ISSUE 1—SEPTEMBER 2017

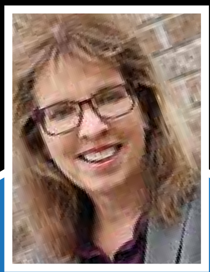
PART BUYERS AUTHORITY

METAL PARTS ADDITIVE MANUFACTURING INNOVATION

(and why it matters)

In the last decade, new waves of technology have been crashing over the foundry and metal forming markets. Leading part manufacturers have brought these tools in-house, and now provide new options that compress lead times and in some cases eliminate the need to track and maintain old tooling.

MARKETING OPTIONS



WELCOME TO OUR FIRST ISSUE

The Part Buyers Authority is aimed at bringing some clarity to the desk of anyone involved in the decision-making process of purchasing, designing, or producing a part in an industry where manufacturing technology is quickly changing.

Instead of "tackling all parts" we will limit our thinking to either a type of part, material, or industry. Our goal is to provide a small but content rich reference guide specifically for people involved in part design and manufacturing decisions, to understand newer technologies for part production.

We wanted a true manufacturing voice – not an outsourcing voice. Therefore, all of the authors we've selected for this issue are currently deploying the technologies on their own production floors. Early adopters of Additive Manufacturing methods have a journey to tell, which will be helpful to making production decisions for your parts.

And, because this is a collaborative environment – you have a voice too. Do you have a technology or type of part you would like us to discuss? Simply Complete Our Form. We would appreciate hearing from you and understanding the material and technology questions you may have regarding your parts.

Our first issue is about Additive Manufacturing and metal parts. Our mission is to provide you with what you need to know to navigate these newer production technologies. Please check out the Resource section on the last page. In every issue we will list places to learn more.

Our foreword for this issue is by Will Shambley, president of Metal Fish. Will consults globally on Additive Manufacturing technologies in metal casting, investment casting, metal forming, composites and plastics. I think you will find his insight to be very helpful.

Within the changing world of 3D printing, scanning, and the types of automation that are being developed, our publication will attempt to help anyone on the decision-making end to understand manufacturing's digital transformation from design to delivery of your parts.

Barb Castilano
Owner, Marketing Options
Founder/Editor, Parts Buyers Authority

MARKETING OPTIONS

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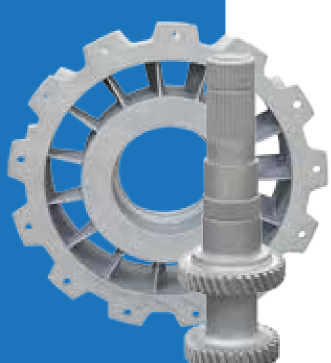

FOREWARD

WILLIAM SHAMBLEY
President, METAL FISH LLC

Buying a casting has always been more complicated than buying other components. Keeping track of tooling, or getting new tooling, managing long lead times, quality and certifications of the producers makes it a task far beyond ordering widgets from a catalog. That was true before the foundry market went through the last couple decades of offshoring, closing, restructuring, and consolidation.

In the last decade, new waves of technology have been crashing over the foundry market. Leading foundries have brought these tools in-house, and now provide new options that compress lead times and in some cases eliminate the need to track and maintain old tooling.

The goal of this publication is to shed some light on the advancements made by a handful of foundries, with focus on a different production method in each case. However, there is no better way to familiarize yourself than to contact the foundries featured here, and see the technology in action.

Many paths to a casting
Each of the additive or robotic systems provides an alternative route to the final casting. Each has its own value and its own associated costs. I break them down as follows. Also, some methods have been around longer than others and therefore have more data and design history behind them. Knowing which methods are acceptable for your end customer is critical to buying the right kind of casting.

Direct metal
Companies like Renishaw, Concept Laser, Desktop Metal, and EOS make printers that build a metal part directly from the CAD file – essentially a digital casting process. These systems build the casting directly from grains of metal that are sintered together. Some systems fully melt the metal, forming fully dense parts. For some alloys they produce high-quality metal rivaling or exceeding traditional casting processes. The disadvantages of these castings are that they use expensive raw materials. Still, compared to the cost and lead time associated with making tooling, direct metal can still be competitive on a total cost perspective. Digital casting processes create the part in metal in days regardless of shape complexity. At Innovative Casting's Dualtech Foundry, you can even order the same part, printed concurrently on different printers, in different alloys, and vary the designs.

3D Printed Sand Molds & Cores
One of the most versatile methods of creating a metal part without tooling, 3D printed sand molds and cores can be made using an ever growing selection of sands, ceramics, and binders. The most well established systems use a furan "no-bake" resin on silica sand. Molds and cores created in this process can be built-up in hours, even for 2 to 3 foot flask sizes. Because you are pouring your casting in a traditional mold material, many companies find this to be one of the most comfortable methods of 3D printing to use on a daily basis. The percentage of foundries using 3D printed molds and cores from a local service bureau like Hoosier Pattern is much higher than most would hazard to guess. Still, the foundries like Trident Alloys that have brought 3D printed sand under their own roof have the greatest agility when it comes

to casting larger parts out of a range of alloys. Like direct metal, printed molds and cores allow foundry engineers to challenge old design limitations, moving gates, risers, parting lines, and vents to the places where they are the most useful, and eliminating assembly errors by making complex, multi-piece cores in a single model. This method is also frequently faster and cheaper than building tooling, even with existing designs.

3D Printed Investment Casting Waxes

Probably the second most well established Additive Manufacturing (AM) process for making castings is to print the "wax". Once again, by forming the target shape in an additive process, but making the shell with the traditional process, manufacturers can more rapidly accept that they are pouring the alloys they want, in the shell materials which they are familiar with. Tech Cast, in their article, outlines the slight differences in 3D printed patterns – which are more than offset by saving (in that example) $35K and 5 weeks on the casting. While the SLA process outlined by Tech Cast is well documented, other materials such as PMMA, PLA, and regular old WAX are available through other 3D printed platforms. Each process provides a different combination of speed, accuracy, cost, and processing time. A variant of this method, lost foam casting, is in development several places. In this case, the "foam" pattern is made by a hollow 3D printed shell. The thin shell decreases the time and cost of 3D printing very large parts.

