Launcher SDM Case Study

Title: Improving Critical Rocket Engine Performance with Advanced Metal AM

Subtitle intro copy: *Launcher uses Stratasys Direct Manufacturing's additive manufacturing expertise to develop critical components for world's highest performance liquid rocket engine using VELO^{3D} end-to-end metal AM solution.*

Partners:
Launcher: a company committed to building the world's most efficient rocket,
SDM: CM Network partner

Max Haot, Founder & CEO of Launcher,
Andre Ivanovic, Mechanical Engineer for Launcher,
Andrew Carter, Stratasys Direct Manufacturing

Intro

As satellites shrink from the size of a bus to the size of a loaf of bread, more and more companies are racing to develop smaller, lower-cost rockets to support them. Enter Launcher, an innovative developer of high-performance rockets designed to deliver small, remote-controlled satellites to orbit via its Engine-2 (E2) rocket engine.

Optimized for mass production and low cost, the Launcher E-2 liquid rocket engine is an incredible piece of technology; one that aims to be the highest performance liquid rocket engine of its class—running on liquid oxygen (LOX) and kerosene (RP-1)—in the world. Its end use will be the central thrust component for Launcher's Light rocket, which is set to take its first test flight in 2024.

Since its inception, the E-2 was designed to be the highest performance engine in the small satellite launcher class—with the largest thrust, lowest propellant consumption, and lowest cost-per-pound of thrust.

But innovative designs like the E-2 require the use of equally innovative technology. To help the E-2 transition from design to fully realized part, Launcher leveraged 3D printing and additive manufacturing (AM) at every stage of development, which helped keep project costs low and its design optimized for mass production.

To carry out the critical component fabrication and execute the E-2 engine development, Launcher turned to experts at Stratasys Direct Manufacturing, a 3D printing and manufacturing services company based in Valencia, CA.

Challenge

“If we look at any liquid rocket engine that can reach orbit, the turbopump is one of the most challenging parts of the project…or at the very least, half of the challenge,” said Max Haot, Founder & CEO of Launcher. “And if you’re talking about a turbopump for a stage combustion closed cycle, that level of challenge increases.”

Engineers at Launcher required the LOX pump’s impeller to be highly balanced to enable it to spin at the required 30,000 rpms, in cryogenic conditions, while transporting liquid oxygen.

“I want to point out how significant this is. We’re dealing with liquid oxygen and an impeller spinning at 30,000 rpm to produce about one megawatt of power from the Turbine,” said Haot. “In this type of environment, at four thousand psi of discharge pressure, any anomaly, any rubbing between the rotor and the stator, can result in an immediate, rapid, unplanned disassembly.” In other words, rotating components like Launcher’s inducer/impeller, part balance is key to ensuring that the part, pump, and rocket engine performs as designed.

This project required the use of cutting-edge metal AM technology to produce the designs for Launcher’s space-bound rockets. The challenge with more commonly used metal additive technologies is that overhanging surfaces of a part tend to require support material. These support structures are difficult to design correctly and both difficult and expensive to remove from the part during post-processing. The need for support material often leads to engineers compromising their optimal design to avoid requiring support material, and the modification of existing designs for printability.

The problem, however, is that many metal 3D printers struggle to accommodate the complex designs and designers scarify part performance to accommodate the method of additive manufacturing.

To avoid the use of difficult-to-remove internal supports, additive manufacturing engineers are forced to tilt the impellers at an angle to complete the AM build. This tilt, designed to make the part printable, often creates unbalanced geometries that would be detrimental for this type of component. While this approach may result in a part that looks like a functional impeller, metal printed parts printed in this way often become elongated or out-of-round and impossible to balance within the tolerances needed for the final product.

Solution

Launcher turned to Stratasys Direct Manufacturing to manufacture a key component – a well-balanced inducer impeller that would accelerate and drive the LOX to the combustion chamber, creating greater fluid flow and ultimately more thrust for the rocket.

Stratasys Direct created the E-2’s impeller by integrating two separate parts – an inducer and an impeller, into one co-joined and more efficient component. The company also chose to print the component using INCONEL® 718, a corrosion-resistant material with decent LOX compatibility and excellent mechanical strength at cryogenic temperatures.

To overcome the problems encountered with more commonly used metal 3D printers, such as tilting the build plate, using supports, or making unwanted design modifications, Stratasys Direct utilized their VELO^{3D} Sapphire system with its inherent SupportFree™ AM process.

Outcome

Using VELO^{3D}'s SupportFree™ capabilities, the design and manufacturing compromises associated with commonly used metal AM technology were easily overcome.

Leveraging the VELO^{3D} Sapphire system allowed Stratasys Direct to achieve true design freedoms without compromising on part quality, which is common with other solutions when attempting to print similar complex geometries.

"For metal AM, and due to the stress accumulation during the build, we cannot tilt parts and still meet an engineer's intent of a well-balanced spinning component," says Carter. "The Velo3D system enables us to print impellers in the ideal orientation and still avoid the need for internal supports. This is critical to our ability to deliver compliant complex inducer-impellers like the one sourced by Launcher."

The ability to print without internal supports allowed Stratasys Direct to print the impeller flat and round, which was a critical design requirement. "By printing the part flat, we got a nice symmetric mass distribution of the part relative to that central rotational axis," said Andre Ivanovic, Mechanical Engineer for Launcher.

Once the part was printed, Stratasys Direct's engineering team managed a comprehensive series of customized post-processing operations and validation steps to bring the component to its final dimension and to substantiate the efficacy of the part. After removing the impeller from the Velo system, Stratasys Direct partially machined the component to ensure all powder was evacuated from the internal channels, before undergoing a series of certified heat treatments. The company then confirmed the impeller met material density and integrity requirements. After this was completed, thermal processes were applied, such as solution heat treatment, hot isostatic pressing, and precipitation hardening.

Following positive results, Stratasys Direct oversaw the abrasive flow machining process to smooth the fluid flow paths of the component before conducting final precision CNC machining. The component also underwent fluorescent penetrant inspection, and coating to validate conformity to project specifications. As a last step in the process, the impeller went through final verification, including CMM inspection.

Part of the challenge with a project like Launcher's is delivering on designs that have already gone through so much modeling, refinement, and iteration. With the VELO^{3D} and its synergy between its Flow™ software and Sapphire® printers, Stratasys Direct was able to deliver these complicated designs with a true end-to-end additive solution.

Stratasys Direct's AM expertise and rigorous secondary post-processing techniques, combined with Velo3D's ability to print SupportFreeTM, ensured the successful build of a highly complex and functional part that would have been more costly and labor-intensive to print if conventional manufacturing processes had been used.

Launcher's field tests of the impeller proved successful, meeting or exceeding all metrics of efficiency. The project is currently in testing phases for a VELO^{3D} printed inducer/impeller, which will further deepen the contributions metal AM is making toward the end goal of Launcher's E-2 project: a cost-effective, high-performance rocket ready for mass production.