ADVANCES IN SQUEEZE CASTING TECHNIQUE FOR PROCESSING DISCONTINUOUS CERAMIC FIBRE REINFORCED METAL MATRIX COMPOSITE MATERIALS

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ABSTRACT

Squeeze casting is used for processing of ferrous, non-ferrous materials and metal matrix composites for different metals as well as alloy based matrices. The advantages of the squeeze casting method include the minimization of porosity, pinhole and shrinkage defects, a 100 percent casting yield, an improved attainment of part details having complicated contours, a good surface finish, better dimensional accuracy, high strength to weight ratio, better wear resistance and corrosion resistance, improved hardness, better heat resistance, improved fatigue and better creep strength. Hence engineering components manufactured using squeeze casting processes require fewer post machining operations.

INTRODUCTION

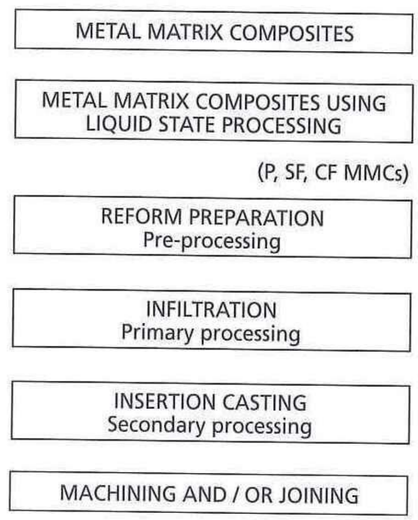
Squeeze casting which is also known as liquid forging has advantages of traditional high pressure die casting, gravity permanent mould casting and forging. It is a new developing casting process often known as squeeze forming, liquid pressing, extrusion casting, liquid metal stamping, pressure crystallization and corthias casting. This technology was first discovered by the Russians and later, it was developed in the USA, Europe and Japan.

Metal matrix Composites (MMCs) castings have been developed with greater success by using fibre reinforcements in metallic materials (ASM Metals Handbook on Casting, 1988). An overview for the flow chart of metal matrix composites processing using liquid metallurgy route is shown in Figure 1.

Several difficult challenges need to be overcome inclusive of but not limited to issues such as higher processing temperatures, fibre-matrix bonding and the ability to produce desired geometries (Franklin and Das, 1984). However these problems can be solved.

ADVANCES IN SQUEEZE CASTING PROCESS

Based on current research, the future of these materials lies in the ability to economically produce desired shapes by pressure infiltration systems and the need for improvement in fibre-



P: Particle reinforced MMCs
SF: Short fibre reinforced MMCs
CF: Continuous fibre reinforced MMCs

Figure 1.
Flow Chart for processing of MMCs using liquid metallurgy route

matrix bonding and perhaps significant alloy development (Clegg and Lim, 1996). Fibre reinforced metal matrix composites have fibres that are discontinuous and they are typically circular and vary in diameter from 0.1 cm to 0.1 mm (Stefanescu, 1993).

Fibre-matrix bonding is a key factor in the effective transmission of load from the matrix to the fibre. In order to obtain proper bonding, wetting of the fibre by the matrix material is essential. Hence, squeeze casting is used to apply very high pressures to increase the bonding between the liquid metal and alloy with the fibre.

The most common method used to apply the reinforcement in the desired location has been with the use of fibre preforms (Askeland, 1984). A fibre preform is similar to a sponge made of fibres that will incorporate with the composite. The main challenge to the use of preforms is the high pressures currently used to infiltrate the metal. These high pressures may break the preform.

Theory on Squeeze Infiltration kinetics

Liquid metal is injected into the interstices of short fibres referred to as a preform. Preforms are made up of alumina-silicate fibres and are designed with specific shapes to form an integral part of finished products in the as-cast form (Kaczmar *et.al,* 2000). The pressure required for infiltration can be calculated readily on the basis of the necessary meniscus curvature and corrections can be made for the melt-fibre wetting. In most cases, fibres do not act as preferential crystal nucleation sites during melt solidification (Strong, 1989).

One consequence of this is that the last liquid to freeze which is normally solute-enriched tends to be located around the fibres. Such prolonged fibre-melt contact often under high hydrostatic pressure and with solute enrichment tends to favour the formation of a strong interfacial bonding (Taha, 1992).

Reasons for selecting Squeeze Casting Technology

In processes like pressure die casting, the molten metal is forced into the die cavity through a gating system with an enormous amount of pressure. Air is also injected into it ,causing porosity, while releasing during solidification. The castings are subjected to shrinkage porosity, thereby producing an air gap between the casting and the mould wall (Peng *et al.,* 2002; Mortensen *et al.*, 1989; Mortensen, 2000).

This causes a lower heat transfer rate and grain size will be higher in the produced castings. This favorably lowers the properties like hardness and strength. The casting yield is also low in the pressure die casting process. But, in the squeeze casting process, no gating system is provided, and a metered quantity of molten metal is poured into the die cavity. There, it forms a tight contact with almost no air gap formation between the casting and the mould wall. Since pressure is applied throughout the process, molten metal flows into the shrinkage cavities and gases like hydrogen dissolve and remain in the solution.

Hence, defects like porosity and shrinkage are eliminated. The casting yield is 100% due to the absence of a gating system (Cornie, 1995). Because of the higher interfacial coefficient values, the heat transfer rate will be more and castings of finer grain size will be produced. Hence this produces high strength castings.

Steps in Squeeze Casting process

Steps in the squeeze casting process are shown in Figure 2. The basic steps are pouring the liquid melt into the plunger and then applying pressure to eject it into the die cavity by docking. The pressure is maintained until the liquid metal is fully solidified.

PROCESSING METAL MATRIX COMPOSITES USING SQUEEZE CASTING TECHNOLOGY

Ceramic fibre reinforced MMCs are produced by liquid forging and the process steps are explained in Figure 3 (Chawla, 1992; Dullien, 1992).

The process involves placing ceramic fibre perform, having known volume fraction of fibres expressed in percentage, in a die cavity and pouring metered quantity of molten metal over it. Further pressure is applied for infiltrating the molten metal into the porous preform (Serope and Steven, 2001).