3D Printed Tooling for sand casting (patterns & core boxes)

This is probably the most straight forward path to metal using AM. Making your pattern board's gates, and risers with a plastic or composite 3D printer isn't rocket science, but it does provide one goose-bump inducing benefit... a new 'patternmaker' pool of employees is graduating from tech schools around the country. While these students aren't studying woodworking or patternmaking in school, they are getting a decent primer on CNC programming, robotics, and 3D printing. So, whether you are running a plastic filament extruder, SLA, SLS, or direct metal printer – you can always "print" your traditional tooling. In the case of permanent molds or die casters – you can near net cast your iron tooling – reducing the cost and CNC time of machining a traditional tool, while enabling tricks like weight reduction, built-in features, and conformal cooling. Foundries like AFG, Alliant Castings, and Danko have all been using 3D printed patterns for a while, and many others are bringing the technology in-house.

Another Technology of Note:

Robotic Sand Milling – while the devil is in the details, the big picture concept is easy to grasp. Modern robots, like those made by ABB, can be converted into 6 axis milling systems, with automatic tool change. CAM software can let you plan tool paths, and mill the sand molds directly from pre-cast blocks of traditional resin bonded sand. This process is highly complementary to 3D printing, as the trade-offs in cost and speed for each process essentially dovetail with the other process. There are a few integrators who specialize in this, and they can keep you from reinventing the wheel. Southern Cast Products, in AR, has several systems running. The killer app for this process is with BIG molds. You can machine mold sections up to 8' by 8' and never make tooling for those large, low volume tools again.

In Summary

As casting buyers you'll want to know the details of how additive manufacturing is changing the economics of procurement. Each of the foundries in this publication has already put their own process into place, and has shown the commercial viability. As other foundries start to follow the pioneers, a buyer will be able to search for the right foundry and the best process for any given casting. These articles are a good start, but I urge you to reach out to all of these foundries, to visit and learn more.

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PART BUYERS AUTHORITY

Are you a manufacturer of metal, plastic, or composite parts?

If so, we encourage you to contribute as an author in our next issue of ***The Part Buyers Authority***, an industry online publication. Featured authors are positioned as the topic expert in your 2-page article. Your company will also receive a full page advertisement (for a total of 3 pages). As an additional benefit, competitors to you cannot contribute in the same publication to provide you with dedicated space to your expertise.

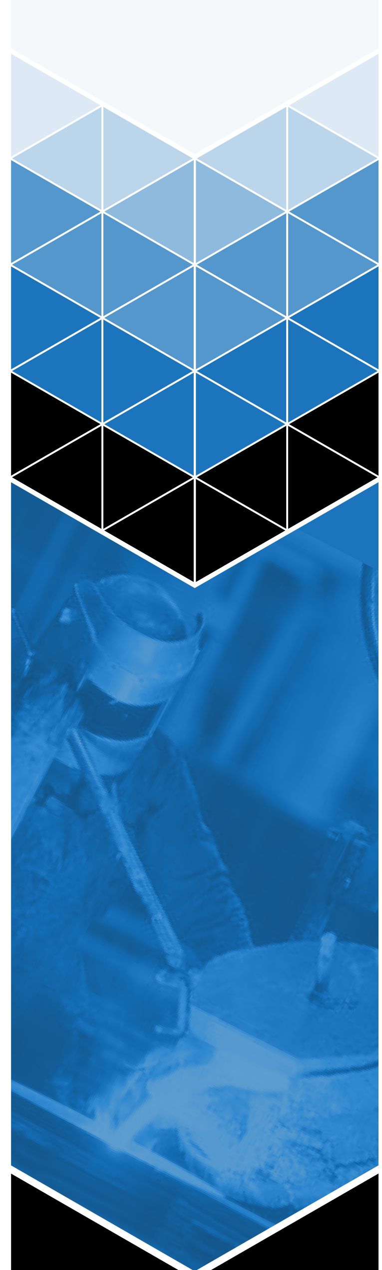
Our sole focus of ***The Part Buyers Authority*** is to provide technical information to assist anyone that designs, specifies or purchases metal, plastic or composite parts. Specifically we will address the changing technologies that affect the many ways that parts can be manufactured.

The Part Buyers Authority will be issued several times a year on topics of interest to buyers of parts. Our planned editorial line-up includes:

Fall 2017	Additive Manufacturing – Metal Part Manufacturing
Winter 2018	Automotive/Truck/Transportation Part Manufacturing
Spring 2018	Aerospace Part Manufacturing

SPACE IS LIMITED IN EACH ISSUE...

To be considered, please contact Barb Castilano by calling 937-436-2648 or email barb@moptions.com



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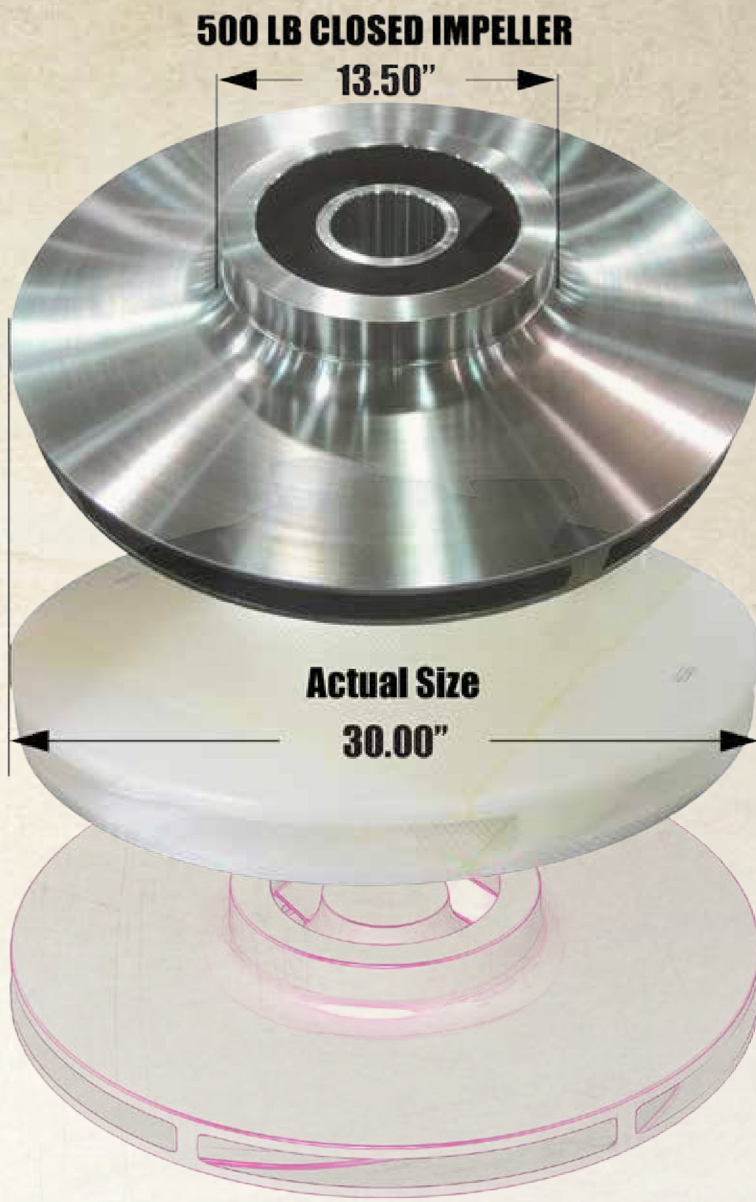

Tech Cast is your partner in engineering and manufacturing precision complex investment castings for demanding industries.

