Study case : Foundry core Design Bureau Ivchenko

Due to the need of more efficient engines for aerospace industry, foundry cores -that are used in the production of turbine blades - have to be more and more complex and become difficult to produce by the conventional ceramic injection molding process.

Foundry cores are an **essential** part of the production of blades for combustion engines. Efficiently cooled blades allow to ensure higher temperature of working media, which leads to increase of engine power and efficiency.

To meet this challenge, the blades are hollowed with integrated cooling channel. As the alloys that make up the turbines' blades are not easily machinable or forgeable, investment casting is used for their production. In this complex process that involves many steps, the ceramic core is the sacrificial material that will be used as a negative once the alloy is melted over the core. Today, the need for complex core design has increased dramatically with customers' demands for smaller, more efficient and cost-effective engines. They can include internal passageways and chambers to promote the airflow to cool the blades. These new complex cores are difficult to produce using usual industrial processes like ceramic injection molding because it requires to make the core in several pieces that are then assembling manually, which is very complex and can induce an extremely high waste rate. Moreover, the lead time to develop new forms of cores with the traditional methods can be very long due to the complex natures of the molds, so little modifications can be made to the cores during production.

In this context, 3DCERAM has developed a process of producing ceramic foundry cores based on the laser stereolithography (SLA) 3D printing technology.

This process consists in a layer-by-layer fabrication procedure in which the selective curing of a photopolymerizable ceramic suspension by a computer-controlled UV laser beam enables the fabrication of a three-dimensional part. This innovative technology brings a **new dimension** to the traditional industrial process used for cores production. Indeed, in addition to saving time and increasing productivity, additive manufacturing delivers the following benefits: **flexibility of design, possibility of increased complexity of cores, quick creation of new designs** (no mold used, parts are produced directly from CAD files), **better responsiveness and increased profitability** (lower investment and change costs, no tool maintenance and storage costs).

The choice of the ceramic that is used for the production of foundry cores depends on the type of alloy that is employed and must meet the following criteria: **no chemical reaction between the core and the metal during the casting phase, heat and mechanical resistance to resist the metal casting**, good leachability after the metal cooling and low CTE.

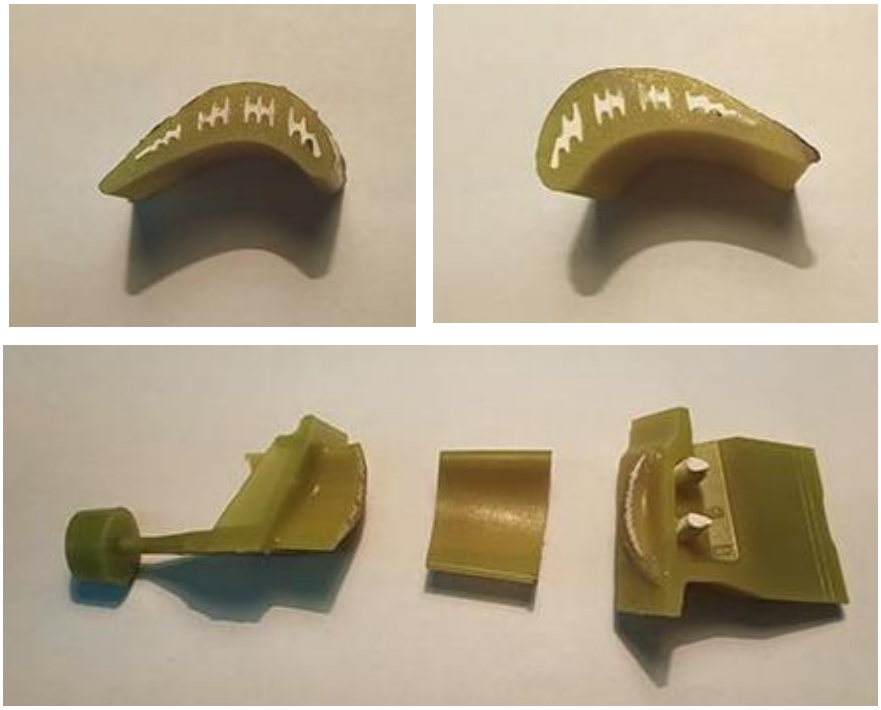
To meet the requirements of this market 3DCeram has developed a silica-based composition **SILICORE**. Silica-based compositions are extensively used in the casting of Ni-based turbine blades for many decades. Indeed, fused **silica ceramic cores have good thermal stability** resulting from a low coefficient of thermal expansion (about 0.6×10^{-6} K^{-1}) as well as excellent thermal shock resistance and high leachability. Moreover, a silica core is easily removed in solutions of soda or potash, not harmful to alloys. Finally, the sintering of a silica core leads to the formation of cristobalite by a devitrification process, which ensures the temperature resistance of the core.

In 2019 3DCeram signed a joint development contract with Zaporozhye Machine-Building Design Bureau Progress State Enterprise named after Academician A.G. **Ivchenko** in Ukraine. The aim of this development works was to validate the ceramic formulation used on Ceramaker 900 printer Customer has by real industrial casting of blades tests using Single Crystal Casting (SX casting).

The challenge consisted **to achieve optimal printing results of foundry cores on CERAMAKER 900 machine and to guarantee a quality of product equal to traditional methods and validated by real investment casting**.

The high precision and accuracy of SLA technology for ceramic 3D printing combined with well-known method of measuring of cores by mechanical gauges used by cores manufacturers in their everyday quality control process allowed **to obtain a perfect wax casting**, first stage of complex investment casting traditional process:

3D Print Silicore - In the WAX mold



Core in the wax mold, sections analysis

X-ray control was implemented on all wax moulds and **showed no cracks of ceramic cores**. At the next stage Customer assembled casting blocks and processed with casting of foundry moulds.

Foundry moulds (Ni-alloy with Silicore cores).

After the leaching of ceramic cores series of additional controls were implemented on each blade:

- ***X-ray control***, which confirmed the full leaching of ceramic material inside the blade
- ***Ultrasonic control*** to measure the thickness of different sections of the blades

To conclude

High accuracy foundry cores with complex geometry and tailored properties were produced through a breaking stereolithography 3d printing process.

The properties of the sintered cores were optimized thanks to the use of a specific ceramic formulation developed by 3DCeram, SILICORE. During the SX-casting process real scale industrial tests the properties of SILICORE are in accordance with the specifications of this casting process. Moreover, porosity of this material combined with certain cristobalite content ensure a high dimensional stability during the casting as well as a very good leachability of the ceramic core.

This material is qualified by leading industrial user as compliant for the production of foundry cores.