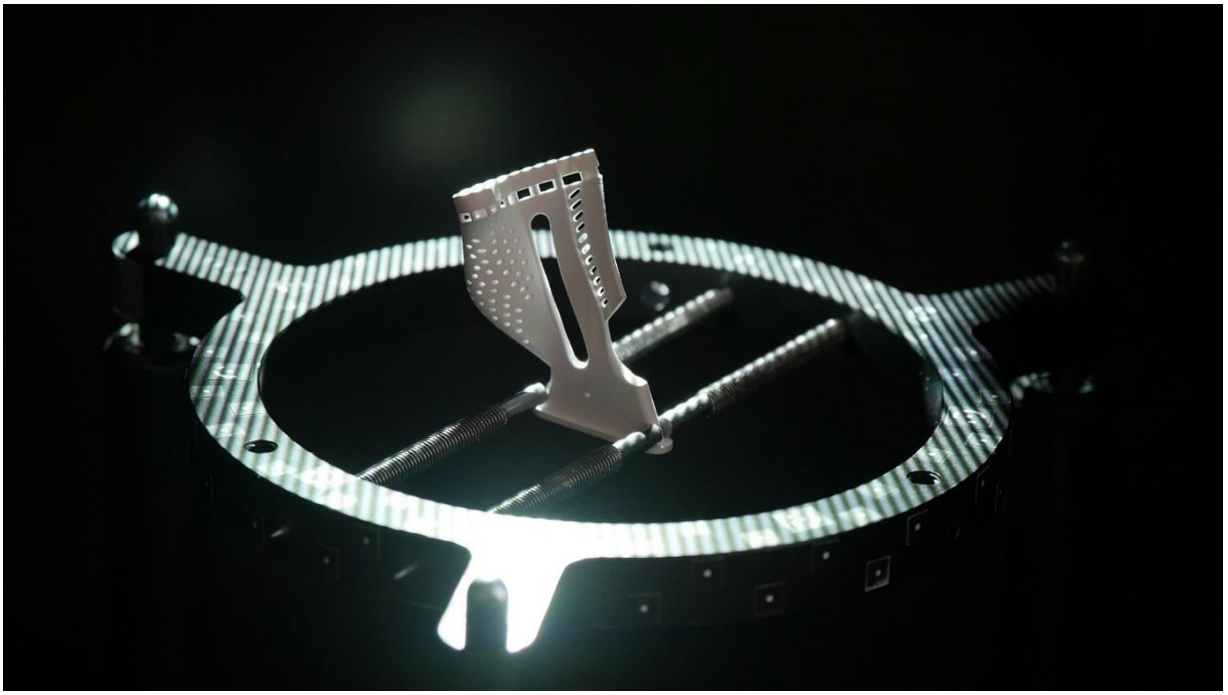
The Leading Ceramics Additive Manufacturer

Additive Manufacturing of Ceramic Cores



Foundry cores are an essential part of the production of turbine blades for aviation, aero derivative and land based gas turbines. The internal cooling structure of the turbine blade facilitates a reduction in the substrate temperature, creating opportunities to lower fuel consumption, improve turbine efficiency and decrease engine emissions. The need for complex core design has increased dramatically with customers' demands for smaller, more efficient and cost-effective engines running at higher temperatures, stretching existing alloy technology to its limit.

These new complex core designs can prove to be difficult to produce using traditional methods due to the web of internal passageways and chambers present to promote the increased surface area and airflow to cool the blade.

What kind of impact can the distributive technology of 3D ceramic printing have on foundry core production in the future?

3DCERAM has developed the process of producing ceramic foundry cores for turbine blades. Traditionally casting cores or foundry cores have been an essential yet complex process that involves many steps in the production process for turbine blades. The ceramic core is the sacrificial material that will is used as a negative once the alloy is melted over the core.

Jet engine

Up until now manufacturing cores has been a time and labor intensive process. Today, designs of foundry cores are becoming more and more complex. To make a porous ceramic foundry core, the method consists of making the core in several pieces and then assembling them manually. The possibility of an issue arising somewhere along the production process is large, mainly during the joining process, hence there can be an extremely high waste ratio. The lead-time to develop new forms of cores can be very long due to the complex nature of the molds, leading to limitations in the ability to modify the cores during the development phase on new component designs.