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Using Additive Manufacturing to produce Rapid Prototypes through Investment Castings

TECH CAST, LLC

ANDY BOMBERGER & ANDY MILLER

TECHCAST LLC

It's a problem every buyer dreads - engineering or production needs a single piece, or maybe just a few, of a part that has not been tooled, tested, or approved for production. They need it in a few weeks, the budget does not allow for large tooling expenditures, and waiting months for tooling to be built, samples produced and final approval is not an option. Until recently, there was no solution that would meet everyone's needs - but thanks to recent developments in additive manufacturing, and collaboration with investment casting foundries, help is on it's way. Tech Cast would like to present the following cast study as a perfect example of how you can use this exciting fusion of new and older technology today.

Finding the optimum design for pump impellers is critical to making the most efficient, powerful and effective pumps no matter what the application or the market. However traditionally it has been difficult to design and accurately predict how the actual, physical part will perform with so many complex components playing a role. In the past this was accomplished by building a tool, making samples, testing it, and then either making expensive alterations to the existing tool or building a whole new die - all at considerable time and cost. All too often this has resulted in an incomplete development process, with the customer choosing a "good enough" design rather than an "optimized" design.

Figure 1.
Pattern created through Additive Manufacturing –in this cast through stereolithography

However, in this case Tech Cast, worked with 3D Systems to produce a pattern **(See Figure 1)** via stereolithography, that would replace the traditional wax pattern used in investment casting. Patterns produced through additive manufacturing, introduced over the past several years, provide increased design versatility without physical constraints of conventional tooling. Because these patterns are created using an additive manufacturing technology, (a process that requires no tooling), this makes it possible to have a prototype pattern created at a fraction of the cost and time required for tooling. Creating patterns using additive manufacturing, enables customers to evaluate several design alternatives inexpensively, and simultaneously, to quickly develop a better performing impeller.

STUDY OBJECTIVES

This case study had several objectives:

- Determine the quality of castings created with SLA (stereolithography) patterns relative to those created with wax patterns. Included in the quality evaluation will be:
  - Dimensional accuracy
  - Surface roughness
  - Surface quality
- Determine the relative total cost to create the first casting.
- Determine the time required to create the first casting with each method.

TEST GEOMETRY

In this case, a double suction impeller roughly 16 inches in diameter was chosen, pictured in Figure 2 as the test geometry. The conventional wax injection tooling for this design cost $40,000 and had a lead time of eight to 10 weeks.

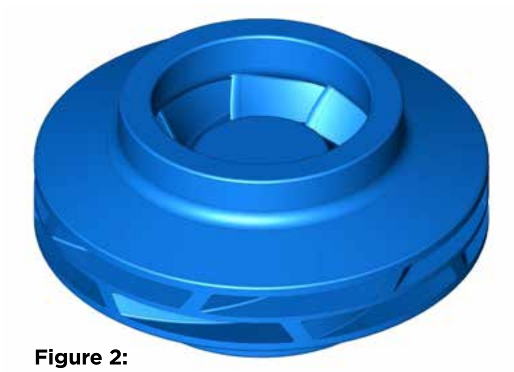

Figure 2:
Test Geometry

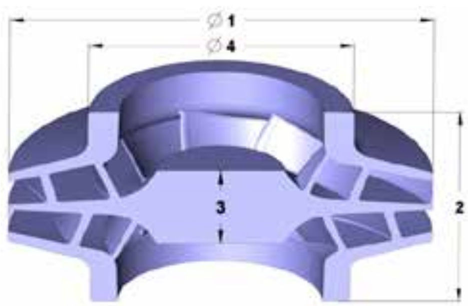

Figure 3:
Measurement Locations

Figure 4:
Casting from Additive Manufacturing/SLA Pattern

TEST & CASTING PROCEDURE

Tech Cast processed the SLA pattern using the standard investment casting process. This involves dipping the pattern into a resin slurry, and building up enough layers to create a shell that is durable. The shell is then heated to 1500° F, causing the SLA pattern to burn and leave a void in the shell. The shell is then washed out to ensure no debris remains, and the molten steel is then poured into the shell mold. Once the metal has cooled, the shell is broken up and the actual part is ready to be inspected. Tech Cast documented labor hours at each step of the process and compared the casting results between SLA patterns and conventional wax patterns.

RESULTS / Dimensional Accuracy

Tech Cast measured critical dimensions on both the patterns and their respective castings. Figure 3 shows the location of the four dimensions measured on each pattern or casting. Table 1 shows measurements of the patterns which are scaled to compensate for shrinkage. The accuracy of the additive manufactured pattern was comparable to the wax pattern. The largest deviation from an individual measurement for the SLA pattern was .004”. All deviations were less than one tenth of a percent compared to the nominal value and insignificant when compared to the tolerances of the casting requirements. **This is significantly better than can be produced in either green sand or no bake methods.**

Table 1:
Additive Manufacturing /SLA Pattern Comparison

Dimension ID	Target	Actual	Deviation	%Deviation
1	15.955	15.959	0.004	0.03%
2	7.782	7.779	-0.003	-0.04%
3	3.030	3.032	0.002	0.07%
4	9.745	9.747	0.002	0.02%
Average Absolute Percent Deviation				**0.04%**

Dimensional inspection of the castings is shown in Table 2 below. Both castings showed similar deviations to the intended casting target with an average dimensional error less than one percent. From a dimensional accuracy viewpoint, the SLA pattern demonstrated the capability of producing a predictable, precise casting.

