The Best Unknown Casting Process

Graphite permanent molding (GPM) is a niche process used for casting zinc-aluminum alloy parts. Akin to diecasting and permanent mold casting, it is often used in short or moderate production runs.

Jim Tenglin, President, Castechnologies, Inc.

It is so easy to fall into routine practices when selecting a manufacturing process. You're designing a part. Now you have to consider production methods. Machining worked for prototype development, but the volumes are too high to make that option cost effective. Yet the volumes are too low for typical casting methods. Perhaps a compromise is needed. You could manufacture the part out of plastic — injection molding. But if you want the quality, feel, strength, and durability of a metal part, there are other alternatives.

Using graphite molds for zinc-aluminum casting is a little-known process with significant benefits. Graphite, a form of carbon, is an excellent, yet largely unknown, mold material. Every casting method has its niche with some overlap occurring between processes, but it is safe to say that one process will be best for a given part. The prerequisites for selecting the proper casting process will be guided by the casting's material, size, design, annual quantities, or application. This article explores the benefits of the graphite permanent mold (GPM) process.

Being one of the "permanent" mold processes, the GPM

An assortment of parts and products made by the graphite permanent mold (GPM) technique.


Air traffic control trackball housing is cast and machined complete, as shown on a CMM.

process falls into the same category as the more familiar diecasting process; one mold is used over and over during production. This is in contrast to "disposable" mold casting processes, such as sand or investment, whereby the mold is destroyed in order to extract the casting. The basic design of the graphite mold is similar to diecasting molds, exhibiting a split or multi-piece mold, with cavities to accept the molten metal. The metal is allowed to solidify, the mold is separated and the casting is removed. The mold is then closed again and the casting process is repeated. The one major difference between these two processes is the mold material, which for a diecasting is metal, and for GPM, obviously, graphite.

Molds Made of Graphite

Why use graphite? Most people would recognize graphite as the black stuff in a pencil. The graphite for the GPM process is of a premium grade with a medium grain and extremely low porosity. GPM manufacturers purchase graphite in billets or blocks. These are cut to size and precision machined to the dimensions required for the part to be cast.

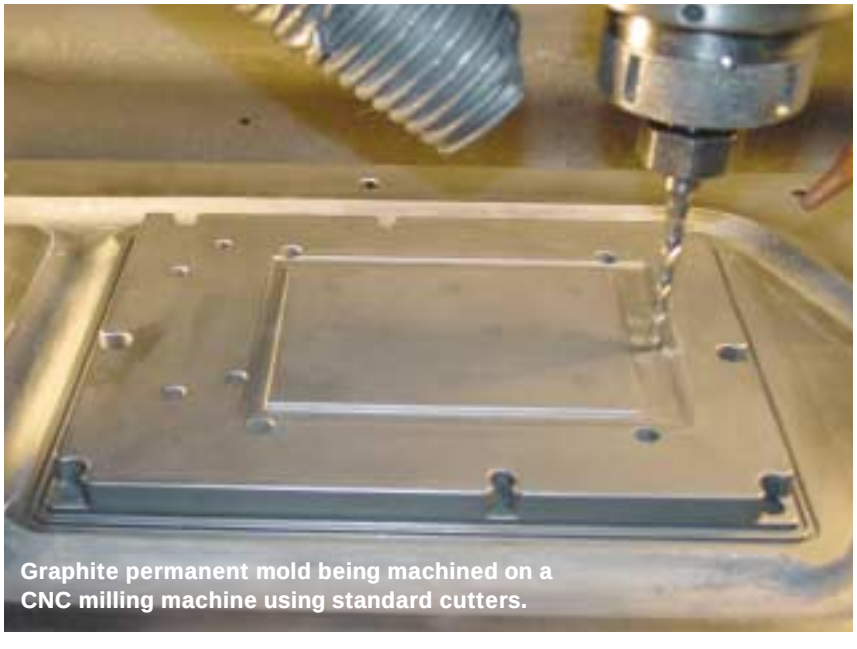
Graphite has many qualities that make it an ideal material for a mold. The material is extremely stable; it won't warp, twist or check when metal is injected. It exhibits a lower coefficient of expansion, so parts can be cast with higher accuracy than in other processes. The cavity surface is non-wetting, so casting release agents, which can negatively impact surface finish, are unnecessary. It can be stored indefinitely without the concern of changing shape, rusting, oxidizing, or deteriorating in any way. Overall, these characteristics enable manufacturers with medium or sporadic manufacturing volumes to take advantage of a process that will deliver tight tolerances, cost effectiveness, and repeatability.

