CASE STUDY

500 mm & Beyond: Lessons Learned From Printing 'Super-Sized' Rotational Parts

Introduction

Rotating Machinery Services (RMS) is a global provider of engineering, repair, and maintenance services for equipment integral to critical infrastructural support. RMS specializes in managing the seamless operation of large industrial rotating equipment crucial to energy, petrochemical, food and beverage, and steel sectors.

Embracing Metal Additive Manufacturing

RMS initiated its exploration of metal AM (Additive Manufacturing) by partnering with Velo3D and contract manufacturer Duncan Machine Products (DMP) to explore the feasibility of fabricating a Ø 10.7" (272 mm) Inconel® 718 shrouded impeller using metal AM without the need for internal support structures.

The impeller passed initial tests based on industry standards and was eventually pushed further, tested up to 25,000 rpm, where it showcased remarkable resilience.

However, many of RMS's projects involve larger impellers. Unfortunately, most conventional metal 3D printers cannot produce a part in the near 500 mm size range. This limitation combined with the lack of engineering experience with near 500 mm printing physics, means that very few printers and fewer companies in the world today would even attempt a part like this.

The Velo3D Sapphire XC is a large format metal 3D printer with a build volume of 600 mm Ø by 1000 mm z-height and 8 1kW lasers.

Go Big: Overcoming Challenges Associated With Large-Format Printing

Velo3D's large-format Sapphire XC metal 3D printer is the market leader in 600 mm metal AM solutions outselling the nearest competitor by almost 2 to 1[1]. One of the reasons for this market leadership is the support that Velo3D provides through its applications engineering team. These highly trained engineers work daily with complex solutions, like low angle shrouded impellers, to find technical solutions that work in a production environment on the Sapphire platforms.

The new project aims to utilize Velo3D's large format solution and the expertise of its applications engineering team to create a 483 mm diameter impeller featuring a 2-degree shroud. The impeller, made from Inconel® 718, must undergo successful spin testing and require minimal post-processing. The main challenge lies in its extensive span features and low overhang angles, allowing only a 7.3 mm clearance for support structure removal within a 4.7" x 3" area.

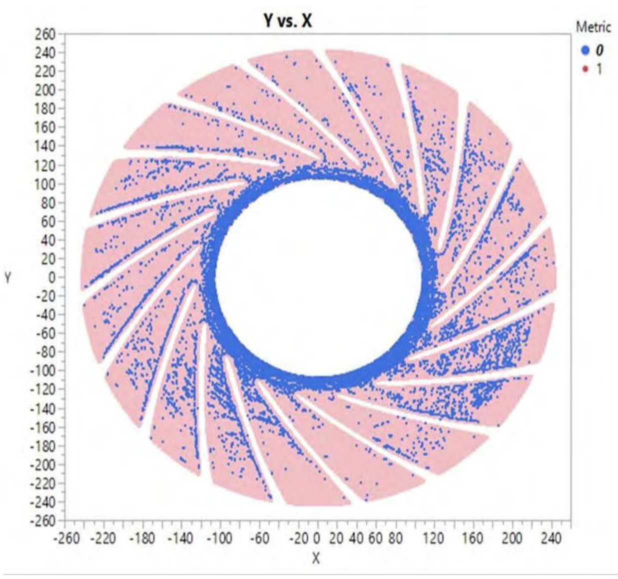
The first exploratory impeller was one of the largest and shallowest impellers ever attempted at greater than 500 mm (about 1.64 ft) scale.

Through risk mitigation builds, the team determined that when printing at this scale, low angle impellers can experience a greater amount of melt pool instabilities (MPIs) that lead to small metal 'stalactites' forming on the upper shroud.

> **"We've explored various systems for our application needs, but Velo3D stood out as the best fit. Not only did their technology perfectly align with the complexities of developing a large impeller, but the level of support we received from the Velo3D team was unparalleled. They were with us every step of the way, ensuring that the project was executed to the highest standards."** - Benjamin Wagner, Engineering Manager, RMS

1 CONTEXT, Additive Manufacturing/3D Printer Report, History through Q4'22 - Forecast Q1'23 through 2027

MPIs can occur on downskin surfaces where the printer attempts to melt metal onto a powder substrate. If the laser delivers too much energy, this extra heat melts more material than desired, resulting in a metal sphere forming on the underside of the overhang, as shown in Figure 1. MPIs can be difficult to remove from inaccessible places leading engineering to find novel solutions.



