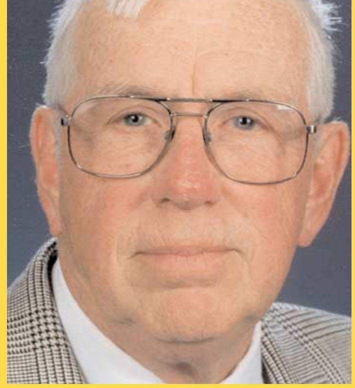

Bob Rapp

Casting aluminum

Lay people unfamiliar with metallurgical processing, and maybe even most materials scientists and engineers, may have little knowledge of the steps required to cast Al commercially. Perhaps I can interest the reader with a summary of this important process. I refer to casting large Al shapes suitable for rolling, forging, pressing, extruding, or drawing to make plates, sheet, foil, and structural wrought shapes for uses in transportation, construction, households, and other areas. I will not consider the casting of Al to a final, small shape in the foundry.

Consider first the many ways to cast several tons of Al. The traditional batch route is to pour the liquid Al gradually from an elevated holding furnace into a water-cooled 'collar' (caster) with cross-sectional dimensions of about 2.5 m x 0.6 m, and withdraw the solidified metal into a pit ~10 m deep to form a semicontinuous ingot. Because the surface is solidified and cooled in the caster, no contacting mold needs to be separated, although blemishes are removed by scalping. An alternative technology for much smaller sections includes 'continuous' casting of Al, whereby the solid is formed in the water-cooled caster in the horizontal plane and immediately rolled into a round or rectangular section without any intervening handling, cutting, or interruption of the metal. This technology requires significant coordination and control of the combined casting, rolling, coiling, and materials-handling stages. A third method used in the Al shop is 'strip casting' of sheet or plate, whereby liquid Al is poured into the nip of a water-cooled pair of rollers or belts so that the desired thinner product gets a fast start on its path to its final net shape.

These processes may not sound too difficult, but many complications must be addressed before liquid metal enters the caster. Al is melted, transported, and poured in contact with humid air, so reaction with water vapor always leads to significant dissolved (atomic) hydrogen content. Upon solidifying pure Al at its melting point (660°C), a melt equilibrated with 1 atm of H_2 would release 2.2 cm^3 of gas per 100 g (37 cm^3) of solid Al. That is a formula for creating metallic gruyere cheese, not a structural metal. The H-saturated solid Al would still contain 0.05 cm^3 per 100 g, which would gradually evolve internal bubbles upon cooling and ruin the mechanical properties. So, to permit commercial use of Al at all, dissolved H is removed to a low level from the liquid Al prior to casting. One process bubbles pure Ar gas through special rotary nozzles, so that the H leaves the liquid and enters the gas bubbles that are discharged. Another process adds a few percent Cl_2 gas to the Ar to eliminate alkali metal solutes and inclusions. These fume-containing, environmentally objectionable gases must then be cleaned in a bag house before their release.

If commercially pure liquid Al is degassed and cast, the grain boundaries would naturally collect the low-melting and least-soluble impurities. These lead to cracking as a result of casting stresses. So, a precasting treatment must be introduced to limit the grain size of the final wrought product to a few hundred microns. Specialty master alloy companies have developed Al-base alloys in several shapes that contain an extremely fine dispersion of TiB_2 or TiC particles, which exhibit the lowest solubility in liquid Al. The typical master alloy composition of 5% Ti-1% B-Al is achieved by reacting a pure Al melt with a salt cover of K_2TiF_6 and KBF_4. A specific temperature-time treatment of the melt is needed to optimize the fine dispersion of TiB_2 particles without agglomeration or density segregation. These master alloys are then cast into chunks or rods convenient for the big Al producers to toss or feed into the trough that passes degassed liquid Al to the casting machine. The micron-size TiB_2 or TiC particles of the 'grain refiner' then act as nuclei for restricted grain growth, while controlling microsegregation, in the cold-rolled and annealed wrought product, resulting in favorable physical and mechanical properties.

Other precast additives are provided by master alloy companies to introduce elements such as Mg, Si, Cu, Zn, and Mn for specific compositions. These so-called 'hardeners' are highly enriched alloys added to the melting furnace in the cast shop (also as 'pigs' or rods) for an easy, accurate, and reliable way to achieve a composition. Problems such as density separation and fuming may be minimized compared with the addition of individual pure metals at the caster.

Without degassing, grain refining, and alloying/hardening, wrought Al could never be applied in engineering. After all, would you like to fly over an ocean in an updated version of Howard Hughes' Spruce Goose?

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