LIQUID STATE FABRICATION OF METAL MATRIX COMPOSITES

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification.
In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained.
Wetting improvement may be achieved by coating the dispersed phase particles (fibers).
Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix.

The methods of liquid state fabrication of Metal Matrix Composites:

- **Stir Casting**
- **Infiltration**
- **Gas Pressure Infiltration**
- **Squeeze Casting Infiltration**
- **Pressure Die Infiltration**

Stir Casting

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring.
Stir Casting is the simplest and the most cost effective method of liquid state fabrication.

The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.
Stir Casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30 vol.%).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:

1. There are local clouds (clusters) of the dispersed particles (fibers);

2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.

- The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition.

The method using stirring metal composite materials in semi-solid state is called **Rheocasting**.
High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase.

Infiltration

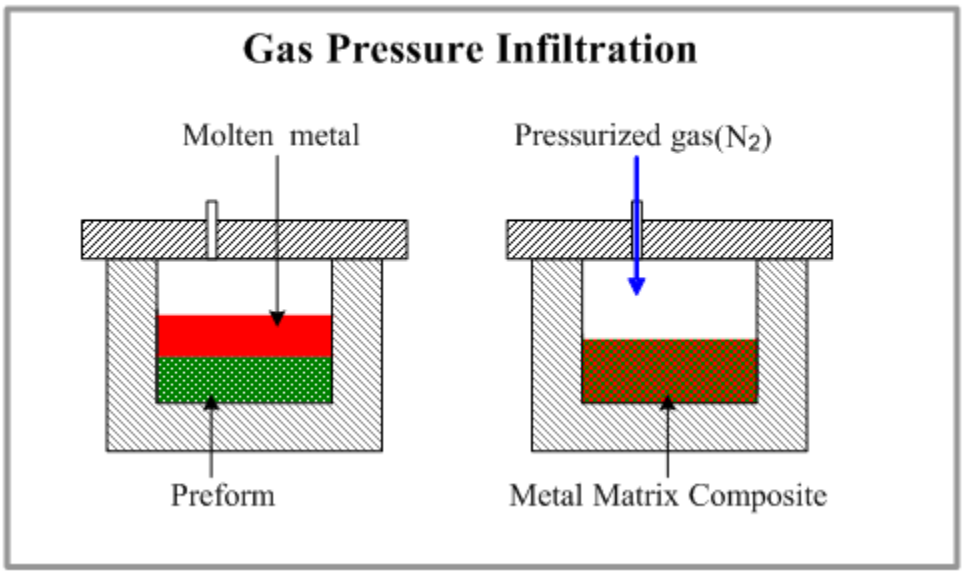
Infiltration is a liquid state method of composite materials fabrication, in which a preformed dispersed phase (ceramic particles, fibers, woven) is soaked in a molten matrix metal, which fills the space between the dispersed phase inclusions.
The motive force of an infiltration process may be either capillary force of the dispersed phase (**spontaneous infiltration**) or an external pressure (gaseous, mechanical, electromagnetic, centrifugal or ultrasonic) applied to the liquid matrix phase (**forced infiltration)**.

Infiltration is one of the methods of preparation of tungsten-copper composites.
The principal steps of the technology are as follows:

- Tungsten Powder preparation with average particle size of about 1-5 mkm.
- Optional step: Coating the powder with nickel. Total nickel content is about 0.04%.
- Mixing the tungsten powder with a polymer binder.
- Compacting the powder by a molding method (Metal injection molding, die pressing, isostatic pressing). Compaction should provide the predetermined porosity level (apparent density) of the tungsten structure.
- Solvent debinding.
- Sintering the green compact at 2200-2400F (1204-1315C) in Hydrogen atmosphere for 2 hrs.
- Placing the sintered part on a copper plate (powder) in the infiltration/sintering furnace.
- Infiltration of the sintered tungsten sceleton porous structure with copper at 2100-2300F (110-1260C) in either hydrogen atmosphere or vacuum for 1 hour.

Gas Pressure Infiltration

Gas Pressure Infiltration is a forced infiltration method of liquid phase fabrication of Metal Matrix Composites, using a pressurized gas for applying pressure on the molten metal and forcing it to penetrate into a preformed dispersed phase.



