Squeeze Casting

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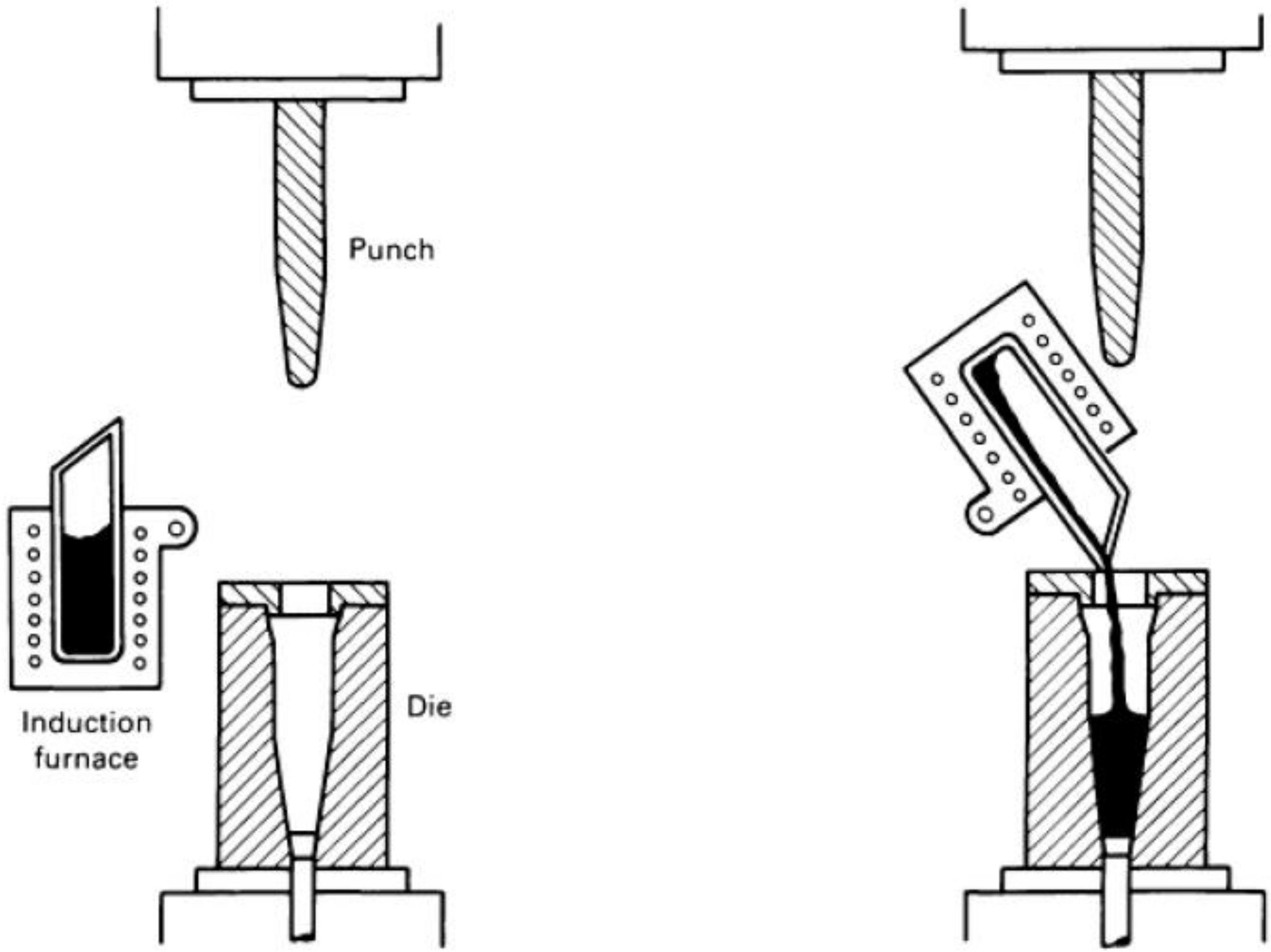
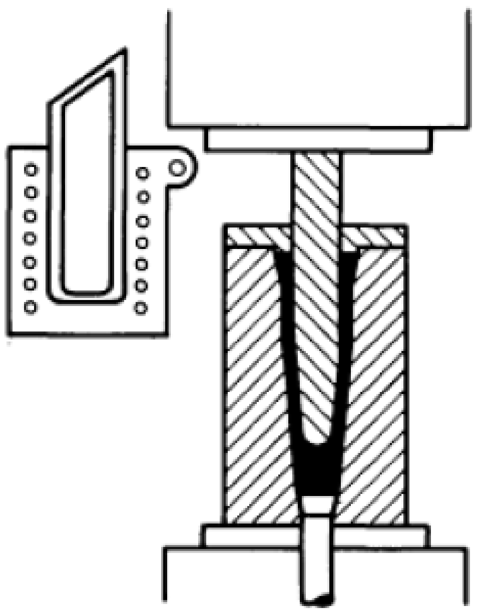
Squeeze casting, also known as liquid-metal forging, is a process by which molten metal solidifies under pressure within closed dies positioned between the plates of a hydraulic press. The applied pressure and the instant contact of the molten metal with the die surface produce a rapid heat transfer condition that yields a pore-free fine-grain casting with mechanical properties approaching those of a wrought product.

