THICK and THIN: Designing Copper-Base Sand Castings

Designing thin and thick sections is an issue with all castings. For copper-base alloys, particular attention must be paid to the wide freezing range alloys to ensure sound castings.

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The rules in casting design are fairly simple when it comes to thick and thin sections. Do not design a casting with both a thick and thin section in it!

Obviously, this isn't reality, but it is something to keep in the back of the mind when designing copper-base alloy castings.

One of the greatest benefits afforded by the metalcasting process is the ability to produce complex geometries (including thin and thick sections) unable to be produced in one component by any other metal forming method. However, casting designers must be able to manipulate component designs to keep thin and thick sections from adjoining in a casting design, and when they have to be in proximity, provide a gradual transition to ensure soundness.

Possible Defects

The issue with adjoining thick and thin sections in casting design is what happens when the molten metal solidifies in the mold.

A thin section will complete its solidification first. As it solidifies, it begins to shrink and draws metal to refill this shrinkage from the larger section adjoining it. The thin section draws metal until it solidifies. The thick section is the last to solidify. However, as it solidifies it is looking for somewhere from which to refill its metal. Since the thin section adjoining it has already solidified, the thick section has nowhere to draw from and a shrinkage defect (an area of lesser density level often referred to as porosity) will develop on the exterior or interior of the casting.

One of the tools casting designers and foundries use to avert the shrinkage dilemma is risers. These resevoirs of hot metal are designed to be the last to solidify and are placed at the thick sections of the casting to feed them as they solidify (risers are part of a casting's gating system and are cut off during cleaning and finishing). A problem occurs when the casting design doesn't allow a riser to be connected to the thick section or the casting design only allows the riser to be the first part of the mold to receive molten metal and thus one of the first parts of the mold to have its metal solidify. A solidified riser cannot feed metal to a thick section.

A gradual transition between thin and thick sections, while still open to shrinkage defects, helps to alleviate the shrinkage problems because the disparity in solidification times between the adjoining sections doesn't cause a combative situation.

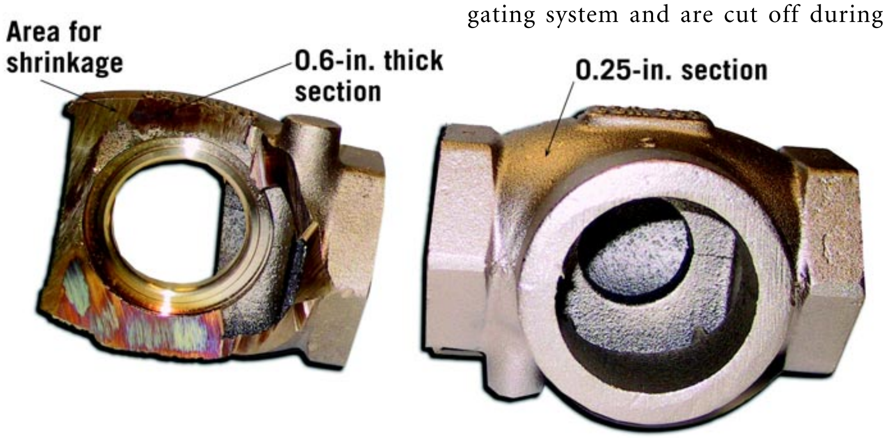

Fig. 1. This tin-bronze globe valve body casting required a chromite sand core in the interior to ensure proper solidification of the 0.6-in section on the interior. A 0.25-in globe section surrounds the interior of the casting.

Copper Dilemmas

Thick to thin section design becomes an even larger problem for copper-base alloys with wide freezing ranges such as the red brasses, tin bronzes and, to some extent, the medium freezing range alloys such as the yellow brasses. These alloys are the workhorses of copper-base casting and account for the highest level of casting production.

These alloys, however, don't solidify directionally (solidification that occurs furthest from the riser first, then moves toward the riser); instead they follow more of a mass freezing where pockets of metal throughout the casting solidify at the same time and pull from surrounding areas that haven't solidified. While proper risering helps combat the non-directional solidification to ensure sound castings, it doesn't have the same affect as with directional solidification.

With these alloys, the shrinkage defects normally are internal (referred to as centerline shrinkage). As a result, when the internal shrinkage defects are found, it is during machining and the casting is scrap. That is why the thick to thin section design issue is critical in copper-base alloy casting design for the wide freezing range alloys.

To counteract the solidification issues with wide-freezing range copper alloys, foundries employ molding tools such as chills and chromite and zircon sand cores to promote the proper solidification of the metal. In fact, chilling these sections is more effective than using a riser. However, each of these tools increases the cost of the finished casting. The best option is sound casting design without abrupt changes from thick to thin sections.

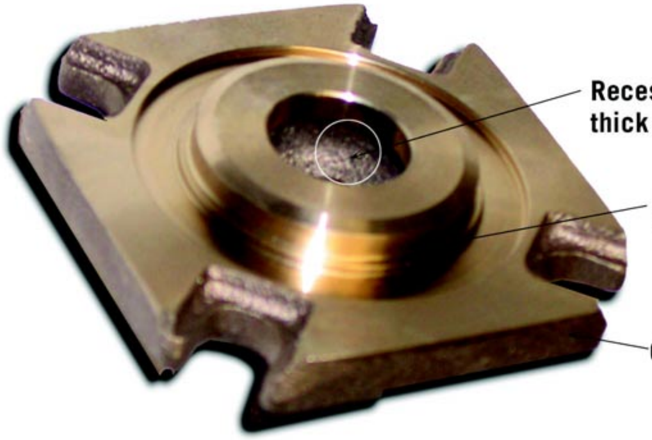

Fig. 2. This 2-lb red brass shaft seal housing required a recess on the interior to accommodate the thin (0.25-in.) sections that adjoined to form a thick (0.5-in.) section.

