

Advantages of the Casting Process

The casting process has nearly unlimited flexibility compared to other manufacturing processes and is excellent for optimizing designs based on performance and weight requirements rather than processing limitations. Material can easily be added or subtracted to local areas to meet stress requirements, and weight can be decreased by incorporating lightening pockets, adding holes, or reducing cross sections, all with little cost impact. Castings have the unique capability to produce complex geometries in both external and internal areas that would be impossible to produce cost effectively using other manufacturing methods. With a casting's inherent isotropic properties, directionality for strength is not a concern versus other metal processing methods that have a grain direction similar to that of a piece of wood. Furthermore, there are an unlimited number of metal alloys that can be cast, some of which cannot be hot worked using other manufacturing methods.

In addition, size is virtually limitless - from a 1 oz. die or investment casting to a 50,000 lb. pit-molded iron casting. Another advantage is that whether a single casting or thousands are needed, there is a casting process that can meet the requirements. Casting has the unique capability of being able to take multi-piece assemblies produced using other processes and combining them into a single-piece casting. This saves both time and money over making several pieces or small assemblies and combining them into a larger assembly. The more pieces that are being produced and assembled, the more chances there are for an error in one of the pieces which can extend the lead time out on the entire finished product, affecting the bottom line and end item cost. Tooling costs can vary also widely but are generally much less in comparison to other methods requiring forging tooling or complex welding fixtures.

Sand Casting

Green sand casting is the most cost effective and has been the backbone of the foundry industry for centuries. It has the largest tolerance and typically the least expensive tooling based on the end product. The exception to this is sand casting tooling involving intricate cores, which could be tens to hundreds of thousands of dollars. Extremely small to very large castings are possible using green sand molds. The green sand is compatible with both ferrous and nonferrous alloys. Green sand is very well suited for meeting high production requirements. Although some specialty alloys in ferrous and nonferrous alloy groups can be poured in green sand molds, they would be more compatible with other processes for higher quality and yield. Casting steel alloys in green sand molds does tend to significantly increase decarburization issues, which can be a problem. Green sand is easily recycled and can be reused for many cycles. The resulting surface finish can be very smooth to extremely rough, depending on the alloy; aluminum is smooth and steel is very rough, for example. Typical surface finishes are 400 RMS, and down to 200 RMS is possible.



Ductile iron green sand casting for Disneyland¹



Steel green sand casting for Disneyland¹

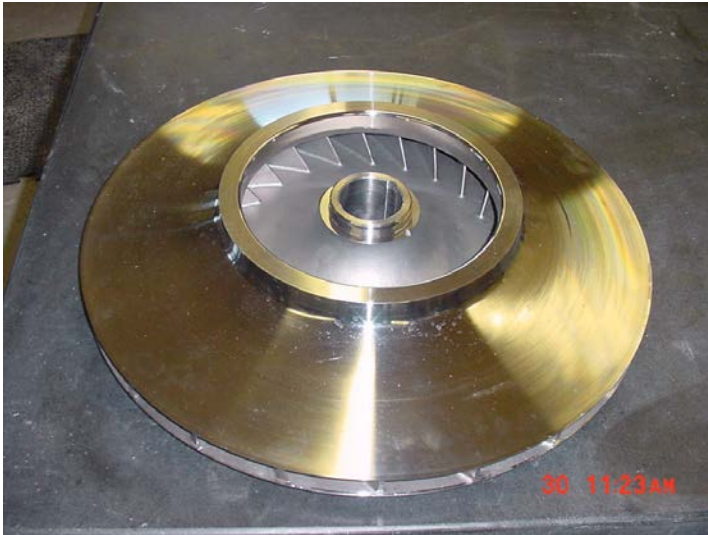
The no-bake (air set) process uses a chemical reaction binder process to harden the sand molds and cores. Air set has much greater dimensional accuracy and can be handled and assembled with cores much more easily than green sand. For example, adding cores in the cope (top mold) is relatively easy in air set versus being nearly impossible in green sand. Tooling is relatively low cost and tooling materials such as urethane tooling board machine easily on conventional and CNC machines and is extremely durable in the harsh foundry environment. Air set sand, while reusable, is much more difficult to recycle than green sand and needs to have the binder baked out or blasted apart against a hardened plate to break apart the larger bonded pieces of sand. Another advantage of the air set process is the reaction which causes decarburization in green sand is nearly nonexistent using the air set sand.



