BRASSES AND BRONZES AS CASTING ALLOYS: PROPERTIES, DEFECTS, AND CASTING TECHNOLOGY

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Copper alloys occupy an important place among engineering materials due to their unique combination of mechanical, physical, and chemical properties. They are widely used in various branches of industry, including mechanical engineering, shipbuilding, energy, and chemical equipment manufacturing. The demand for copper alloys is primarily due to their high strength, good ductility, excellent corrosion resistance, and favorable antifriction properties. These properties make them especially suitable for producing parts operating under conditions of friction, aggressive environments, and variable loads.

In modern foundry practice, copper-based alloys are considered one of the key groups of non-ferrous casting materials. Among them, brasses and bronzes have found the widest application due to their good castability and the ability to tailor their properties through alloying. The structure and properties of these alloys largely depend on their chemical composition, cooling conditions, and casting technology, which determines their performance in service [1].

At the same time, despite their advantages, copper alloys are characterized by certain technological challenges during casting. These include a tendency to shrinkage, formation of porosity, hot cracking, and non-metallic inclusions. Therefore, improving the quality of castings requires careful control of melting and solidification processes, as well as optimization of mold design and gating systems [2].

Copper alloys possess relatively high strength, ductility, corrosion resistance, and good antifriction properties. Among copper-based casting alloys, brasses and bronzes are the most widely used.

Brasses are copper–zinc alloys containing 4–40% Zn. In addition, they may include small amounts of Al, Mn, Ni, Si, and other elements. Casting brasses are characterized by fairly high strength ($\sigma_u \approx 705$ MPa), ductility ($\delta \approx 20\%$), corrosion resistance, and antifriction properties. They exhibit satisfactory fluidity but relatively high shrinkage (up to 2.2%). As a result, castings often contain shrinkage cavities and porosity. All copper alloys are prone to cracking. Brasses are used for manufacturing various types of fittings for marine engineering, bushings and bearing cages, and components of rolling mills.

Bronzes can be divided into tin bronzes and tin-free bronzes. Tin bronzes typically contain 9–11% Sn, or 2–6% Sn with additions of 3–6% Pb and up to

15% Zn. Tin-free bronzes contain 8–11% Al and may be additionally alloyed with Fe, Mn, Ni, and other elements. Tin bronzes have good fluidity and relatively high shrinkage (up to 1.6%). Due to the wide solidification range, porosity often forms in their castings [3].

Tin-free bronzes also exhibit high fluidity, but their shrinkage is higher than that of tin bronzes (up to 2–2.4%), which increases the risk of shrinkage cavities. Tin bronzes are used to produce cast fittings, gears, bearings, bushings, and similar components. Tin-free bronzes are often used as a more economical substitute for expensive tin bronzes; they are applied in the production of large ship propellers, gears and gear wheels, pump housings, and components of chemical equipment.

For casting operations, copper alloys are melted in channel-type low-frequency induction furnaces, arc furnaces with horizontally arranged electrodes under a charcoal layer, or in protective gas atmospheres or vacuum.

To produce castings from copper alloys, sand and shell mold casting methods are commonly used; less frequently, permanent mold casting, centrifugal casting, and die casting are applied. To prevent shrinkage cavities and porosity, risers and chills must be properly designed in the mold. To avoid cracking in castings, molding mixtures with high collapsibility are used. Methods for preventing non-metallic inclusions are similar to those used for other non-ferrous alloys, including the use of filters and expanded gating systems.

The technology for producing castings from copper alloys requires strict control of melting and casting conditions, including the use of protective atmospheres, proper gating system design, and the application of risers and chills. To reduce casting defects, melt filtration and the use of highly collapsible molding materials are essential.

Thus, the effective use of copper alloys in casting production is achieved through a comprehensive consideration of their physicochemical properties and optimization of process parameters.

References

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