Design Examples

Figure 1 shows a 10-lb tin bronze globe valve body sand casting. This

Selecting Copper Alloys for Fabricability

Castings often require further processing after cleaning and finishing in the foundry. Machining is the most common secondary operation. Welding often is needed to repair minor defects or join several castings into a larger assembly. Surface treatments are commonly applied to plaques, statuary and decorative products.

Each of these processing steps contribute to the cost of the finished component. Therefore, the ease and efficiency with which an alloy can be processed influences its economic viability.

Machinability

As a class, cast copper-base alloys are easy to machine (especially when compared to stainless steels and titanium, their main competitors for corrosion resistance). Easiest to machine are the leaded copper-base alloys. These alloys are free cutting and form small, fragmented chips while generating little heat.

Next in order of machinability are moderate to high-strength alloys with second phases in their microstructures such as unleaded yellow brasses, manganese bronzes, and silicon brasses and bronzes. These alloys form short, brittle, tightly curled chips that tend to break into manageable segments. While the surface finish on these alloys will be good, the cutting speed will be lower and tool wear higher.

The most difficult copper-base alloys for machining are the single-phase alloys such as high conductivity copper, chromium copper, beryllium copper, aluminum bronze and copper nickel. A general tendency during machining is to form long, stringy chips that interfere during high-speed machining operations. In addition, pure copper and high-nickel alloys tend to weld to the tool face, impairing surface finish.

Weldability

Castings often are welded to repair minor defects. It also can be economical, depending upon assembly design, to weld-fabricate several castings and wrought products into complex shapes that couldn't be cast as one piece.

Both gas-tungsten-arc and gas-metal-arc can produce X-ray quality welds in copper. Shielded-metal-arc welding also can be used, but is more difficult to control. Oxyacetylene welding is mainly used to join thin sections. Electron beam welding produces precise welds of high quality in both oxygen free and deoxidized copper.

Following are some general comments on the weldability of various copper alloy families:

- small shielded-metal-arc weld repairs can be made to red and semi-red brasses, yellow brasses and silicon brasses, even those with small amounts of lead, but these alloys are not good candidates for cast-weld fabrication;
- high strength yellow brasses can be welded by a variety of techniques but a pot-weld heat treatment must be applied to return the heat affected zone to high corrosion resistance;
- when welding manganese bronzes, manganese aluminum bronzes and nickel manganese bronzes, stress relief may be required for alloys C86500 and C86800 to minimize stress-corrosion cracking;
- copper nickels are weldable but softening may occur. To return to maximum strength, heat and slow cool after weld;
- tin bronzes tend to become hot short and are difficult to weld, but they can be brazed. Nickel tin bronze can be welded but it may require post-weld heat treatment to ensure optimum mechanical properties.

In general, alloys containing appreciable amounts of lead cannot be welded as the lead remains liquid after the weld solidifies, forming cracks in high stress fields.

Brazing, Soldering

All cast copper alloys can be brazed and soldered to themselves as to steels, stainless steels and nickel-base alloys. Even leaded copper alloys can be brazed, but the conditions must be controlled.

Copper phosphorous alloys, silver-base brazing alloys and copper-zinc alloys are most often used as filler metals. Gold-base alloys are used for electrical applications and tin-base solders for household plumbing.

The heat of brazing may cause some loss of strength in heat treated copper alloys, but special techniques have been developed to remedy the problem. Corrosion resistance of copper-base alloys is not affected by brazing, except in special situations.

—Information courtesy of Copper Casting Alloys, Non-Ferrous Founders' Society and Copper Development Assn.

casting has a 0.60-in thick section on the inside of the casting with a 0.25-in. thick globe-shaped ball surrounding it. This design makes it impossible to feed the inside thick section with a riser. During solidification, the outside ball will freeze first, leaving the inside thick section to fend for itself when looking for feed metal. As a result, shrinkage will occur in the thick section. For a pressure-tight casting application, this defect won't suffice.

To solve the problem, a chromite sand core is used to form the internal passages on the component. This sand core absorbs the heat from the thick section of the design and acts as a chill to solidify the casting quicker. As a result, an external riser on the casting can feed the entire component because it chills at a more uniform pace.

Figure 2 is an example of a casting that was redesigned to eliminate an internal shrinkage issue due to thick and thin sections. This 2-lb red brass shaft seal housing has 0.25-in. sections that adjoin and form a 0.5-in. section. During solidification, this component would have internal shrinkage in the 0.5-in. section.

To counteract the problem, the internal shaft of the casting was redesigned to incorporate a core that recessed the internal side of the 0.5-in. section and removed 0.125 in. of excess metal. By using this molding tool, a less abrupt thick to thin section transition was provided, eliminating the possibility for internal shrinkage.

While these two thick to thin section designs were adapted to produce quality copper-base castings, designers should look for opportunities to reduce these abrupt transitions. The effort will result in higher quality cast components at a lower cost. **ECS**

About the Authors

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For More Information

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