A357 T6 aluminum air set sand casting for Honeywell¹

Investment Casting

Investment castings can be produced using standard wax patterns (wax injected into a mold), additive manufactured patterns, or foam patterns. This process can be used to produce extremely close tolerances and much thinner cross sections than sand castings. Using the ceramic mold media allows for heating of the ceramic mold to as much as 1,800 F which allows molten metal to be fluid much longer than in sand casting and increases flow length into thin sections. Another advantage is that gates and risers can be placed nearly anywhere to achieve proper feed and progressive solidification to ensure casting soundness. Surface finish is another big plus of investment castings; the process can easily achieve the standard 125 RMS surface finish. With the increased accuracy of the investment casting process, many surfaces that would need machining in sand casting can be left as-cast on investment castings. Furthermore, the issue of decarburization is non-existent in investment castings. Size, while generally in the small to mid-range, can vary from an ounce to over 500 lbs. at some specialty foundries. Titanium castings are almost exclusively produced using the investment process and can reach a very large size of as much as 9 feet long and 72" in diameter for airframe structures and could weigh over 800 lbs. finished weight.



125 lb. 23" dia. 17-4 PH stainless steel 22 Vane Compressor Wheel Impeller. Cast weight is 165 lbs.¹



304 stainless steel investment castings for Disneyworld¹

Die Casting

Die casting is used when high-volume production castings are required. This is mainly due to the high tooling costs for molds and trim dies. Die castings are typically under 75 lbs. and are generally not high-strength castings. They are non-ferrous castings of usually aluminum, zinc, or magnesium. The process can produce small holes and excellent surface finishes (64 RMS typically) along with achieving extremely close tolerances. Typical types of die castings range from a large aluminum transmission housing to a thin-wall magnesium chassis for a cell phone.



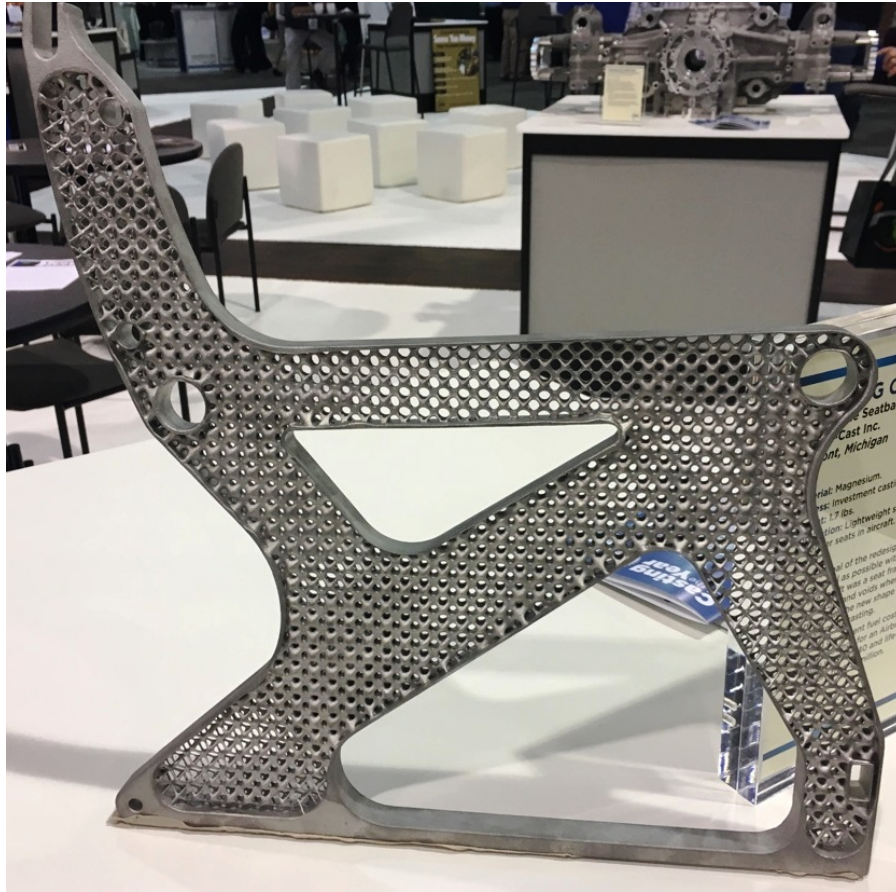
OEM aluminum die cast turbo 400 transmission case. Approximate weight 75 lbs. Courtesy HK AA website.²