Table 2:
Casting Comparison

Dimension ID	Casting Target	Casting from wax pattern			Casting from SLA pattern		
		Actual	Deviation	%Deviation	Actual	Deviation	%Deviation
1	15.75	15.880	0.130	0.83%	15.728	-0.022	-0.14%
2	7.63	7.560	-0.070	-0.92%	7.615	-0.015	-0.20%
3	2.93	2.933	0.003	0.10%	2.949	0.019	0.65%
4	9.62	9.648	0.028	0.29%	9.581	-0.039	-0.41%
Average Absolute Percent Deviation				**0.53%**			**0.35%**

Table 3:
Surface Finish Comparison

Pattern pattern	Surface Roughness (µin Ra)
Wax	122
SLA	159

Surface Roughness

Surface roughness was measured on each of the castings as shown in the table below. The casting from the additive manufactured pattern had a rougher surface but remained within limits for the casting application, and well below the typical surface roughness of a no bake casting (150-600 µin Ra) or green sand (250-900 iµ Ra)

Surface Quality

Surface quality refers to the absence of surface imperfections that detract from the appearance and functional performance of the component and may require repair. Such imperfections can include negatives to the surface such as pitting or cracks, or positives to the surface that could result from shell imperfections. The casting made from the SLA pattern exhibited an increase in negative areas on the casting, however, the severity of the surface defects did not impact casting performance.

COMPARING THE PROCESS

As outlined earlier, the basic casting process remains the same if the foundry is using a traditional wax pattern compared to a 3D printed pattern - however the cost and time savings are realized through additive manufacturing not requiring tooling to be built.
A comparison of the respective timelines is shown below.

Table 4:
Process Comparison

Step	Description	Wax Pattern	SLA
CAD Modeling	Incorporate pattern shrink, solidification modeling and gating into the casting design	0-1 Week	
Pattern	Obtain soluble core and pattern tooling or SLA pattern	7-9 weeks	1-2 weeks
Foundry Processing	Process the pattern through the foundry and clean the casting	1 -2 weeks	
Time to First Casting	Time from receipt of order to shipment of first casting (Casting complexity and value added services may affect this time)	9-12 weeks	2-5 weeks
Cash Expenditure	Purchases required to obtain first casting	$40,000	$3,150

CONCLUSIONS

- **Casting Quality**
  While not quite as good as a casting made from a wax pattern, the quality of a casting made from an additive manufactured/SLA pattern is good enough for all but the most demanding applications.
- **Cost of the First Casting**
  The foundry must invest $40,000 into tooling before obtaining the first casting when using wax patterns. If they choose to use SLA patterns, they need only invest $3,150, less than 10% of that required for molded wax patterns.
- **Labor Content of Castings**
  Casting a SLA pattern requires similar labor compared to a wax pattern.
- **Time to First Casting**
  Additive manufactured patterns allows the foundry to deliver the first casting 6-8 weeks faster than wax patterns.
- **Machining**
  Due to the combination of improved surface finish and the processes ability to hold tighter tolerance, in many cases parts can be produced without the need for additional machining operations, which may be required if using traditional green sand or no bake casting methods.
- **Applications**
  - **Direct manufacturing**
    SLA patterns reduce the total costs of finished casting for limited runs or low volumes without significant sacrifice to casting quality.
  - **Repair Parts**
    No investment of injection tooling for one-off repair or legacy items.
  - **Concurrent Designs**
    An additive manufactured pattern ordered simultaneous with wax tooling allows the foundry to prove out processing during tool construction.
  - **Research & Development**
    Multiple variations may be tested at the same time without incurring tool alteration costs.

As this technology continues to be developed, we can expect to see a further reduction in lead times, equipment costs, raw material pricing, and improved efficiencies as the foundry becomes more familiar with the process. Companies such as Tech Cast are there to help our customers not only just produce parts, but to educate design and purchasing teams on these new technologies and how they can be applied to each customers unique need.

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JACK LAUGLE
President, INNOVATIVE CASTING TECHNOLOGIES

3D metal printing an additive manufacturing technology that is revolutionizing the design and prototyping world especially in industries such as truck, transportation, medical parts, agriculture, aerospace and motorsports. With increasing application of the technology, there is potential for metal additive manufacturing to become an integral part of every engineer and designer's toolkit. It is complementary to traditional subtractive methods - like CNC machining as well as the traditional foundry.

Additive Manufacturing (AM) is a process used to create three-dimensional parts from a digital file. It involves building up thin layers of material to create complete, complex parts that are difficult to produce using traditional methods such as casting, forging, and machining. 3D metal printing brings new design possibilities to the table, including being able to combine multiple components in production, minimize material use and reduce tooling costs.

THE TECHNOLOGY

Our Renishaw Metal 3D printing system can produce parts up to: 12" x 12" x 12" in these alloys: Aluminum, Stainless, Titanium, Inconel and numerous tool steels. Currently the industry does not support any of the iron based (gray iron/ductile iron) materials.

3D metal printing is ideal for parts that are in the development stage where modifications and redesigns are part of the design process. 3D metal printing allows engineers to have creative freedom during the production process versus other prototyping methods, saving you time and money.

One of the most recognized benefits of additive manufacturing is that it reduces the weight of the part significantly. Parts can be as much as 65 percent lighter than traditional, subtractive manufacturing methods, making them especially ideal for industries that require lighter weight parts to reduce fuel consumption such as aerospace and transportation.

GET PARTS FASTER!

3D metal printing is where parts and prototypes are needed quickly. Other benefits of 3D metal printing:

- Speeds up and simplifies your build process
- Produces complex parts you can't get with traditional manufacturing
- Offers new design possibilities
- Minimizes material use
- Reduces tooling costs
- Combined multiple components in production
- Parts maintain strength and rigidity
- Improves production cycle times
- Reduces material waste
- Reduces part weight
- Saves you time and money

Part design, complexity, alloy, surface finish, and volumes will dictate the best option for your part. That's why working with a foundry that offers choices in production is often your ideal situation. Foundries that can keep your production in-house from the 3D printer to a high run production in their sand casting operation will serve many casting buyers well.

WHY 3D METAL PRINTING

Organizations using metal parts can make a thorough analysis of current product and production lifecycles to reveal gaps where metal additive manufacturing could prove advantageous - in reducing development time, production steps, costs and use of material.

- **Automotive**
  - The motor sport industry has adopted metal additive manufacturing to produce customized parts such as cooling ducts.
  - Speed of turnaround of prototyped parts is key to maintaining a competitive advantage. Functional metal parts can be rapidly produced and performance tested.
  - Lighter parts can contribute to greatly reduced fuel consumption for cars and trucks.
- **Aerospace**
  - Metal additive manufactured parts are used in the aerospace industry for functional parts including engine turbine blades, fuel systems and guide vanes.
  - The topological optimization of parts can improve functionality and reduce weight.
  - Lighter parts can contribute to a lighter aircraft and greatly reduce fuel consumption.
- **Healthcare**
  - The medical orthopedic industry benefits from manufacturing complex geometries and structures in high grade materials such as titanium.

