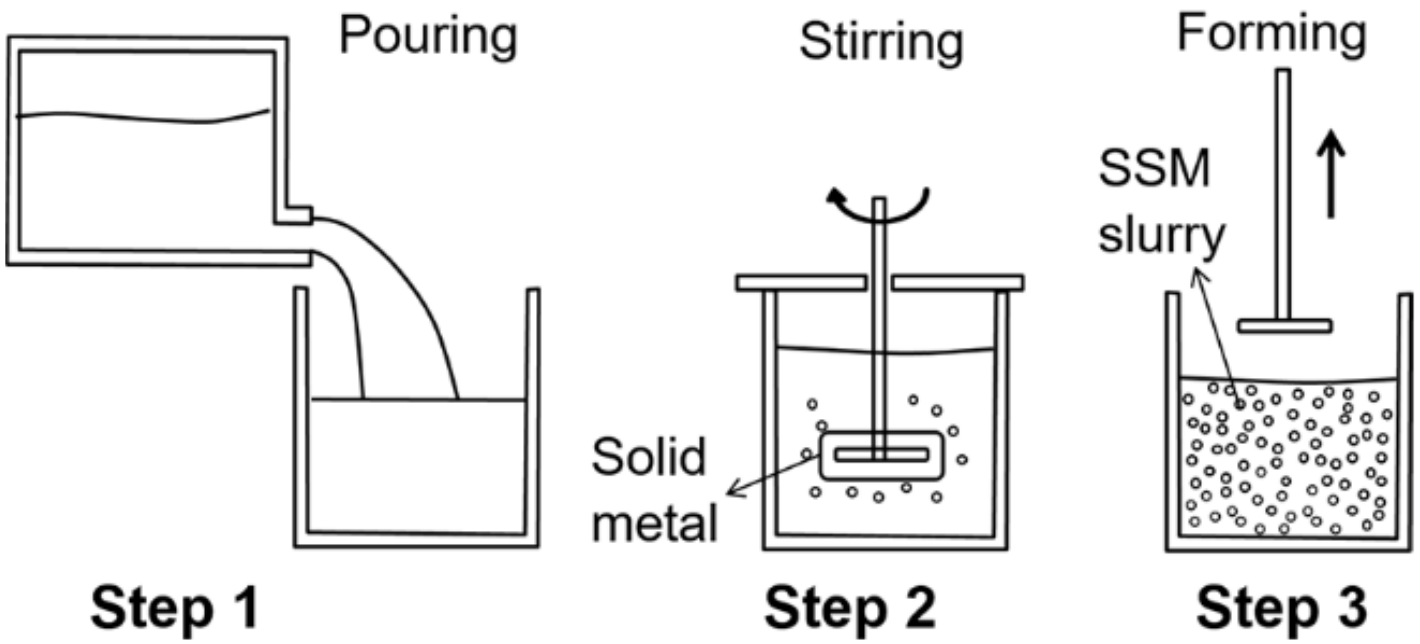



Apparent viscosity and shear stress of model Sn-15Pb semisolid melts as a function of fraction solid at constant shear rate.