TYPES OF MOLDING

There are 3 types of molds related to, Equiaxed, Directionally Solidified (DS) and Single Crystal castings are all methods that are used in the traditional core production industry.

- *Equiaxed casting*: The cheapest and quickest method, the exterior walls of the mold are heated to just below the temperature of the solidification of metal. Once the metal is melted it sets very quickly, creating a uniform equiaxed grain structure in the parts.
- *Directionally Solidified casting* (DS): Based on the same concept as Equiaxed, however the walls are not heated uniformly, a gradient of temperature from high to low is maintained on the walls as the alloy is being melted onto the core. This equates to a microstructure of long crystals oriented axially in the blade, strengthening the creep resistance of the blade when in service.
- *Single Crystal casting* (SX casting): Is similar to DS however the mold is designed to restrict the flow of the molten alloy and the growth of the crystal is strictly controlled resulting in improved high-temperature properties and the ability to increase engine perfromance.

Some of the **constraints** applied to core production:

- Dimensional accuracy +/- 0.1 mm
- Structural strength
- Surface roughness
- Material porosity

All these elements can be controlled by the production of cores using 3D printing

Additive manufacturing brings a new dimension to the conventional industrial process. In addition to saving time and increasing productivity, 3DCERAM's breakthrough technology delivers the following benefits:

- ✓ Flexibility of design
- ✓ Possibility of increased complexity of cores
- ✓ Quick creation of new designs
- ✓ Better responsiveness and productivity
- ✓ Increased profitability
- ✓ Maintaining the strengths of core

RETURN ON INVESTMENT CASE STUDY

The increase in productivity of core manufacturing is one of the highlights of using 3D Printing. With new development optimized, 3D AM can provide a large number of cores per production and hence maximize the ROI in the medium term.

Below is an example of standard sized cores:

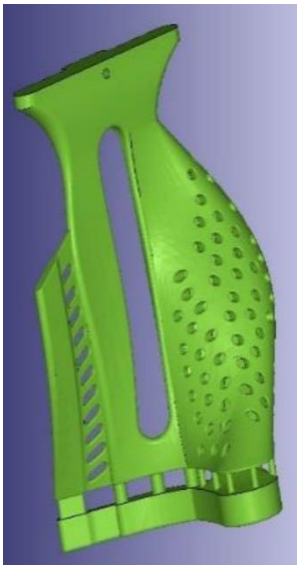
CERAMAKER ® 900 FLEX. Printing platform 300mm x 300mm Material used: 3DMIX Alumina, Silica mix
Size of the cores produced: 90 mm x 35 mm x 15 mm

Parts	Minimum cores per platform	Maximum cores per platform
Core	16 approx.	60 approx.
Production time	35 hrs approx.	140 hrs approx.

The large delta in the numbers can be attributed to the method in fabrication. 16 cores can be produced while lying horizontally on conformers. This will decrease the build time but will increase the cost per core ratio.

The second production is when cores are produced vertically with a new-patented system, smart support design between each core. This is unique to 3DCERAM. It is the optimization of core production for large-scale industries.

3DCERAM has developed turnkey solutions to allow industrial manufactures of foundry cores to benefit from the flexibility and high performance production of cores through the process of 3D printing.



CAD file of the part

Part after printing and firing

CHOICE OF MATERIAL

The choice of ceramic used for the production of foundry cores is a very important part of the 3D process. There are some important points that the manufactures of cores must take into account when deciding on which ceramic to use

- The type of alloy used for the core production
- The complexity of the core
- There must be no chemical reaction between the core and the metal during the melting phase
- The ceramic must be dissolvable after the melting phase has taken place
- A low coefficient of thermal expansion (CTE) and relatively high mechanic resistance

3DMIX

3DCERAM has been developing their own line of pastes, 3DMix, to use in conjunction with their 3D printing machine the CERAMAKER ® 900 and related models (C100, C3600). We have developed a range of pastes and suspensions to achieve optimal printing results of ceramic cores. These pastes have been developed to provide a product equal to traditional methods. 3DCERAM have optimized their paste according to the customer's criteria in many cases, in the form of on-demand development of ceramic paste to conform to the machine's parameters. This has allowed customers to use their own certified ceramic powders while using the breakthrough technology of ceramic 3D printing.

