SLM SOLUTIONS

Case Report
Monolithic Thrust Chamber

CellCore
BIOMIMETIC ENGINEERING

Rocket Propulsion Engine Built with Selective Laser Melting

Additive Design Optimization with CellCore GmbH

COMPANY PROFILE

CellCore GmbH

CellCore is a start-up engineering firm from Berlin specializing in a new kind of engineering and design for components and products. Their bionic engineering draws on highly efficient and evolutionarily optimized natural structural principles and applies these to technology. In its role as a development partner, CellCore creates innovative solutions for individual applications and ideas when conventional approaches encounter dead ends. Their core expertise lies in calculating and constructing cellular structures that combine with form-optimized outer contours that are tailored and adjusted to the specific application.

Through the design of a thrust chamber for a rocket propulsion engine, CellCore demonstrates the advantages of the selective laser melting process and how they are used in the aerospace industry. Printed in a nickel-based superalloy, the monolithic component was created in collaboration with SLM Solutions.

CURRENT SITUATION / CHALLENGES

Rocket Propulsion Engine: Single-Piece Thrust Chamber and Injector

The manufacture of rocket components requires many criteria be taken into consideration. Not only is consequent lightweight construction essential, materials must also be able to withstand particularly high stresses and temperatures. Additionally, the manufacturing costs for their complex geometries are very high when limited to conventional manufacturing processes.

The engine manufactured by CellCore and SLM Solutions consists of a thrust chamber, the core element of a liquid-propellant engine with a combustion chamber wall, a fuel inlet, and an injection head with oxidant inlet. The chemical reaction in the combustion chamber creates a gas that expands due to heat development and is then ejected with enormous force. The thrust required to drive the rocket is therefore created using recoil. Extremely high temperatures are created in the chamber during the combustion process, so the wall must be cooled to prevent it from burning, too. To achieve this, the liquid fuel (e.g. kerosene or hydrogen) is fed upwards through cooling ducts in the combustion chamber wall before entering through the injection head. There, the fuel mixes with the oxidant and is lit by a spark plug. In conventional constructions, the cooling ducts are countersunk in a blank and subsequently sealed through multiple working steps. With selective laser melting the cooling is integrated as part of the design and created together with the chamber in one process. Due to the engine's complexity, the traditional manufacturing process is

cost-intensive, requiring half a year minimum. In the 3D printed engine, CellCore demonstrates the possibilities of the SLM® technology can offer for the aerospace industry, as the additive manufacturing process takes fewer than five working days while creating an improved component.

SLM® SOLUTION

Filigree Structural Cooling to Increase Efficiency

The single-piece rocket propulsion engine, combining the injector and thrust chamber, reduces numerous individual components into one, with multi-functional lightweight construction achievable only with the selective laser melting process.

The internal structure developed by CellCore is the fundamental element of the engine and cannot be manufactured by traditional methods. It is not only suited to heat transport, but also improves the structural stability of the component. The cooling properties of the CellCore design considerably outperform conventional approaches, such as right-angled, concentrically running cooling ducts. It offers an optimized relationship between stability and mass application and exhibits low current resistance with a simultaneously high reaction surface, making it more efficient while integrates additional functions and also reducing weight compared to conventionally manufactured components.

Fig. 1: CellCore developed a monolithic rocket propulsion engine with internal structural cooling.

SLM Solutions collaborated with CellCore in the preparation of this highly complex component in order to ensure success by optimizing the selective laser melting process. SLM Solutions customer success team developed specific parameters for the geometry, focusing on downskin optimization. Build plate orientation was recommended after

