Permanent Mold Casting

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Permanent mold casting, as the name implies, is a metal casting process that uses non-expendable molds. Unlike processes like sand casting and investment casting where the molds are broken apart to extract the finished part, the molds used for permanent mold casting are reusable. The term “permanent mold casting” usually refers to the pouring process where gravity is used to fill the mold. However, there are other types of casting methods that also employ reusable molds. These processes include die casting, semi-solid metal casting, and centrifugal casting. Permanent mold casting is also sometimes called “gravity die casting”. It is usually used in production run to produce more than 10,000 or so parts. Parts produced from this process include car transmission casings, gears, pipe fittings, and engine pistons.

Permanent mold casting has many advantages over expendable mold casting. It produces parts with high dimensional accuracy and good surface finishes. The mechanical properties of the metal are also typically superior to those produced in processes such as sand casting. Permanent mold casting can also be very cost-effective for large numbers of parts. The high initial tooling costs are typically offset by the reduced prep time for each pour. The mold can just be re-assembled and poured into again instead of needing to be entirely rebuilt.

The disadvantages of permanent mold casting are the process’ high initial costs and the inflexibility associated with the parts produced. Molds that can withstand the high temperatures of metal casting for several thousand cycles are very expensive to produce. The molds must also be periodically cleaned and touched up to counteract wear and tear from the casting process. They are also very expensive to modify or change. In other words, the part you originally designed and made is the part you’re stuck with.

(A brief) History

The first permanent mold castings were done using stone molds sometime around 2000 BC. The process was used to cast tools out of copper. The "discovery" of iron and the ability to forge and cast iron lead to permanent molds made from iron, which were mostly used to cast bronze (although some ancient weapons were made from iron cast in these permanent molds). Today, permanent molds are made from a range of materials including iron, steel, and graphite. A wide range of metals are cast in these permanent molds. Aluminum is arguably the most common metal cast, but bronze, iron, and sometimes steel are widely cast as well.

Design Considerations

All mold designers must take several items into consideration when making a mold for a part. These considerations include feeding systems for getting the molten metal to the part, draft to allow for mold separation, venting to allow air to escape, and part shrinkage due to cooling metal. Permanent molds behave differently from expendable molds, so a number of considerations must be taken into account during the design of a mold.

First off, permanent molds cannot be easily changed or modified. An engineer or designer should be absolutely sure there are no potential changes to the part before starting to build a permanent mold. However some changes are easier to make than others. A change that requires adding material to the final part is typically easier to make because it involves removing material from the mold. Changes that involve removing material from the final part should be avoided, because that involves adding material to the mold, which is much more difficult.

The mold should be designed to open easily. The permanent mold cast process is usually run continuously to produce a set number of parts and to avoid thermal shock to the mold. Parts are ejected from the mold as soon as they solidify so that the next part can be poured as quickly as possible. In larger foundries, the pieces of the die are operated by pneumatic or hydraulic cylinders. Dowel pins, wedges, and tapers should be used to ensure all the mold pieces fit come together properly every time.

Unlike sand molds, which have “built-in” venting due to the porosity of the sand, permanent molds have no natural means of clearing air and gas out of the casting. Vents should be built into the system to allow gasses to escape.

In addition to other casting defects, permanent mold castings can also suffer from a defect known as “heat tear”. Heat tear happens when a cast metal cools and contracts. The permanent mold does not contract with the cast metal, so tearing can occur in the casting. This problem can be avoided by proper mold design as well as ejecting the finished part shortly after it solidifies.

Permanent molds are also unique in that they can be designed to allow for different cooling rates in different areas. Thicker sections of the mold will absorb more heat and can be placed in areas to facilitate local cooling, enabling heavier sections to draw from nearby risers. Cooling circuits that pump water or air over parts of the mold can also be used to control the temperature in areas. However, the designer must also consider the potential of mold degradation due to thermal shock and temperature variations when these methods are used.

Conclusion

Permanent mold castings offer a cost-effective way to produce large quantities of parts with tight geometric tolerances and good surface finish. Material properties of permanent mold cast parts are superior to sand cast parts due to better control of the casting process. However, the high initial costs and low flexibility means the process would not be ideal for an artist/sculptor or prototype engineer. A permanent mold only becomes cost-effective at part quantities around 10,000. The process should then be carefully weighed against other options.

References

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