

SEMI-SOLID METAL CASTING – Reducing the Cost of Copper Alloy Parts

Introduction

Today's economy, influenced as it is by foreign competition and rising overhead, demands that parts buyers constantly find suppliers that offer both low cost and high quality. The parts manufacturer is then driven to find ways to reduce production costs to maintain a reasonable margin and stay in business. Part quality cannot be sacrificed; in fact the buyer often demands higher quality standards at no price increase. For the manufacturers and users of copper alloy parts, Semi-Solid Metal forming (SSM) can be an alternative, and in many cases, lower cost method to produce parts in large numbers. The ability to apply SSM forming to copper alloys is a direct result of the successful development of a high temperature nickel-base alloy die system that significantly extends die life in die casting metals and alloys with high melting temperatures. As described below, SSM forming has the potential to significantly reduce production costs for a wide variety of copper alloy parts because of the near net shape character of the process, the ability to achieve high production rates, the high part density that reduces section size and part weight and reduced machining and finishing costs.

What is Semi-Solid Metal Forming?

Semi-solid metal forming (SSM), or die casting in the semi-solid state, is a near net shape manufacturing method that offers the favorable costs of die casting with much improved part quality. Pressure die casting has long been regarded as an economical, high productivity process for manufacturing a broad variety of metal parts, but one that is subject to quality issues because of entrapped air and shrinkage porosity. Porosity can degrade mechanical properties and pressure tightness or show up as surface defects after machining or polishing.

SSM forming is done at a temperature between the liquidus and solidus temperatures, with the fraction solid being in the approximate range of 30 to 65%. The semi-solid billet (Figure 1) maintains its shape and is convenient for loading into the shot sleeve of a conventional die casting machine. For the semi-solid metal to have sufficiently low viscosity, the structure at the forming temperature must consist of a globular primary solid phase surrounded by the liquid phase. The technical and economical feasibility and success of the SSM process are determined to a large extent by the approach used to produce the starting stock with the essential precursor structure.



Figure 1: 1-inch diameter copper alloy semi-solid billet being squeezed by an adjustable pliers at 50% solid/50% liquid. This SSM material has the consistency of modeling clay.

Benefits of SSM Forming

As an innovative casting process, SSM casting offers great potential to save costs, energy and material, and reduce the environmental impact of casting.

The benefits of SSM forming can be summarized as follows:

- Net or near net shape processing.
- Less thermal fatigue heat, less mold or die wear, and less solidification shrinkage due to reduced temperature of feedstock.

- Much reduced gas entrainment, porosity, shrinkage, hot tearing and other solidification defects due to less turbulent die filling, resulting in better mechanical properties and pressure tightness with reduced section thickness.
- Finer, more uniform, microstructures leading to higher mechanical performance.
- Increased casting speed relative to liquid processing due to lower thermal demands on the dies.
- As substitute for sand casting, SSM cast parts production is relieved of the costs and environmental problems of reclamation and disposal of lead-contaminated sands.
- Allows for the lead content of red brasses to be much reduced, and combined with a semi-solid charge should enable alloys normally prone to hot tearing to be die cast.

Breakthrough in Extending Die Life for Copper Alloys

Pressure die casting has generally been applicable only to relatively low melting metal alloys (e.g., aluminum, zinc and magnesium) because of severely limited die life experienced in die casting higher melting materials such as copper and its alloys. High die amortization costs have severely limited production of conventional as well as SSM die-cast copper alloy parts. The problem of extending die life has been addressed in the recent development of the copper motor rotor. This project of the world copper industry, partially funded by a DOE NICE³ grant, has solved the manufacturing problems associated with die casting pure copper and demonstrated the increased energy efficiency of the induction motor achievable by substituting copper for aluminum in the rotor squirrel cage. Motors with copper rotors are now in commercial production, using the heated nickel-base alloy die system developed and demonstrated as the way to greatly extend die life over that of conventional die steels. The nickel-base alloys, INCONEL alloy 617 and HAYNES alloy 230, provide the high temperature mechanical properties and oxidation resistance required for handling copper and copper alloys. Operating the dies at high temperature (600 – 625°C) significantly delays the thermal fatigue failure mechanism known as heat checking by reducing the cyclic thermal and resulting strain gradients in the die.

This high temperature die technology is now available for application to SSM forming of copper alloy parts. Because the melting range of the alloys is lower than that of pure copper, and because only about 50% of the heat of fusion will be transferred to the dies from the semi-solid charge, the die operating temperature to achieve good die life will be somewhat lower than that required for pure copper.

Contacts

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Vforge, Inc. has been working with the Copper development Association on copper alloy SSM process development, and offers production capability for SSM formed copper alloy parts.

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