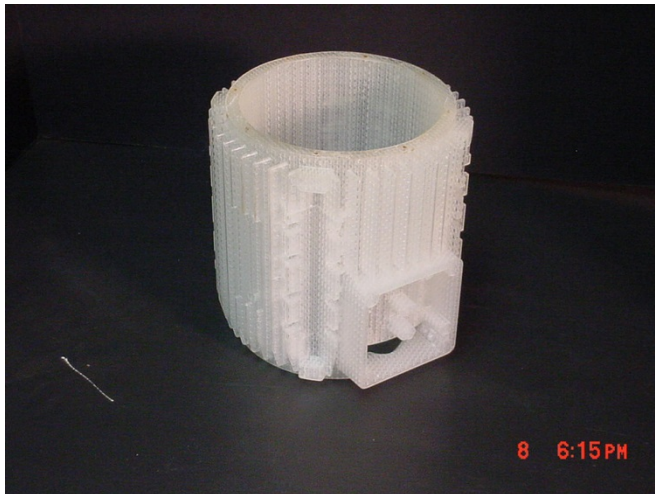
Die cast magnesium tablet frame chassis. Approximate weight 6 oz. Courtesy Dynacast website.³

Additive Manufacturing

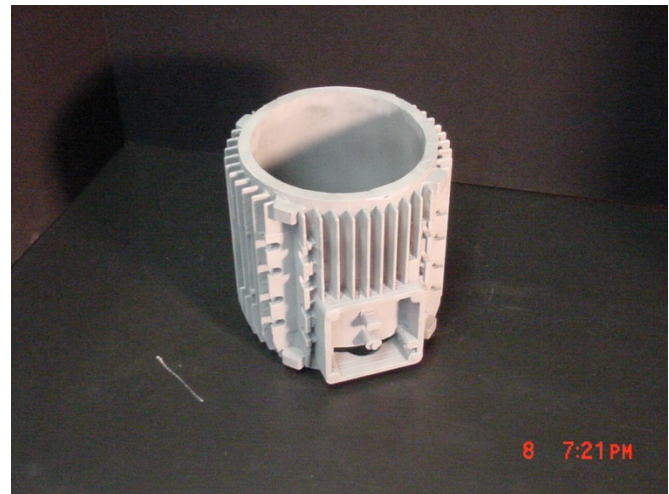
Additive manufacturing (AM) was adopted early-on by the foundry industry and has advanced the state of the art into castings that were unimaginable only a few decades ago. The investment casting process was the first to achieve good success using AM, producing castings quickly and accurately from printed patterns made from a liquid polymer known as stereolithography (SLA). The polymer is hardened using a laser beam guided by a CAD model. In the early days, SLA patterns were somewhat difficult to use and left significant ash residue in the ceramic shell which, if not cleaned out, could make the resulting casting unusable. Today, with the advent of updated computer software, being able to build a honeycomb structure with a thin skin on the outside, the process can produce a casting with excellent tolerance and surface finish. Since no tooling is required using AM printed patterns with investment casting, configurations that could not be produced from standard hard tooling are possible. The biggest issue has been getting the ceramic shell material to coat internal surfaces of the pattern that are not readily accessible. Here AM is breaking ground with printed-preformed ceramic cores that can be used to create the internal surfaces eliminating the need to get the ceramic slurry onto the internal cavities. These advancements will allow engineers to produce high performance castings they could only dream of in the past.