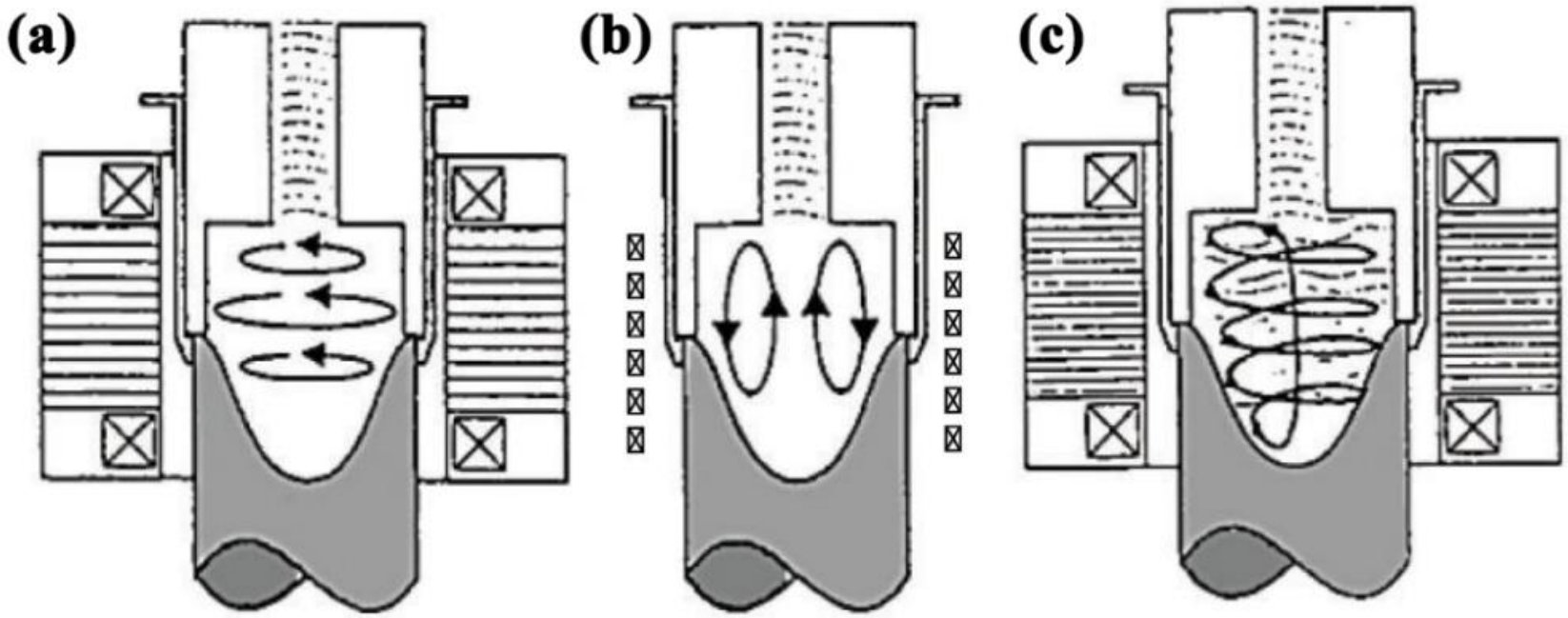



Schematic illustration of evolution of structure during solidification with vigorous agitation: (a) initial dendritic fragment; (b) dendritic growth; (c) rosette; (d) ripened rosette; (e) spheroid

