DISPERSING FLYASH PARTICLES IN AN ALUMINUM MATRIX

An economical method for dispersing flyash ceramic particles in molten aluminum enables the fabrication of low-cost metal matrix composites.

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Ultalite is a patented, low-cost aluminum metal matrix composite reinforced with ceramic particles derived from flyash. Other metal matrix composites can often be expensive because of the high price of the reinforcement ceramic particles and the high costs associated with dispersing the particles in the matrix. However, flyash particles are formed as a byproduct in coal-fired power plants, and therefore are extremely low in cost, less than 10% the price of aluminum. In addition, new inexpensive techniques for dispersing the flyash ceramic particles into molten aluminum have been developed, and these methods are described in this article.

Source of ceramic particles
The composites are based on technology originally developed by Prof. Robert Pond Sr. and patented in 1989. The rights to this patent, together with other intellectual property covering the production and application of Ultalite composites, are now owned by Cyco Systems Corp. of Australia. Prof. Pond’s original concept was to infuse low-cost ceramic particles such as flyash into low-melting-temperature alloys such as zinc, aluminum, or tin to produce economical composites. The technology has now been commercialized by Cyco Systems to produce aluminum/ceramic composites that provide significantly improved wear resistance.

The original flyash material, which was sourced from the Tarong Power Station in North Queensland, Australia, contained a wide range of particle sizes, from less than a micron to greater than 100 microns in diameter. Previous work had shown that the smaller particles can cause problems as they are mixed into the molten aluminum. Therefore, technology recently commercialized by Prof. Robl and co-researchers at the University of Kentucky was applied to narrow this range by eliminating the fines as well as the larger particles.

The original objective of this flyash beneficia- tion process was the separation and collection of finer particles for the manufacture of cement. However, the same technology has been shown to be capable of classifying and cleaning the flyash particles for composites.

Stirring ceramic particles into aluminum
The MC-21 process is a relatively new innovation in which ceramic particles are stirred into an aluminum melt by an extremely efficient, vacuum-assisted mixing process. The process provides good wetting between the aluminum matrix and the ceramic particles, allowing the stirring time to be kept relatively short. This short stirring time, together with the elimination of the fine (<6 µm) flyash particles, minimizes the exo-thermic chemical reaction between the molten A356 aluminum alloy and the ceramic particles.

Figure 1 shows a schematic drawing of the MC-21 mixing unit. The ceramic particles are introduced under the surface of the molten aluminum by feeding through the internal passageway of a hollow impeller tube. The lower end of the impeller tube contains teeth that produce a shear region in the molten aluminum between the impeller base and head. The high shear forces created by the rotating impeller lead to rapid wetting of the ceramic particles, and this produces a uniform distribution of ceramic particles throughout the melt. After mixing, the molten composite is poured into ingots weighing approximately ten pounds.

For the trials described here, the average size of the flyash particles was about 20 µm. Approximately ten pounds of these flyash particles were fed into a bath containing about 105 lb of molten A356 alloy, to produce a composite containing 10 vol% ceramic particles. Figure 2 shows a photomicrograph of the composite.

High-wear applications
The initial application of the composite has been...
the manufacture of brake drums and rotors. As the density of the composite is only 2.3 g/cm³, Ul
talite brake drums are less than half the weight of a conventional cast iron brake drum.

The Ultalite composite brake drum shown on the cover was produced by squeeze casting, which is a liquid-based, near-net-shape process that utilizes a diecasting machine and reusable hardened steel dies. In this process, the molten composite is fed into the die under closely controlled process conditions, which eliminates turbulence and gas entrapment during the filling of the die. After the die is filled, the casting is pressurized to feed solidification shrinkage and minimize shrinkage porosity.

Cyco Systems believes that the combination of low material costs and efficient processing can lead to widespread application of this composite in brakes. In fact, brake dynamometer testing has recently been carried out on squeeze-cast Ultalite brake drums. Results documented that their braking performance is superior to that of cast iron drums.

Dynamometer testing on the Ultalite drums was carried out in accordance with the SAE J2522 standard, with standard off-the-shelf brake linings such as Nisshimbo and DON #8259. Figure 3 depicts results from the fade segment 6.9 of the AK Master Test for cast iron/Nisshimbo, Ultalite/Nisshimbo, and Ultalite/DON #8259 combinations.

The first plot shows brake factor, temperature, and applied-pressure variations across 15 stops for various combinations of materials. Each stop or application is constant-energy based, with a deceleration of 0.4 g.

In addition, due to superior heat dissipation, the operating temperature of the Ultalite brake drums was more than 100°C lower than that of the cast iron drums, thereby reducing brake fade. The data shown in Fig. 4 also shows that the Ultalite brake drum lining wear characteristics are equivalent to or better than those of a cast iron brake drum.

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