Magnesium investment casting aircraft seat frame. Produced using an SLA pattern. Displayed by Aristo Cast at Cast Expo 2017 as “Casting of the Year.”¹



SLA QuickCast AM printed pattern for a motor housing for Honeywell¹

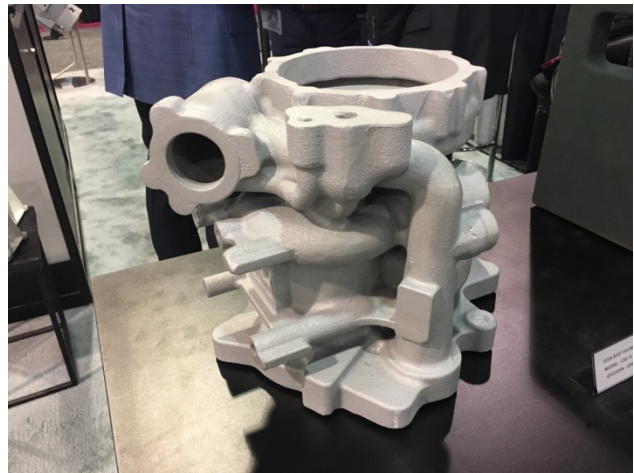


A356 T6 aluminum investment cast motor housing for Honeywell¹

AM sand castings with the introduction of printed sand in the early 2000s have changed the way castings are produced. The printed sand mold and cores use the same type of sand as the air set process except the hardener is added to the previously bonded sand via a print head driven by a computer and CAD model. From printed complex one-piece cores that previously required multiple core boxes to large printed sand molds, the process is now only limited by one's imagination. Today, difficult cores can be printed more cost effectively than conventional cores with more accuracy, quality, and detail. Due to the high cost of the printed sand material, it is most cost-effective to use a hybrid approach employing a conventional pattern to form the exterior mold and AM to print the internal complex core geometry to match the core print locators on the pattern. Although sand molds can be readily printed in cases such as an emergency buy, a scrap casting made from them would require an additional expensive mold to be produced with delivery at the mercy of the open time on the sand printer.