Velo3D's Assure quality assurance software predicts the likelihood and location for MPIs to form.

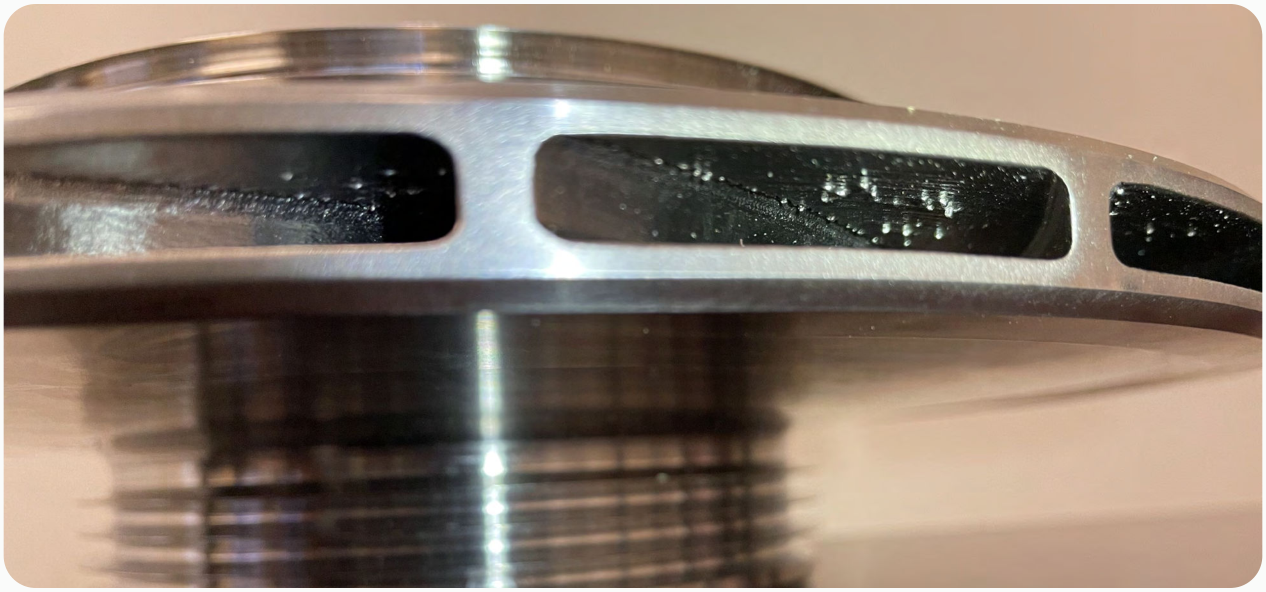
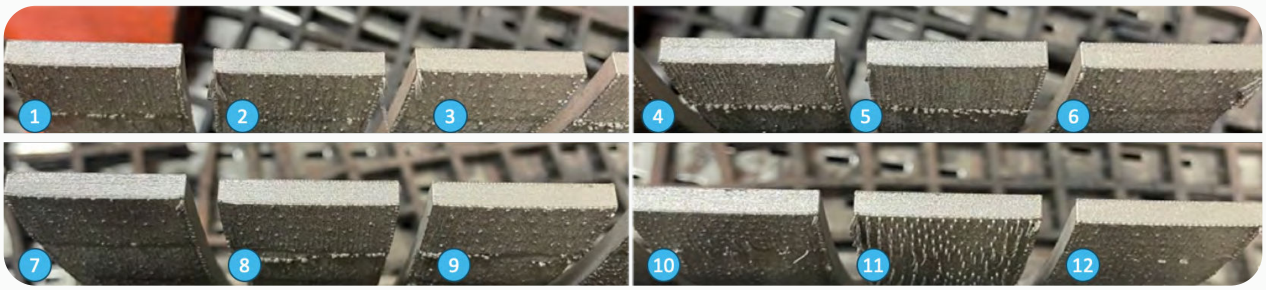


Figure 1: MPIs remain on the downskin surface in flow path after extrude-hone.