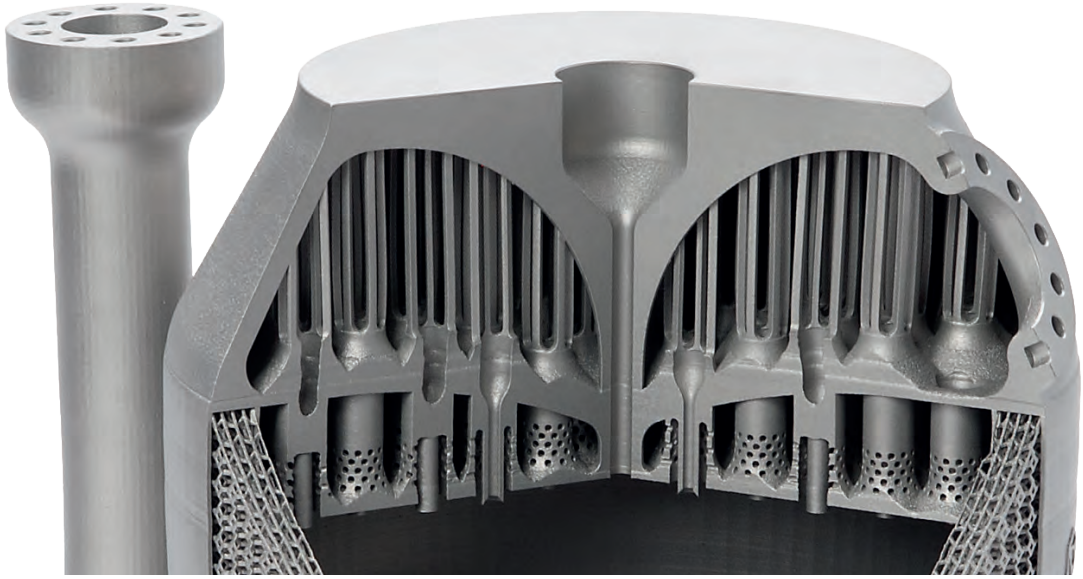

Fig. 2: The structural cooling which was developed by CellCore provides an optimal relationship between stability and mass application.

consultation with the SLM Solutions' application engineering team and critical sections of the part were identified for test-builds to guarantee success of the manufacturing job. To satisfy the aerospace industry's high material requirements, the engine was manufactured in the nickel superalloy IN718 on the SLM®280 selective laser melting machine.

IN718 is a precipitation hardening nickel-chromium alloy with exceptional tensile, fatigue, creep and breaking strength up to 700°C, making it an important material for aircraft and gas turbine components as well as numerous other high-temperature applications, such as rocket propulsion engines. When processed conventionally, the hard material is difficult to machine and causes extreme tool wear. This concern is mitigated through the additive process, as powder material is melted into the end-geometry.

Fig. 3: The engine was manufactured in nichrome alloy IN718 on a SLM®280.

Despite its complex structure, postprocessing is minimized, thus avoiding high levels of tool wear. SLM® technology saves considerable costs by reducing expensive, time-consuming manufacturing steps and simplifying the engine's structure. Selective laser melting offers aerospace companies the opportunity to increase their competitive position by increasing rocket system functionality whilst maintaining exceptional quality, as well as lightweighting and drastically reducing development, testing and production timeframes.

SUMMARY

Monolithic Thrust Chamber

- Innovation: Direct integration of multiple parts and internal features, e.g. internal ducts
- Improved function: Cooling due to innovative lattice structure, which also increases stability
- Efficiency: Minimization of individual process steps while combining multiple individual parts into one component; production time reduced from months to days
- Lightweight construction: Considerable weight reduction due to lattice structures
- Simple manufacturing: Minimal postprocessing despite complex structure and avoidance of high levels of tool wear due to difficult to machine nickel-based alloy (IN718)

About SLM Solutions

The Lübeck-based SLM Solutions Group AG is a leading provider of metal-based additive manufacturing technology. SLM Solutions focuses on the development, assembly and sale of machines and integrated system solutions in the field of selective laser melting.

SLM® technology offers diverse options in the metal-based additive manufacturing of parts, such as a new design and geometric freedom, lightweight construction through the reduction of metal part weight, significant advantages in terms of production speed and the manufacturing of internal undercut parts in low quantities.

Our products are utilized globally by customers from the most varied sectors, particularly in the aerospace, automotive, tooling, energy and healthcare industries, as well as in research and education.

They particularly value the following advantages of our technology partnership:

- Highest **productivity** using patented multi-laser technology
- Highest material density and **part quality** through our innovative gas stream management
- Completely closed **powder management** in an inert gas atmosphere
- Cutting-edge process monitoring using various **quality control modules**
- Multilingual open **software architecture** with customer adaptability
- Ultracompact **modular design**
- Long-term and **confidential customer relationships**
- **A technological leader and pioneer** in metal-based additive manufacturing with decades of market experience

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