The manufacturing of the mold is a critical step in the process. Mold cavities are machined into the graphite blocks by CNC milling machines. The cavities are machined to exact dimensions, accounting for shrinkage and the feeding of metal to the part as it solidifies. The machined cavities are then polished. The accuracy of the cavities, coupled with the high thermal conductivity of the graphite and minimal expansion, typically produces a casting with a precision of ±0.005 in. and a surface finish better than 125 RMS. These features rival a part produced in a diecasting mold for a fraction of the mold price.

Mold Design

In order to guarantee proper solidification of the part, special design considerations focusing on heavier perimeter wall sections will render a casting that is solid and homogeneous throughout. A properly cast part will readily accept subsequent machining operations and will not be weakened by the opening of porous sections often inherent in other casting processes.

There are other design parameters to be considered. The size of a casting produced in a GPM process is generally less than 16 in. long x 12 in. wide x 4 in. deep. These dimensions are maximum limits and should not be combined. Casting weight


Graphite permanent mold being machined on a CNC milling machine using standard cutters.

The Graphite Permanent Mold Process

The GPM process was developed in the late 1960's to produce cast components for the Montreal World's Fair. In subsequent years, the ZA-12 alloy was fine-tuned for the process. It was quickly recognized that the GPM process was a viable option for producing castings in the niche described. Many existing foundries, as well as entrepreneurial start-up companies, made or purchased casting equipment with the intent of capitalizing on this newfound process. Unfortunately, many foundries and their customers experimenting with the new technology were disappointed with inconsistent results. A misunderstanding of the metal's flow and cooling characteristics of the mold caused many suppliers to stop offering this process. Other suppliers grasped the concept and have become successful.

Part being removed from graphite permanent mold showing attached runners and gates.

can be ounces to as much as 10 lbs. Minimum wall thickness is usually 0.100 in., however, 0.060 in. is possible on small, well-fed areas. A minimum draft of 2° is required on all surfaces that are perpendicular to the parting line. Corner and edge radii should be a minimum of 0.015 in., preferably .032 in. or greater. Interior heavy sections should be avoided unless feeding ribs can be accommodated. Like diecast or other permanent mold castings, raised lettering and logos are easily reproduced, holes can be cored, and a third dimensional slide can be incorporated to cast other features that are parallel to the parting line.

Alloy of Choice

The alloy of choice for this process is ZA-12. It is a highly engineered, zinc-aluminum (ZA) material. One in the family of ZA alloys (ZA-8 and ZA-27 are other examples), the alloy number represents the approximate percent of aluminum. ZA-12 offers a compromise between the other two and exhibits the best casting qualities. A low melting temperature of 790° F. and solidification characteristics are qualities that are important in the GPM process. ZA-12 is easily machined, has excellent pressure tightness, is spark proof, non-incendiary, and non-magnetic (suitable for electronic shielding). ZA-12 is often an acceptable option when converting from aluminum, cast iron, steel, brass, or bronze. The inherent lubricating nature of this ZA alloy makes it a good replacement for bronze in some bearing applications. ZA-12 has good corrosion resistance in normal atmospheric conditions, in aqueous solutions, and when used with petroleum products. If greater corrosion resistance is required, finishes such as paint, powder coating, and plating are excellent options.

Comparisons

So why not select a graphite mold for every casting need?

The GPM process is a niche process. Since molten metal is ladled or injected under low pressure into the mold, and cooling is controlled by the conductive ability of the graphite, production is rated in pieces per hour. In comparison, a diecasting mold produces at a rate of pieces per minute. This production rate differential calculates to a diecast piece price that is generally 20-40 percent of a GPM cast part. However, a comparable diecasting mold is upwards of ten times the cost of a graphite mold.