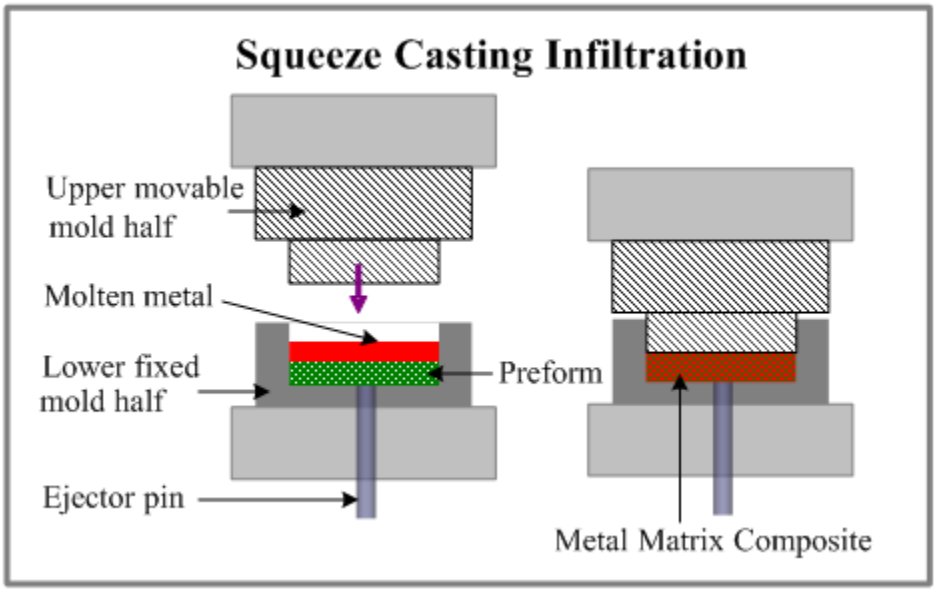
Gas Pressure Infiltration method is used for manufacturing large composite parts.

The method allows using non-coated fibers due to short contact time of the fibers with the hot metal.

In contrast to the methods using mechanical force, Gas Pressure Infiltration results in low damage of the fibers.

Squeeze Casting Infiltration

Squeeze Casting Infiltration is a forced infiltration method of liquid phase fabrication of Metal Matrix Composites, using a movable mold part (ram) for applying pressure on the molten metal and forcing it to penetrate into a performed dispersed phase, placed into the lower fixed mold part.
Squeeze Casting Infiltration method is similar to the Squeeze casting technique used for metal alloys casting.



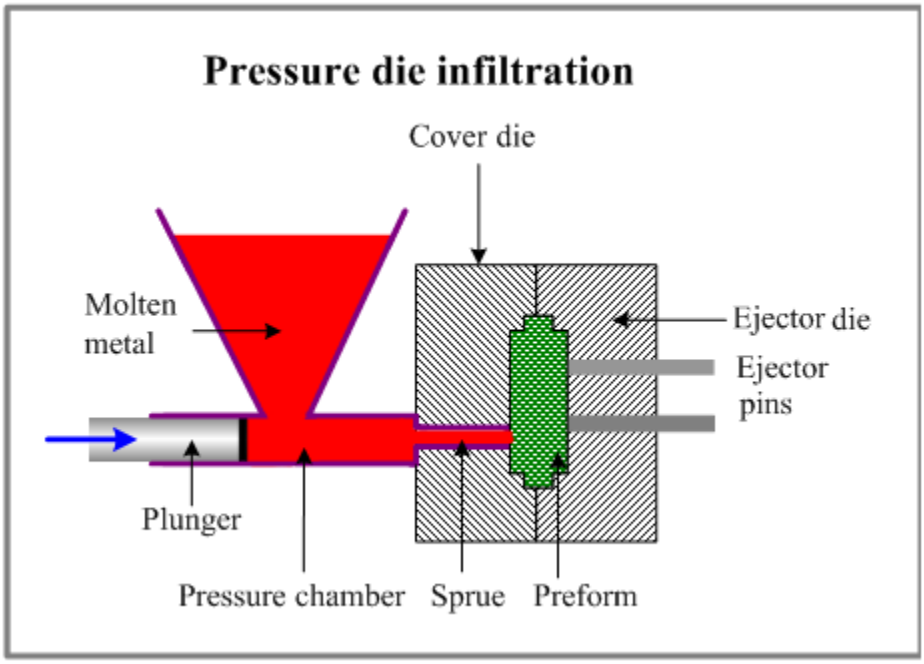
Squeeze Casting Infiltration process has the following steps:

- A preform of dispersed phase (particles, fibers) is placed into the lower fixed mold half.
- A molten metal in a predetermined amount is poured into the lower mold half.
- The upper movable mold half (ram) moves downwards and forces the liquid metal to infiltrate the preform.
- The infiltrated material solidifies under the pressure.
- The part is removed from the mold by means of the ejector pin.

The method is used for manufacturing simple small parts (automotive engine pistons from aluminum alloy reinforced by alumina short fibers).

Pressure Die Infiltration

Pressure Die Infiltration is a forced infiltration method of liquid phase fabrication of Metal Matrix Composites, using a Die castingtechnology, when a preformed dispersed phase (particles, fibers) is placed into a die (mold) which is then filled with a molten metal entering the die through a sprue and penetrating into the preform under the pressure of a movable piston (plunger).



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