The squeeze casting process is easily automated to produce near-net to net shape high-quality components. The process was introduced in the United States in 1960 and has since gained widespread acceptance within the nonferrous casting industry.

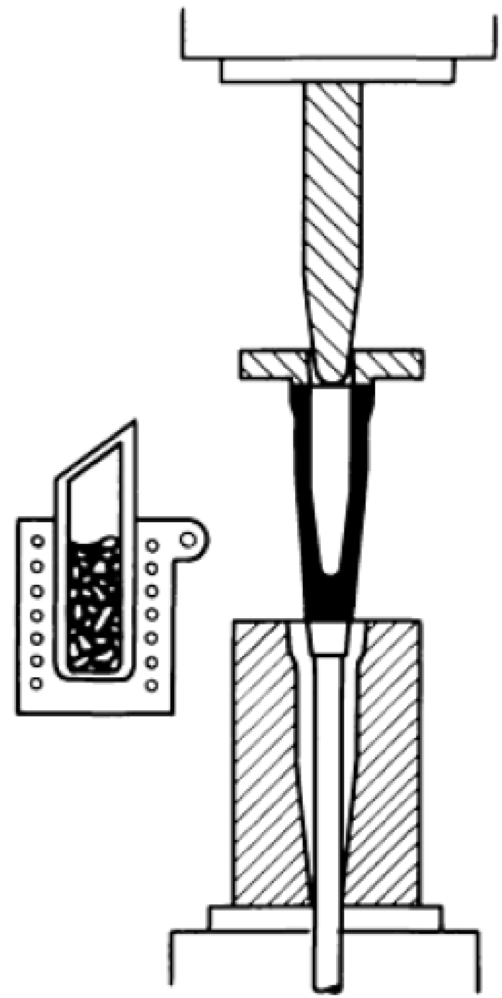
Aluminium, magnesium, and copper alloy components are readily manufactured using this process. Several ferrous components with relatively simple geometry for example, nickel hard-crusher wheel inserts have also been manufactured by the squeeze casting process. Despite the shorter die life for complex ferrous castings requiring sharp corners within the die or punch (tooling), the process can be adopted for products where better properties and/or savings in labor or material costs are desired.



(a) (b)



(c)



(d)

Advantages of Squeeze Casting

With the current emphasis on reducing materials consumption through virtually net shape processing and the demand for higher-strength parts for weight savings, the emergence of squeeze casting as a production process has given materials and process engineers a new alternative to the traditional approaches of casting and forging. By pressurizing liquid metals while they solidify, near-net shapes can be achieved in sound, fully dense castings.

The near-net and net shape capabilities of this manufacturing process are key advantages. Tolerances of ±0.05 mm are not uncommon for nonferrous castings, with yields of 100% in a number of applications. Improved mechanical properties are additional advantages of squeeze cast parts.

Squeeze casting has been successfully applied to a variety of ferrous and nonferrous alloys in traditionally cast and wrought compositions. Applications include aluminium alloy pistons for engines and disk brakes; automotive wheels, truck hubs, barrel heads, and hubbed flanges; brass and bronze bushings and gears; steel missile components and differential pinion gears; and a number of parts in cast iron, including ductile iron mortar shells.

Squeeze casting is simple and economical, efficient in its use of raw material, and has excellent potential for automated operation at high rates of production. The process generates the highest mechanical properties attainable in a cast product. The microstructural refinement and integrity of squeeze cast products are desirable for many critical applications.