While 5-axis CNC machines are capable of positioning tools into tight, hard-to-reach places, there are still features which cannot be accessed by these tools. This isn't the only concern; a feature must have enough strength and rigidity to resist the forces of a milling tool. Failure to account for this can lead to poor quality surfaces, or even damage to the part. These factors may limit the manufacturing of the technician's design to something that only closely resembles what is required, rather than accurately reproducing it. Most often this will lead to manual finishing of the part.

Metal additive manufacturing can be used to help improve production cycle times and productivity in injection molding. Metal mold tools used for injection molding contain channels to cool the mold. With conventional tool-making methods, these cooling channels are drilled into the tool in straight lines. Metal additive manufacturing allows cooling channels to be designed and built to perfectly contour the mold. This helps to improve cooling performance, extend the life of the mold, and reduce waste.

Modern technologies enable us to create both models and secondary tooling in a matter of days or even hours. Prototype models offer the chance to check form, fit, function, and evaluate the new product design visually.

Continued on page 11

SAVE TIME

3D Metal Printing significantly streamlines traditional methods. It brings design and innovation to the forefront. Metal additive manufacturing allows metal parts to be built without the need for traditional tooling and with few limitations in geometry. Modifications and redesigns are part of the designing process, but this method allows engineers to have creative freedom during the production process, saving time and money.

SAVE WEIGHT

3D Metal Printing means freedom from the normal manufacturing constraints. Parts can be easily made hollow or filled with lightweight but strong lattice work. Parts are built with only as much material as needed to support the mechanical and strength requirements, leading to lighter-weight finished pieces and reductions in material consumption.

SAVE MONEY

The old adage is that "time is money." Shorter time between design and manufacturing, faster iteration of part designs, and reduction in startup delays all translate directly into significant savings. Combine that with lower material usage and less infrastructure investment. This is a recipe for massive cost reductions over the long term.

There are a lot of advanced manufacturing methods entering the market from CAD and CAM equipment, to advanced automation in producing castings, core boxes, and finished machined castings. All of these newer technologies complement and make a traditional foundry able to reduce your overall tooling costs and getting your high quality complex parts to market faster.

Newer technologies are being deployed in our foundry every year. How to know the capabilities of your foundry? That's simple, just do an on-site visit. Today's foundries are a far cry from foundries of years past. As an early adopter of many of these advanced automation technologies, there is a lot to be learned from a tour about the options in the production of your part. The more you know – the more you can specify the best technology for your part, and the more you can save.

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RoboMolding
PROTOTYPES & RAPID PRODUCTION

A RoboMolder is the most cost effective way to create a sand mold as it eliminates the need for expensive tooling. Robotic sand milling is also less expensive than 3D printing, for large molds.

Using a RoboMolding alongside traditional molding lines and/or with 3D printed cores gives you choices in having your part produced with the most cost effective manufacturing method.

- **No Tooling**
  reduces total costs
- **Mold Sizes**
  up to 80x90x20/20
- **Mold Media: Can use any media**
  Silica, Zircon, Chromite, Ceramic, Thermally Reclaimed.
- **Works with 3D Printed Sand Cores**
  to create complex molds
- **Non Ferrous & Ferrous Alloys**
  Iron, Aluminum, Steel, Stainless, Duplex Stainless

Big parts or small, prototypes or large production runs, Southern Cast's broad-based equipment know-how and process expertise get you from alloy to casting, on-time and on-budget to get castings quicker and without needing a pattern and corebox. Design changes can happen fast, just change the robot program.

WANT MORE INFO
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ROBO-CASTING

UNDERSTANDING ADDITIVE MANUFACTURING & APPLIED TECHNOLOGIES

Southern Cast Products

DOUG IMRIE
President, SOUTHERN CAST

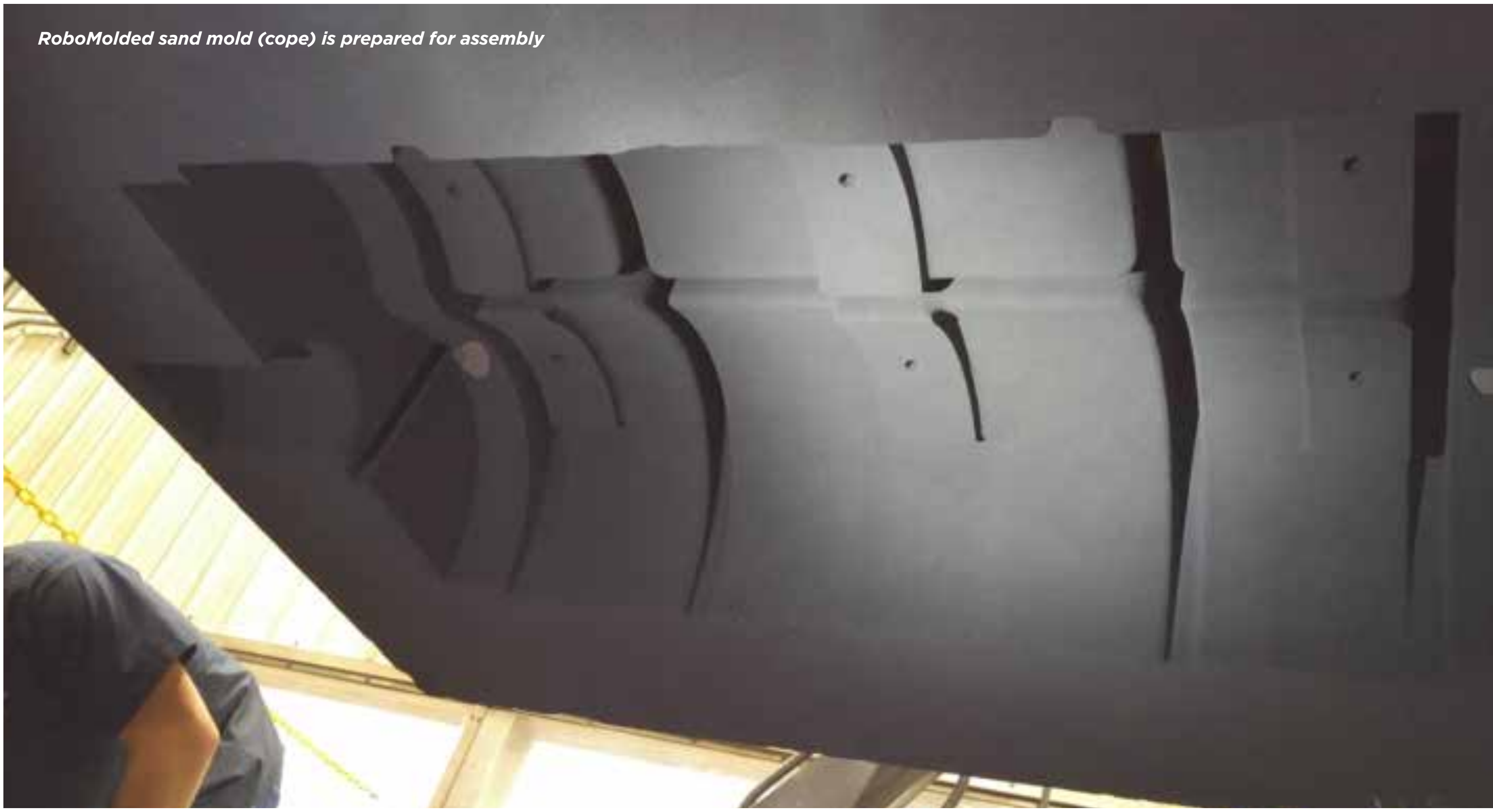
RoboCasting is an applied manufacturing process that creates sand molds for metal casting that eliminates the need for a pattern. A robot is programmed to mill the sand to create the mold, then the metal is poured in the sand Robomold.