The following ceramics that are available from 3DCERAM:

- **Alumina (Al_2O_3)**

  Used with nickel, cobalt, steel and titanium, used in many forms of cores. Very good mechanical resistance, can be difficult to dissolve, using a high-pressure chemical solution.

- **Fused Silica (SiO_2)**

  Used with nickel and aluminum, complex cores, high CTE and low mechanical properties at high temperatures, dissolved easily using a chemical solution.

3DMix & parts printed with the paste

- **Alumina Silica (AL_20_3-$Si0_2$)**

  Used with equiax casting, graphite added to facilitate the dissolving of the core, the presence of alumina will slow the crystallization of the silica, but also reduce the mechanical resistance of the core.

- **Silicore (zircon silica)**

  High mechanical resistance porous ceramic, very stable at high temperature, used with all alloys except cobalt, can be difficult to dissolve the core due to the zircon component.

CUSTOMIZED MATERIALS

Along with the materials listed here, 3DCERAM can provide *on demand services* for when a client wishes to develop their 'own' paste for the CERAMMAKER® range of printers. Our team of experts will take into consideration the needs and demands of the customer when creating a new formulation. The process to obtain a new paste for core production is:

- ✓ Characteristics of their powder
- ✓ Test the reactivity of the paste once mixed with resin.
- ✓ Optimization of the powder and determination of machine parameters.
- ✓ Post process analysis
- ✓ Fabrication of benchmark parts to prove efficacy

This approach has proven to be very beneficial to manufactures of cores. Traditionally manufacturers have not altered their powder to adapt to new technologies. It is essential to offer the knowledge and expertise of the 3DCERAM Team to potential customers to establish a synergy between the parameters of the machine and the characteristics of the ceramic powder required to produce the desired outcome.

3DCERAM had a request from a European aerospace client to develop a paste using their powder, this was a great challenge for the experts in 3DMIX, after 12 months of the development process, cores were successfully produced using the client's custom material. Great team work!

CONCLUSION

The production of ceramic cores up until now has been a relatively closed market, with little innovation over the last few decades. 3D ceramic printing technology can optimize the production of core manufacturing. The process of 3D printing will facilitate the production of complex cores to achieve long-term benefits to the customer.

According to a ten-year opportunity analysis paper, produced by Smartech Markets, the future for ceramic additive manufacturing of technical ceramics and cores is bright. Industrial 3D printing of ceramic molds and cores is expected to represent the larger revenue opportunity during the forecasted 10-year period 2017-2027. There is an encouraging a shift from research to scale production of technical ceramics. An increase in revenue forecast from 8 million to 1.1 billion is estimated.

3DCERAM, with our new disruptive technology and expertise in core production are well positioned to provide world-class and innovative technical solutions to the complex future needs of the casting market!

Turbine core

About 3DCERAM-SINTO:

Created in 2001, 3DCERAM (www.3DCeram.com) is a company based in Limoges, France owned and managed by Christophe Chaput and Richard Gaignon since 2009. In 2018, Sintokogio Ltd. of Nagoya, Japan, acquired 3DCERAM.

In late 2018 the decision was made to expand into the North American market by establishing 3DCERAM Sinto, Inc. in Wallingford, CT, USA. With the Grand Opening in May of 2019, our applications laboratory was opened and provides additional support and services to North American clientele. Peter Durcan, V.P. Sales is the leader for our North American affiliate.

3DCeram has un-paralleled expertise in the technology of 3D printing, offering a complete package by accompanying their clients on their chosen projects, choice of ceramic, production specification, R&D, modification of 3D parts with support to full industrialization, on demand production, the selling of the CERAMAKER® C100, C900 and C3600 printers, the production support accessories and the associated consumables.