Process Description

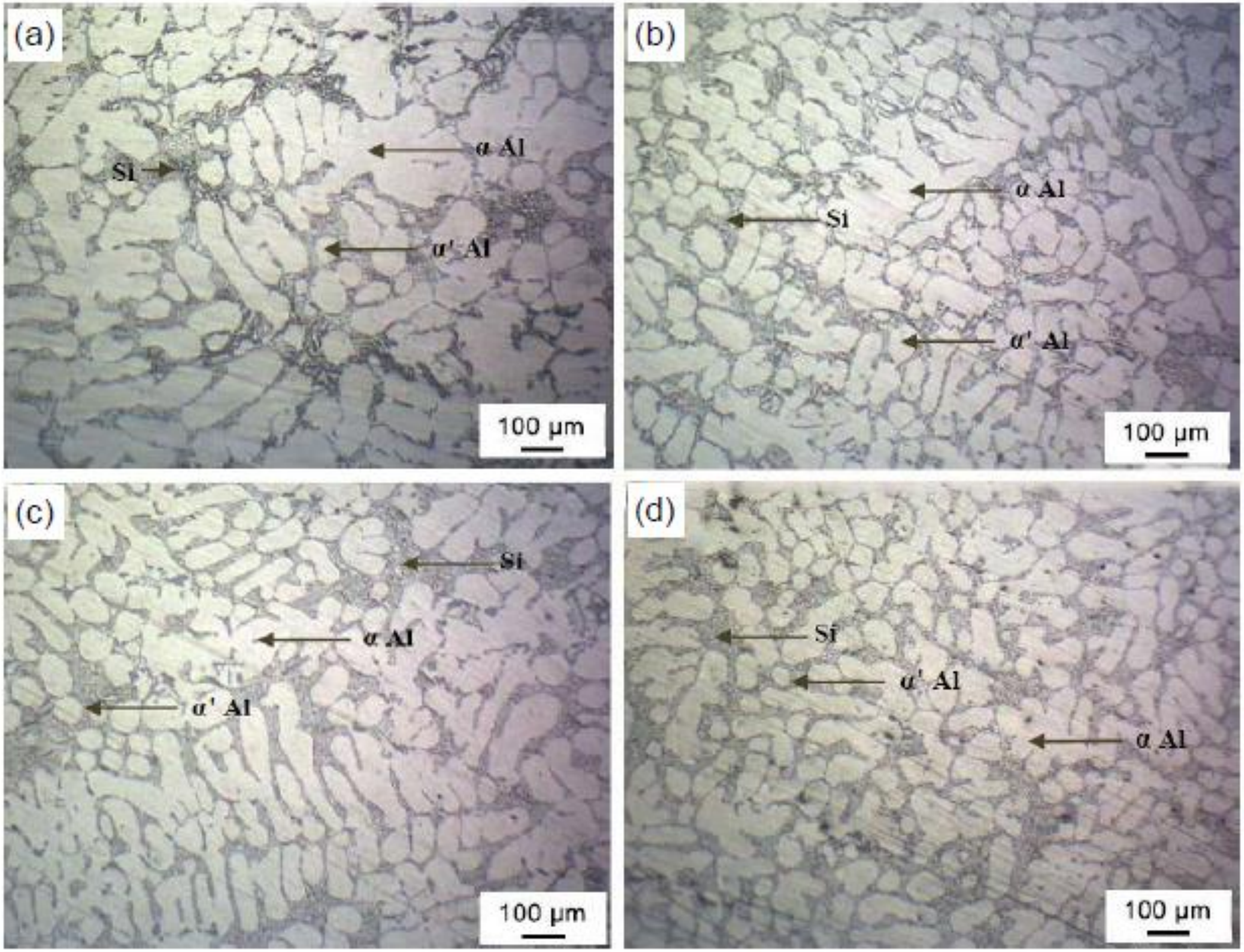
Squeeze casting consists of metering liquid metal into a preheated, lubricated die and forging the metal while it solidifies. The load is applied shortly after the metal begins to freeze and is maintained until the entire casting has solidified. Casting ejection and handling are done in much the same way as in closed die forging.

The high pressure applied (typically 55 to 100 MPa) is enough to suppress gas porosity except in extreme cases, for which standard degassing treatments are used. The tendency toward shrinkage porosity is limited by using a bare minimum of superheat in the melt during pouring. This is possible in squeeze casting because melt fluidity, which requires high pouring temperatures, is not necessary for die fill, the latter being readily achieved by the high pressure applied.

In heavy sections of the casting, which are particularly prone to the incidence of shrinkage porosity, the applied pressure squirts liquid or semiliquid metal from hot spots into incipient shrinkage pores to prevent pores from forming. Alloys with wide freezing ranges accommodate this form of melt movement very well, resulting in sound castings with a minimum of applied pressure.

The squeeze casting cycle starts with the transfer of a metered quantity of molten metal into the bottom half of a preheated die set mounted in a hydraulic press The dies are then closed, and this fills the die cavity with molten metal and applies pressures of up to 140 MPa on the solidifying casting.

During the solidification process in gravity casting, it was discovered that an air gap due to thermal contraction was created between the melt and die wall. The air gap caused a change in heat transfer mode from conduction to radiation and convection, resulting in a decrease in heat transfer coefficient and consequently increase of solidification time. In squeeze casting, the applied pressure increases the surface contact area between the melt and the die wall, resulting in rapid heat transfer or a higher cooling rate and a shorter solidification time. Increasing the squeeze pressure increases the cooling rate, resulting in the nucleation of more refined grains and decrease of dendrite arm spacing.



Micrograph of squeeze cast aluminum alloy (A356) with squeeze pressure of 2.5 MPa (a), 3 MPa (b), 3.5 MPa (c), and 4 MPa (d)

Video links

- https://www.youtube.com/watch?v=3mOVappHlR4
- https://www.youtube.com/watch?v=jhOV9TudAlA
- https://www.youtube.com/watch?v=MG1n5F5tWLA