Comparison to 3D Printed Sand Molds
Both methods use sand held together by a chemical binder. 3D Printing a sand mold is an additive manufacturing method, where the mold is made layer-by-layer. RoboMolding takes a solid block of sand (blank) and carves away at the sand, leaving the desired cavity. Both the Robot and 3D Printer are programmed to 3D Solid Model.

Advantages of RoboMolding
RoboMolding can be used with a variety of mold media, such as: Silica, Zircon, Chromite, Ceramic including thermally reclaimed sand with sand additives, such as iron oxide to improve finish. RoboMolds are capable of using a flask for handling, allowing shipment to other facilities in sizes up to 80x100” in a more time and cost efficient manner than printed molds and cores.

Mold Sizes (inches)	RoboMold Cost	3D Printed Mold Cost ($0.12 per In^3)
30 x 30 x 15/15	$ 1,600	$ 2,592
40 x 40 x 12/12	$ 2,000	$ 4,608
50 x 50 x 15/15	$ 2,800	$ 9,000
60 x 60 x 15/15	$ 4,100	$ 12,960
70 x 70 x 20/20	$ 7,000	$ 23,520
80 x 80 x 20/20	$ 8,500	$ 30,720
80 x 90 x 20/20	$ 14,000	$62,000

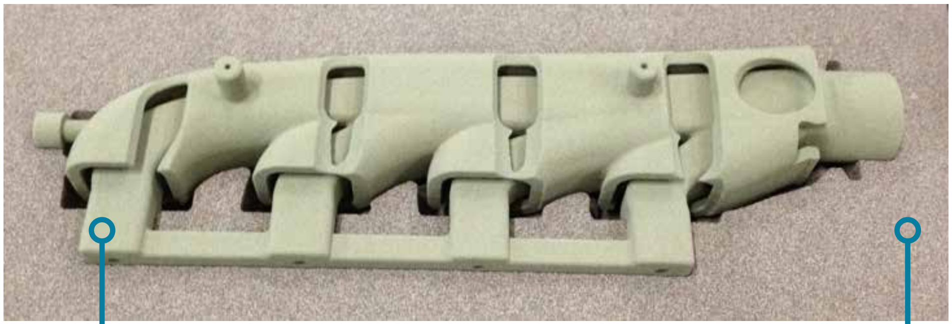
Sand Molding Robot



RoboMolded sand mold (cope) is prepared for assembly

Reclaimable Materials
RoboMolding uses thermally reclaimed sand, just like conventional mold manufacturing. Not only does this allow RoboMolding to be performed alongside traditional mold assembly lines, but it also makes the cost-of-operation more economical than 3D Printing sand molds.

Hybrid Process: RoboMold with 3D Printed Core - RoboMolding can be used in conjunction with 3D Printed sand cores to create complex molds. A 3D Printed sand core with small, intricate geometry is inserted into a RoboMolded sand mold. The hybrid process uses the benefits of both subtractive and additive methods to ensure accurate parts *(See Picture Below)*.



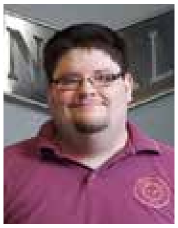
3D Printed Sand Core
RoboMolded Sand Mold

RoboCasting Process
Lead Time: 2-3 Weeks

- Receive customer CAD model
- Translate model into robot program
- Load sand black (blank)
- Run program
- Clean & check mold
- Assemble mold
- Pour metal
- Extract cooled part
- Laser scan to check geometry
- Reclaim sand into new blanks

Contact:
DOUG IMRIE
imrie@southerncast.com

3D Printed Sand Molds:
HOW DOES THIS HELP YOU?



TRIDENT ALLOYS

ETHAN EDWARDS
Foundry Metallurgist, TRIDENT ALLOYS

INTRODUCTION TO 3D SAND PRINTING

When it comes to the foundry industry and the technology that has been utilized to create prototypes and production castings there have been minimal changes. The technology of the foundry industry is one of the most researched areas within the respective engineering discipline and therefor it beckons the phrase “If it isn’t broke don’t fix it”. 3D printing is beginning to change that line of thought by introducing new ways of looking at a job. 3D printing is bringing new advantages to the foundry industry for parts buyers to take advantage of and there are 2 that make the biggest impact, shorter lead times and reduced cost.

Figure 1: Trident Alloys’ Neptune

THE PROCESS

To most people they are still unsure what 3D sand printing is and how it relates to molding. In its simplicity Viridis3D’s sand printer, as seen in Figure 1, is similar to the modern inkjet printer in homes today. Each print pass can be seen as the next piece of paper that was printed and the binder can be seen as the ink that prints the words on the paper. To go a little more in-depth the sand printer uses binder jetting technology in which furan binder is deposited in specific patterns to bond individual layers together to create the mold. This mold is comparable to existing no-bake technology in strength and surface finish all without the need for an expensive wooden/metal/polymer pattern.

The process flow for 3D sand printing is very similar to traditional mold making so any large production orders can be transitioned flawlessly if the need arises. The part begins as a 3D model or 2D drawing provided by the customer, once a satisfactory casting model is achieved (i.e., machine stock added, fillets added) solidification analysis can begin using SolidCast. Running solidification analysis the foundry engineer can design and redesign the rigging (gating and risering) system quickly and efficiently. The major advantage to this is that when the part goes to the foundry floor there is a high confidence that the casting will be sound as the solidification software has predicted/shown where risering was needed and a proper gating system calculated based on known theories.