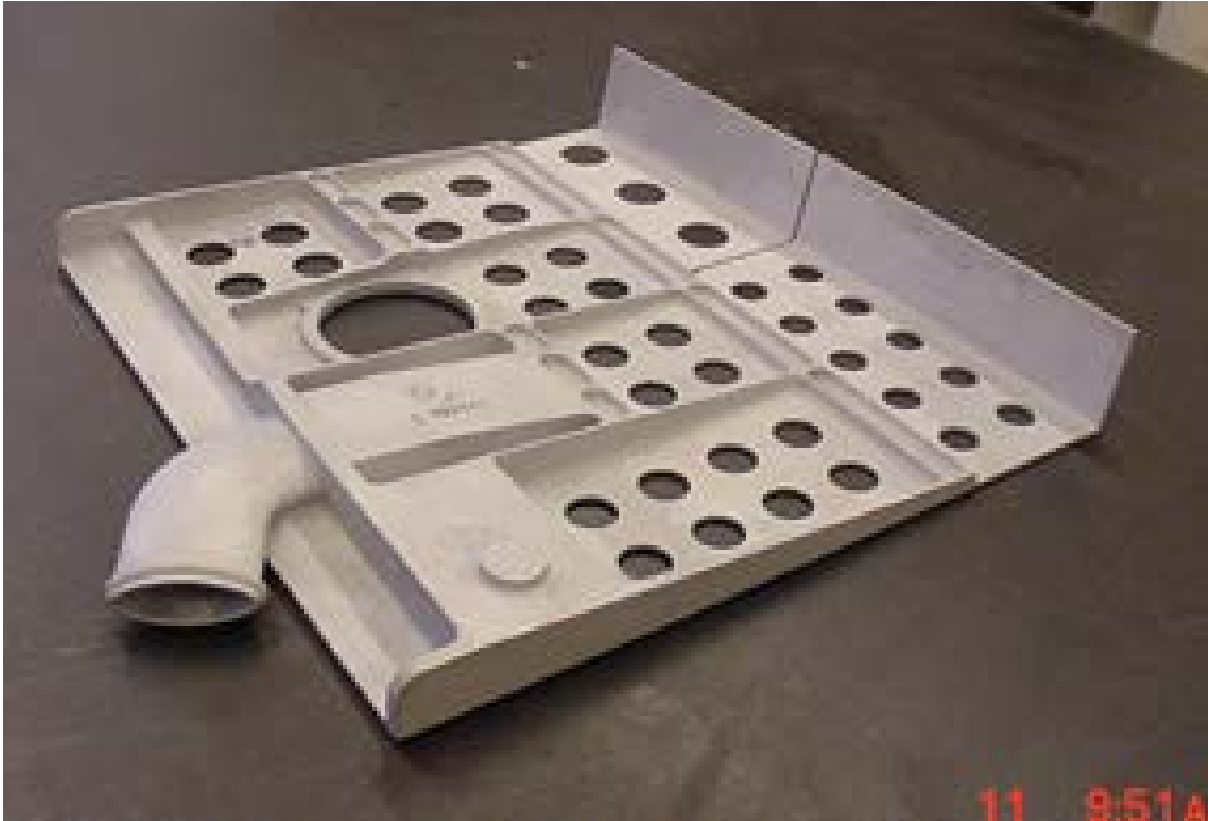


Printed sand one-piece internal passage core assembly for Pump Housing displayed at Cast Expo 2017¹



Aluminum cast Pump Housing using printed sand core assembly in photo on left and printed sand mold displayed at Cast Expo 2017¹

Finally, casting is the only manufacturing process that can use AM technology to produce legacy parts and meet the original requirements of the technical specifications without a change request. Using an AM-printed pattern, printed sand molds and cores, or printed polymer / wax patterns for an investment casting, legacy castings can be produced without hard tooling to meet the urgent demands of industry or the Defense Department for emergency or low-volume buys with no effect on the current technical data.



A357 T6 aluminum platform investment casting with 0.08" walls produced from SLA pattern (no tooling required). Casting met all requirements of the original technical data package with no change requests required. Customer was Military Aircraft Parts in support of DLA Aviation contract. Tooling cost savings were \$18,000. Lead-time savings were 12 weeks for a 5-piece spare parts requirement. ¹



Spanner Wrench casting made from 17-4 PH stainless steel. Produced 10 each of two cast versions from SLA QuickCast patterns meeting all requirements of the technical data package with no changes and no hard tooling required. Tooling cost savings were approximately \$8,000 and casting was made in only 6 weeks lead time. Customer was PMT in support of a DLA Land and Maritime spare parts requirement. ¹

References

1. Photos courtesy of H.A. Burrow Pattern Works, Inc.
2. Online image retrieved 12/1/2017 from https://www.alibaba.com/product-detail/Hot-sale-Die-casting-and-CNC_60719433687.html
3. Online image retrieved 12/1/2017 from <https://www.dynacast.com/tablet-frame>

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