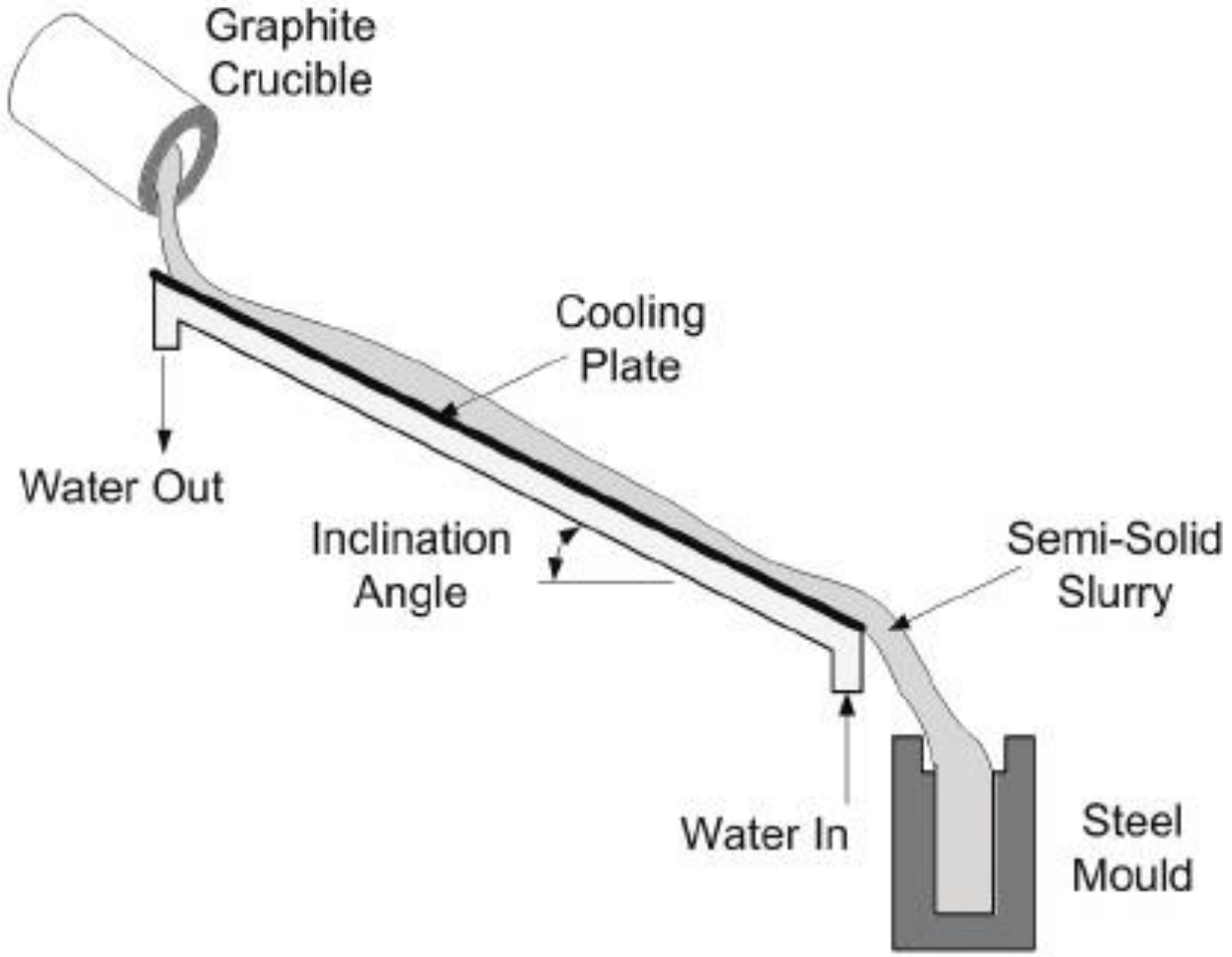

Increase of shear rate and intensity of turbulence
Increase of solidification



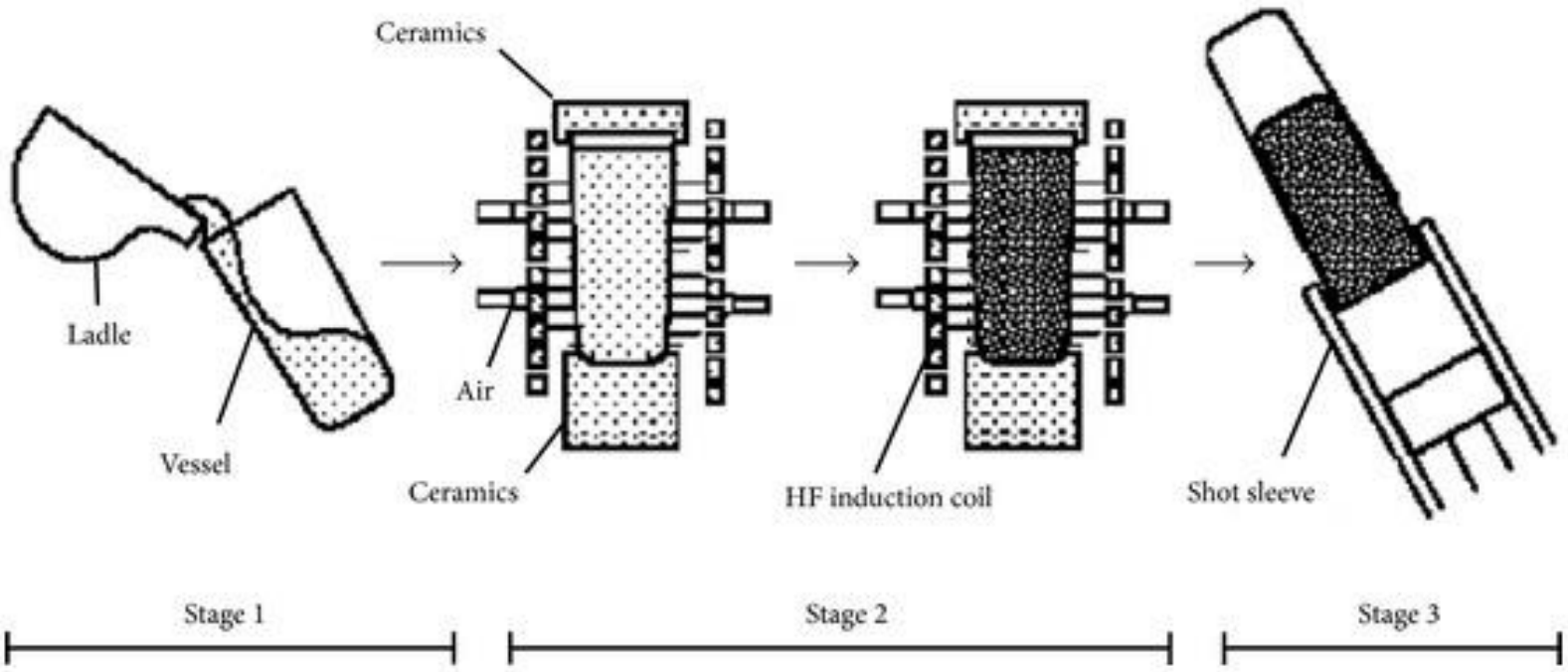

Rapid Slurry Forming (RSF)