Results: Establishing New Support Strategies to Achieve Target Quality and Performance

To overcome this challenge, Velo3D's application engineering team initiated internal development to design a support strategy that could retain surface quality while also being easily removed. Through a Design of Experiments (DOE) conducted on several downskin test coupons and sample impeller geometries, tapered pin supports were found to be the best choices for down skin surface quality after support removal.



DoE test results showing surface quality from 12 different downselected tapered pin support designs.

As shown above, the DOE for support structures yielded the best surface finish utilizing a tapered pin approach. By optimizing for minimized MPI formation and easy support removal, the new support structure yielded the best results overall.

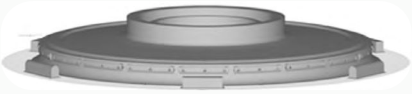
By defining this structure in Flow, Velo3D's print preparation software, application engineers can add them quickly to any application in any location needed and then slice the part creating the two-dimensional instructions needed for printing.

View of completed 483 mm shrouded impeller printed on a Velo3D Sapphire XC. For scale, the impeller is bigger than a typical NY-style pizza (typically 18")

Once sliced in Flow, an applications engineer sent the part print instructions, complete with tapered pin supports, to the printer. This build completed in 62 hours. Upon post print inspection, the application engineers and the team at contract manufacturing partner Knust Godwin were able to verify that MPIs were significantly reduced in the final part. Furthermore, removal of the pins during post processing was accomplished without any special tooling or resources.

Total post processing, performed by KG, included stress relief, HIP, support removal, heat treatment, and machining.

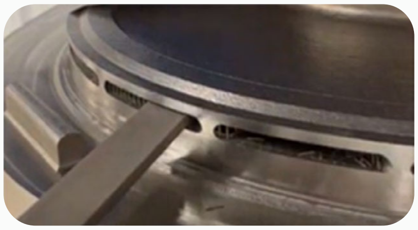
Total manufacturing time, including printing and all post-processing and machining operations, took less than half the time needed for the same impeller through conventional methods.



PRINT FILE CREATION

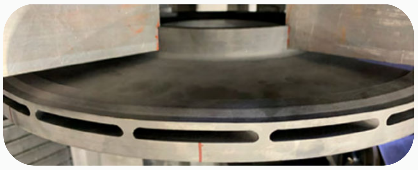
AM BUILD

STRESS RELIEF



OUTER SHROUD & SUPPORT REMOVAL

BUILD PLATE REMOVAL, HIP, HEAT TREATMENT



MACHINING

FINAL PRODUCT

Upon completion of the heat treatment and final machining, the impeller will undergo non-destructive testing (NDT) and dimensional inspection. After this, it will be subject to a spin test at 115% overspeed (9737 rpm). This test is to confirm that no distortion or crack formation occurs under these heightened speeds and stress conditions. Furthermore, the tensile strength of specimens, printed and heat-treated alongside the impeller, have exceeded the strength requirement specified by ASTM F3055-14a standard.

This case study illustrates how the combination of Velo3D's technology, engineering teams, and contract manufacturing network offer key solutions to companies looking to push the limits of manufacturing their designs. Their effort proved integral to achieving reductions in manufacturing cycle time and improving final part quality.

"We've explored various systems for our application needs, but Velo3D stood out as the best fit," said Benjamin Wagner, Engineering Manager, RMS. "Not only did their technology perfectly align with the complexities of developing a large impeller, but the level of support we received from the Velo3D team was unparalleled. They were with us every step of the way, ensuring that the project was executed to the highest standards."

By adeptly addressing the challenges associated with large-scale parts over 400 mm in diameter, Velo3D's fully integrated metal AM solution helped enhance efficiency across the entire manufacturing process. This innovative approach reduced the degree of post-processing and led to tangible improvements in program lead time and cost. The result is a streamlined and adaptive manufacturing model, underlining the technology as a key component in the drive toward faster and more cost-effective production.

Speak with a Velo3D engineer to learn more about our fully integrated metal additive manufacturing solution.

WITHOUT COMPROMISE

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