With a final rigging system designed and verified, through solidification analysis, mold design can begin after the material shrinkage is added to the casting model. At this point the foundry engineer must envision what the mold is going to look like when printed. It is up to the engineer to create this mold as separate pieces, traditionally known as the cope/drag. Unlike traditional molding however, 3D printing is not limited to this thinking. With 3D modeling the foundry engineer can create what works best for that particular casting by cutting the mold into several sections to allow for easier cleaning and handling or even removing mold material in areas that are unneeded to reduce cost and weight on the final mold. Once a final mold package is designed and assembled into a build file printing can begin.

Printing is simple, with the slicing software provided with the computer doing all of the hard labor this part of the process is plug and play. The build file is imported into the software and centered on the build table, once centered printing can start. The 3D printer can run autonomously with very limited outside action needed by an operator. The operator is limited to occasional maintenance and cleaning on the print heads, as well as ensuring the sand is properly supported as the build progresses in height. With Viridis3D's current printer technology the rate of printing is at 2.25in/hr on average and a curing time of 30 minutes to 2 hours depending on the size of the mold printed. It is typical to print a mold and pour it the next day with the time in between utilized by the operator, during another print cycle, to clean all the non-printed sand from the mold and add a mold wash to the casting cavity. This mold wash that is applied increases the quality of the surface finish. The unprinted sand can be easily removed by vacuum or hand without worry of disrupting the mold surface. The clean and washed mold can be assembled the same as existing foundry molds. If the foundry engineer designed the mold right rebar can be utilized to aid in lifting the pieces and in closing the mold. Figure 2 shows a partly assembled mold, in the picture internal riser sleeves can be seen as well as an intricate core.

Figure 2: Partially assembled 3D printed mold

THE ADVANTAGES

This technology in regards to sand casting gives several advantages to the foundry that are passed along to the customer. The biggest advantage to 3D printing is reduced lead times. 3D printing was created with rapid prototyping in mind and printing with sand is no different. The foundry can utilize 3D printing to produce a casting in the time it would take to even receive the pattern. The foundry is looking to print low volume orders for prototyping or replacement parts. The low volume orders translate to cost savings for the foundry and customer as no expensive pattern or major rework are needed. The rapid prototyping nature of 3D printing allows quick modification to any design or casting material changes with no downtime since there is no pattern that needs to be worked on for what may amount to several days. The modifications can be implemented within minutes of the results from the previous mold being seen, however with the utilization of solidification analysis there is a 90% confidence in the first iteration. Lastly, there is an abundance of cost savings for the customer as there is no hard tooling, no need for storage, and no repair/upkeep. Everything can be stored on a flash drive to be used again in short notice if that particular casting is needed within a couple weeks.

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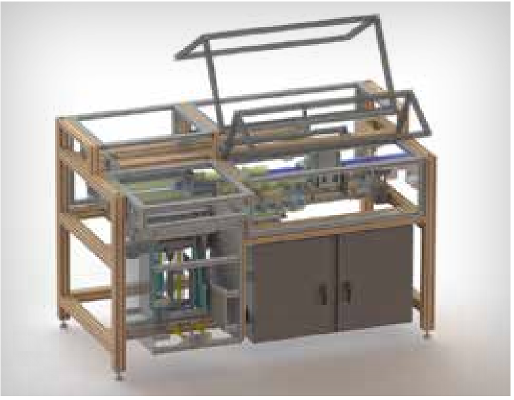
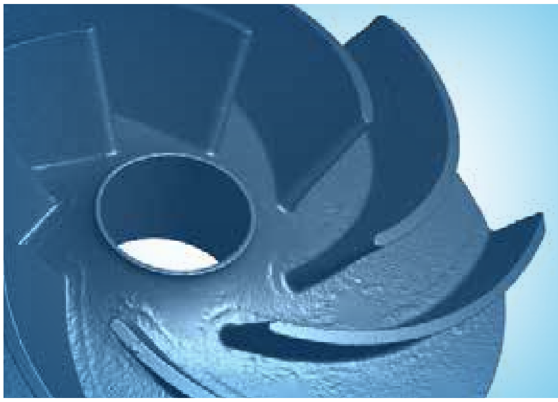
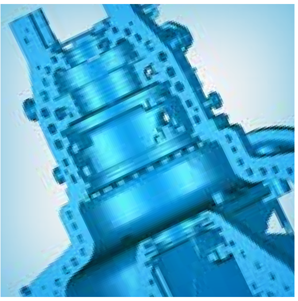
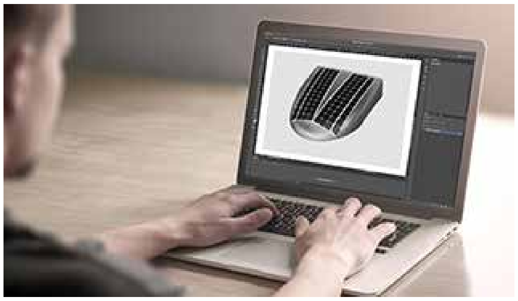







Reverse Engineering & Patternless Technology Process

CARL BERUBE
Manager of Technology, CELERO PARTNERS

In the last few years, there has been a significant increase in the presence of 3D scanning and other additive manufacturing techniques in traditional production processes. 3D scanning technology has the prowess to empower rapid prototyping in today's product design and production stages.

Reverse Engineering Case Study with 3D Scanning

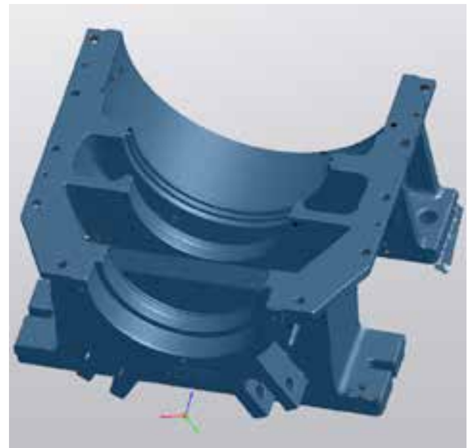
GL&V had a very short window of time to 3D scan a split case pump. There was no 3D CAD model or 2D drawing to reference, so we had to be able to work quickly and accurately. The split case pump that was being reversed engineered was on its last repair cycle and needed to have a replacement casting ready in 6 weeks. The scan data was acquired in about four hours using a hand held scanner.