Analyzing the annual quantity of a part will determine whether or not the reduced piece price will offset the high mold cost. Generally, if the annual quantity is less than 15,000-20,000 pieces, the GPM process will be the best choice. Even if a customer's requirements exceed this quantity, the investment in a graphite mold will offer reduced lead time (usually 3-6 weeks) and enhanced flexibility to

About Castechnologies

Castechnologies, Inc. is a GPM process company with more than 50 years of GPM experience. The company has worked with over 90 customers to manufacture a variety of parts. Castechnologies is one of only a handful in North America produces castings exclusively from graphite molds. In the 16 years since the company's founding, it has produced over 1.5 million castings for a wide array of customers.

make engineering changes because of the relative ease with which a graphite mold can be modified. There is the added benefit of high quality GPM hard tooling to produce a cast component to introduce to the marketplace, followed by production tooling to carry part manufacturing through the production ramp-up stages into diecasting volumes. In some instances, a customer's anticipated sales volume has fallen short of expectations and they were relieved to know that the purchase of a graphite mold kept the tooling investment to a minimum.

At the lower end of the annual quantity range, GPM castings generally become competitive around 300-500 pieces per year. Small quantities may make sand or investment castings, or sometimes machining from raw stock, more attractive. The cost of the mold is often the gating factor. However, the cast precision can reduce or eliminate common secondary machining operations of these casting processes, yielding better part uniformity and reducing labor costs.

Unwarranted Misconceptions

A common misconception is that graphite is weak and can be easily damaged. There are two areas to explore when addressing this concern. First, the mold itself is machined out of a solid billet of material. It typically weighs 40-50 lbs. This is a very solid mass with which to work with and is very difficult to damage. Second, graphite is a crystalline structure. It is, therefore, quite rigid and retains its dimension extremely well. Graphite is very strong and will withstand a significant stress. However, pushed to the limit, graphite will break. This is a benefit over other mold materials that will deform when pushed to their limits, potentially producing an entire production run of rejected parts before the problem is discovered. For products requiring tight tolerance and high yields, few mold substances can compare durability, repeatability, and longevity offered by graphite permanent molds.

Additionally, a graphite mold's life is thought to be relatively short. Depending on the size and complexity, molds can continue to produce high quality castings for 40,000 cycles or more. One of the keys to this longevity is proper up-front engineering. Still, some of the GPM foundries will eliminate any customer concern by guaranteeing the molds for the life of the project.

For more information contact Castechnologies, Inc., P.O. Box 478, Attleboro, MA 02703; ph: (508) 222-2915; or visit www.castechnologies.com

Applications

Castechnologies Incorporated was founded in 1987 to provide an economical source for precision castings utilizing the GPM process. The company has produced a variety of machined, cast components for a broad spectrum of customers and applications.

Digital camera end cover painted white with silk screen lettering.

Medical equipment designers and manufacturers recognized the cost reduction capabilities of the process when compared to aluminum investment castings or heavily machined aluminum sand castings. ZA-12 cast panels and bezels are used in bench top, as well as stand-alone, factory equipment. The non-sparking attributes of the ZA-12 alloy have been advantageously used in mining equipment and landscaping machines. A ZA-12 casting replaced an expensive lead casting in a military marine application. The weight of a ZA-12 frame in an amalgam mixer helps absorb vibration, allowing the table top machine to function as designed. Even a putter made of ZA-12 in the GPM process has found success in professional and amateur golf tournaments.

The misconception that graphite molds are used only in low volume casting applications could be argued in the following two projects. A high-end watch manufacturer had designed a metal watchbox for a new line of watches. One thousand hinged boxes were produced in less than four weeks, with a total of 14,000 more boxes produced in the subsequent four months.

In another situation the pressure tight nature of a graphite mold casting in a hydraulic housing was difficult to replace with a diecast component, so production continued at a rate of over 2000 castings per week. Nearly 250,000 machined castings were produced in the GPM process without one rejection until a die cast part proved acceptable.