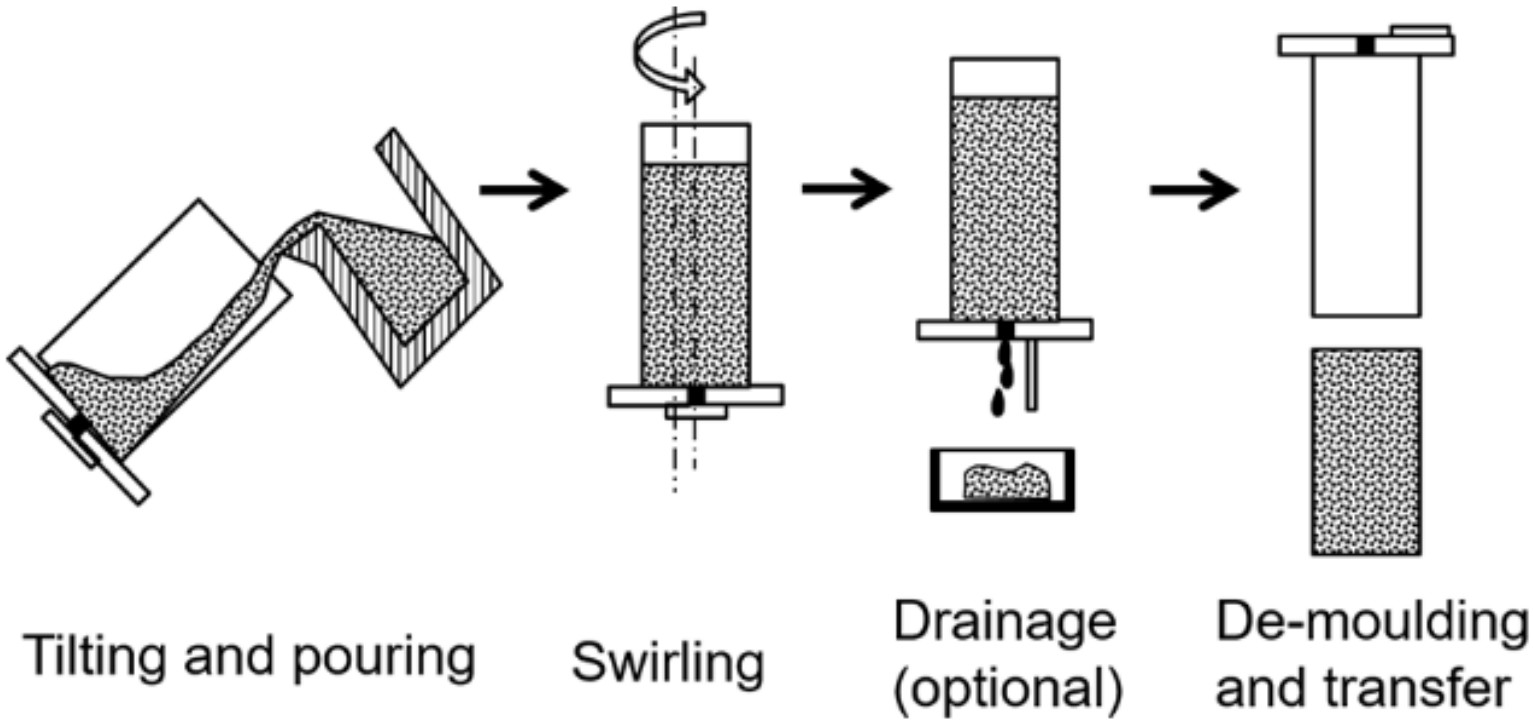

Magnetohydrodynamic Stirring



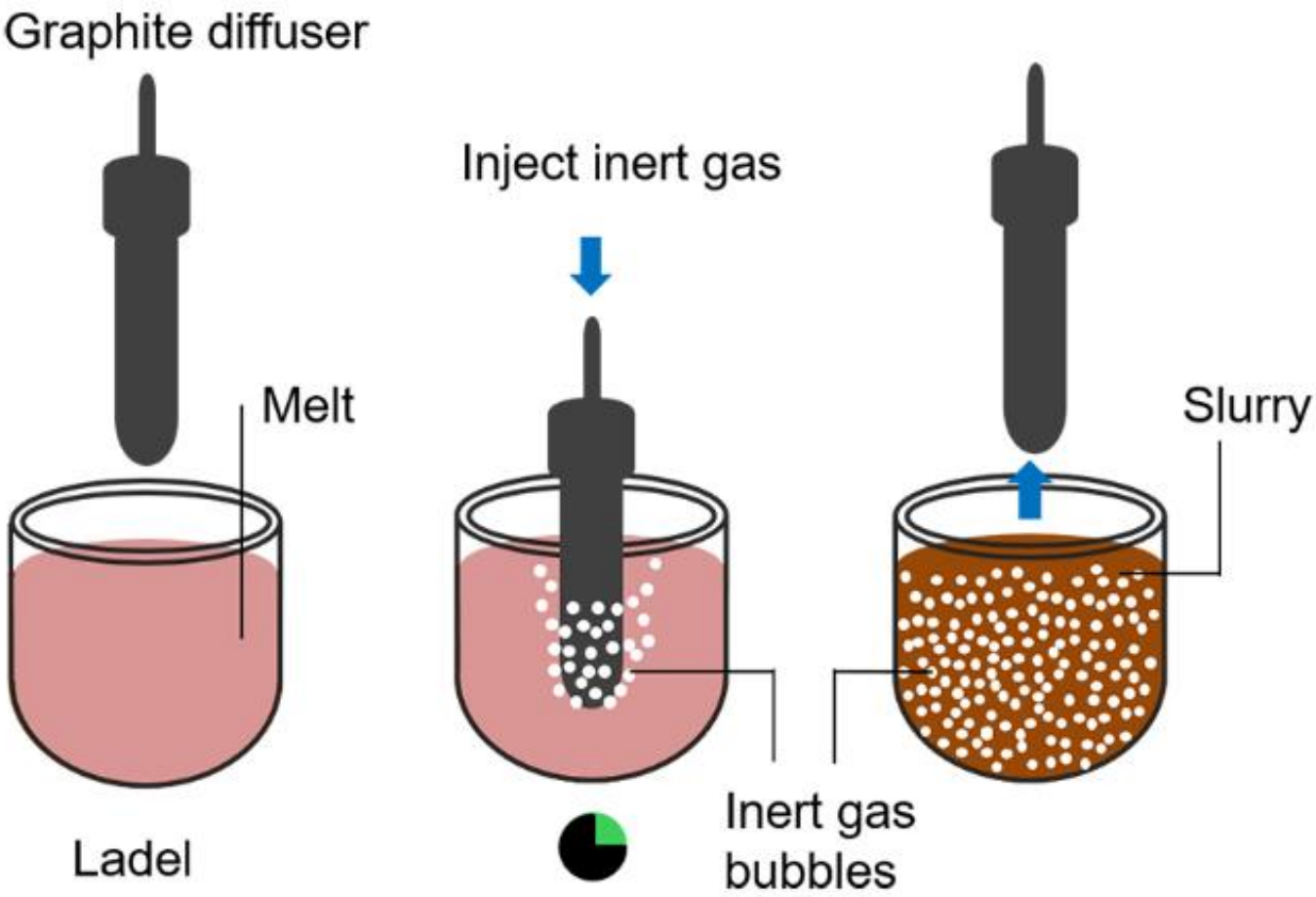

Cooling slope casting




Schematic illustration of the stages of New Rheocasting (NRC)