Neidrach scanning the Split Case Pump casting

Using the scanned data live, we were able to create 2D sketches and smooth lofted surfaces between the two sides of the data and conform it to the casting using hands on methods in VXModel. Doing this revealed several interesting details to the customer:

- The cast surfaces were badly worn & out of typical tolerance
- The volume of each cavity was inconsistent

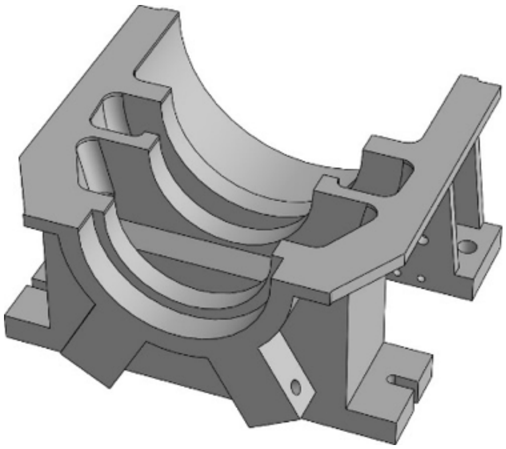
VXModel easily overcame these issues. Neidrach was able to generate sketches on the casting. The surface was then trimmed to match the profile. Comparing this data live with color deviation maps to the scan data, Neidrach was able to ensure that accuracy was within the client's requirements.



The Casting Scan inside VXModel

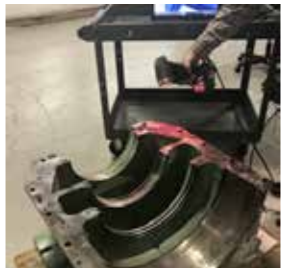
VxModel allowed Neidrach to redesign with design intent. He was able to model the part by extracting the profile, generating a sketch and adjusting the revolution axis to the proper design intent. Lastly, he merged the model and extracted the radii from the scan data, applying it to every blade. Once the model was complete in VXModel, he used the software "Transfer-To-Solidworks" technology to send the entire feature-based solid model into Solidworks and saved it as a native sldprt file for the client.

Using the CAD tools in VXModel and the product knowledge provided by the customer, Neidrach was able to recreate the entire casting as a solid model true to design intent.

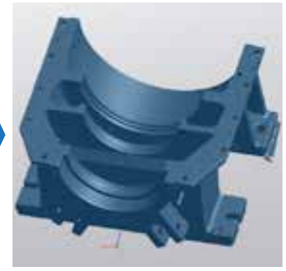


Using the CAD tools in VXModel and the product knowledge provided by the customer, Neidrach was able to recreate the entire casting as a solid model true to design intent.

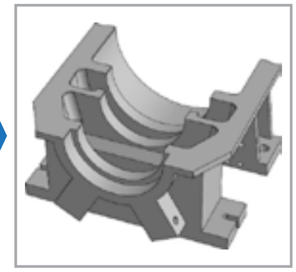
So, we sprang into action using some new tools which have recently become available to us. We had a vendor come to Hudson Falls and 3D scan the existing housing. From this scan a drawing and a 3D model were made of the part.



3D Scan / bottom Half
Day 3-4



Modeled
Day 5-6



CAD Model
Day 6-8

Feedback from Customer:
In January we received a suction roll from our customer in Richmond, VA for rebuild. The Tending Side Bearing/Suction Housing was cracked due to failure of the drive side housing which hung the entire roll off the tending side housing in a cantilevered condition. This was the only spare that the customer had and they feared the worst if the roll in the machine should fail as it would stop production. This roll was not manufactured by GL&V so we didn't have a pattern from which to make a casting, nor did the client have any drawings or other records to help.

Bearing Housing inspection
Bottom half was found to be cracked

Day 1

Day 2

We sent the 3D model to another vendor that also has a tool new to GL&V: RoboMolding. Using this process a sand mold was robotically recreated of the original part (the mold is what the molten metal is poured into to make the desired shape) and a new casting was poured.

RoboMolding was used for the mold
New casting was poured
3D printing was used for the cores

Day 9-15

Day 16

The casting then was moved to the machine shop where it was machined per the drawing created from the 3D scan.

The finished part was assembled to the roll and returned to the customer.

The entire process took 5 weeks to complete from the time of order.

Machining
Assembled back on the roll

Day 17-25

Day 26

Understanding today's additive and advanced manufacturing technologies is critical as you never know when these technologies might be needed. Knowing that your providers also have partnerships in place to execute some of these technologies is equally important.

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cberube@celero-partners.com

RESOURCES

Resources for those involved in purchasing, specifying, and designing of metal parts.
Have a resource you would like to see added to this list or a topic, material, or process discussed?

Complete Our Form

Foundries Featuring Additive Manufacturing Technologies

Southern Cast Products ....www.southerncast.com
Trident Alloys...www.tridenalloysinc.com
Tech Cast..www.techcastllc.com
Innovative Casting Technologies...............................www.innovative-castings.com

Suppliers of Technology for Part Buyers

Celero Partners ....www.celero-partners.com

Part Design Consultant (advice on part production, process, design etc.)

Carl Berube, Celero Partners ....www.celero-partners.com

Additive Manufacturing Consultant

Will Shambley, Metal Fish ....www.themetalfish.com

Industry Trade Associations

American Foundry Society ....www.afsinc.org
Ductile Iron Society...www.ductile.org
Investment Casting Institute.......................................www.investmentcasting.org
Steel Founders' Society of America ....www.sfsa.org
North American Die Casting Association...............www.diecasting.org
ASM International ....www.asminternational.org
SME...www.sme.org
Precision Machined Products Association ....www.pmpa.org
Precision Metal Forming Association......................www.pma.org
National Tooling & Machining Association ....www.ntma.org

Additive Manufacturing

AMUG (Additive Manufacturing Users Group).......................www.am-ug.com
3D Printing Industry News..www.3dprintingindustry.com
Additive Manufacturing ....www.additivemanufacturing.media
America Makes...www.americamakes.us

Additive Manufacturing Glossary of Common Terms

Additive Manufacturing (AM)
Additive manufacturing is the process of building up a three-dimensional object, one thin layer at a time.
Many people refer to Additive Manufacturing as 3D printing.

Computer Aided Design (CAD)
Computer aided design, or CAD. CAD software allows designers to create models in either 2D or 3D.

Rapid Prototyping
Rapid prototyping is a way to make a prototype or production parts from CAD. Manufacturing of the part is often done with 3D printing or another additive manufacturing technology.

Selective Laser Sintering (SLS)
Selective Laser Sintering, (SLS) is a 3D printing technology used for metal parts.

STL
Most 3D printers prefer to use a STL file format.

MARKETING OPTIONS

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