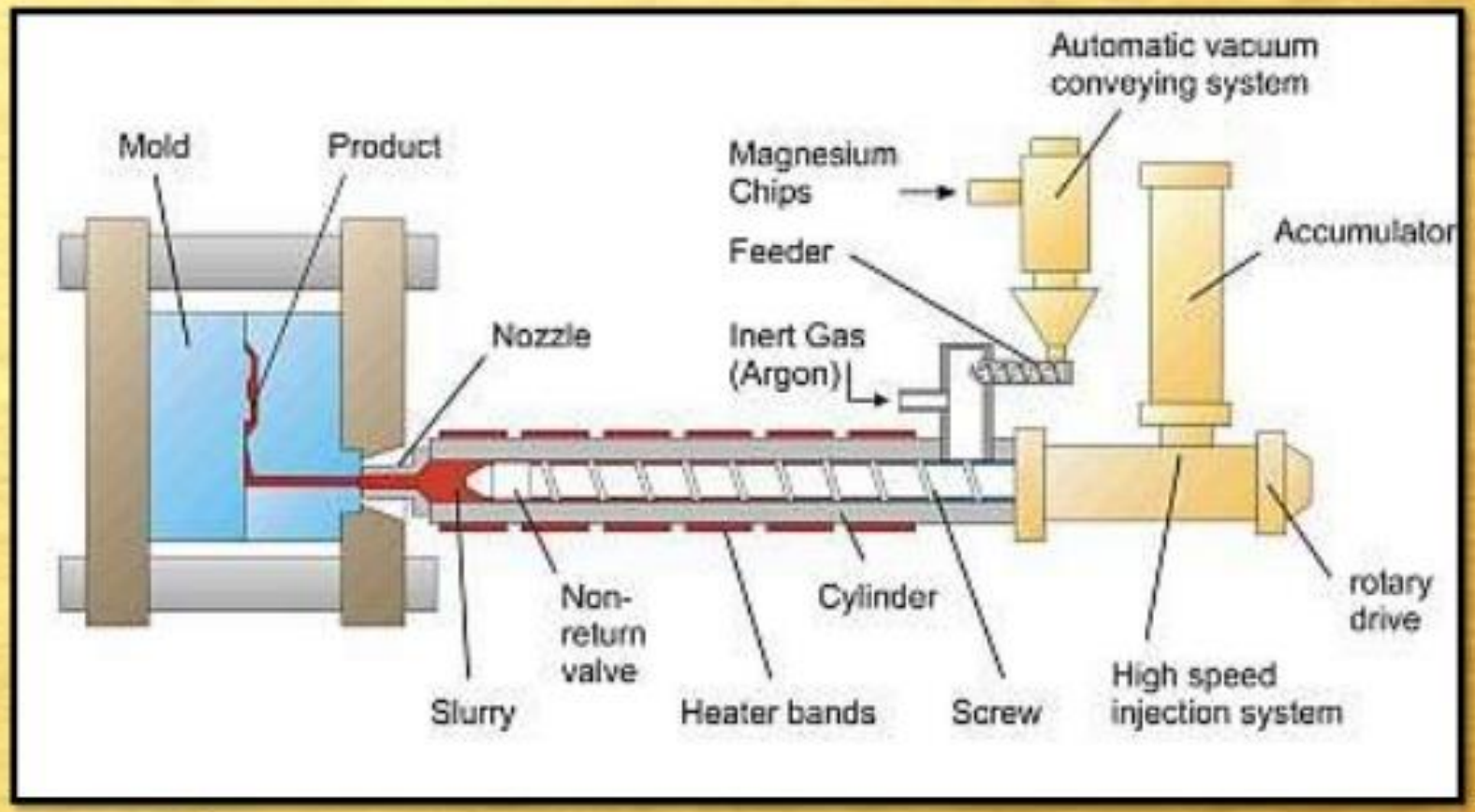



Swirled Enthalpy Equilibration Device Process (SEED)

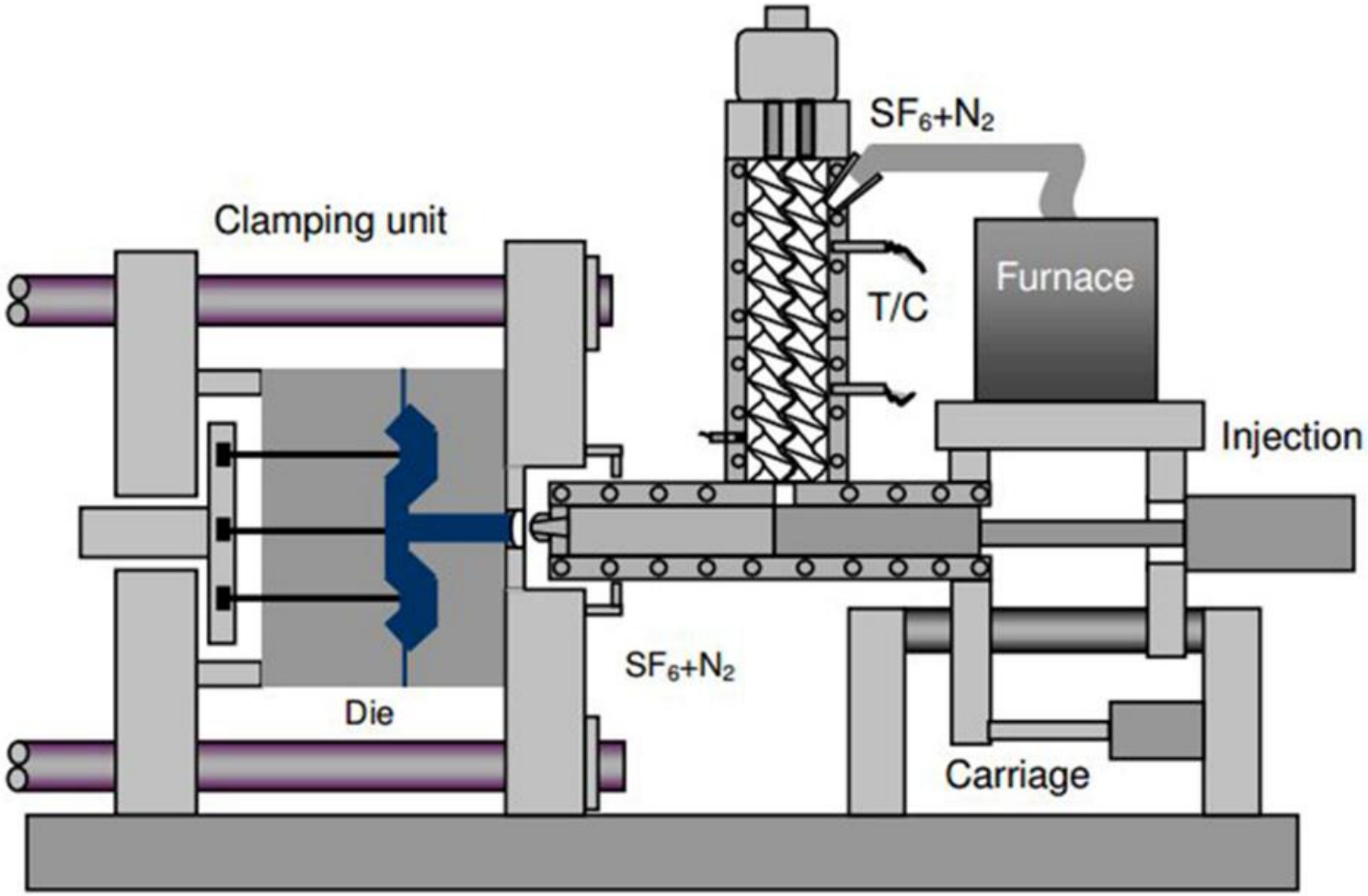



Gas-induced semi-solid process (GISS)

- **The feed stock is heated to the semi-solid temperature and sheared into a thixotropic state in a screw feeder before passing directly into the diecasting machine.**




Schematic of THIXOMOLDING machine




Rheomoulding

## Video links

- https://www.youtube.com/watch?v=_w6eAhMQa9Y
- https://www.youtube.com/watch?v=gvVBhVK4YZA
- https://www.youtube.com/watch?v=ium000rtia0
- https://www.youtube.com/watch?v=-6XwUfSkyo8
- https://www.youtube.com/watch?v=1B__o-axmDY
- https://www.youtube.com/watch?v=mNTIGMHJpTg
- https://www.youtube.com/watch?v=Vf58f-ZtG_g
- https://www.youtube.com/watch?v=bvPAQkCfBEI