Drone-engine Cylinder Redesigned for Additive Manufacturing

Cobra Aero's bench tests of a novel 3D-printed drone-engine cylinder prove-out the value of designing within nTop Platform to simultaneously consider multiphysics simulation, lightweighting and DfAM.

Advanced computational-modeling company nTopology supported Cobra Aero and Renishaw in a project to optimize the design, development and additive manufacturing (AM) of Cobra's new A33 drone-engine cylinder. Test results on the 3D-printed, air-cooled component—which has a novel, interior lattice structure designed with nTop Platform software—demonstrated superior performance to Cobra's current exterior-fin design.

Cobra Aero president Sean Hilbert holds a 3D-printed engine cylinder with a unique interior lattice structure designed with nTopology computational-modeling software. Performance testing showed air-cooling is significantly more efficient with internal lattice than with external fins. Previous models displayed on desk; finished A33N test engine with air-cooled lattice cylinder on top at far right.

Background

Cobra Aero is a one-stop partner for power and propulsion that offers engineering expertise, product-development facilities and manufacturing of engines and related components. The

company designs, develops, and manufactures roughly 2,000 engines per year for specialty markets, including unmanned aerial vehicles (drones) and motorcycles.

nTop Platform is a unique computational modeling software that allows for simultaneous consideration of design, simulation and manufacturing data. It enables users to rapidly create, iterate and optimize performance-driven geometries that take advantage of everything additive manufacturing offers to innovative companies like Cobra Aero.

Any company that makes products for aerospace knows the value of lightweighting designs for flight: decreased fuel consumption, increased payload and range, a reduction in expensive material costs and more. And in the multiphysics world of vehicles that operate above the ground, temperature, pressure, stress, airflow and other environmental variables must also be considered when designing for performance.

Leading additive manufacturing machines (in this case provided to Cobra Aero by Renishaw), can now print the production-quality parts that aerospace manufacturers need. But, until recently, design software has lagged behind production capabilities. The only software that can flawlessly create the unbreakable models and complex geometries 3D printing is capable of producing—a complete toolset for Designing for Additive Manufacturing (DfAM)—is nTop Platform.

The Challenge

Cobra Aero already had a finned cooling system—an AM-adapted, commercially successful design that is being flown now. “The finned part that we’re currently shipping works wonderfully and prints beautifully,” says Cobra Aero president Sean Hilbert. “But it requires a lot of post-processing because it has almost as much support structure on the cooling fins as material in the part itself. And all those support structures have to be manually removed after 3D printing. We knew we could improve on that design.”

Looking for alternatives to fins, Hilbert’s team became intrigued by the internal lattice structures they saw being used across a variety of industries, from aerospace to medical devices. By hollowing out a solid aircraft bracket, or a human joint implant, and filling the space with a lattice, honeycomb or gyroid structure, weight can be decreased and strength improved.

The bonus: lattices are self-supporting so don’t require any support structures during the AM build. , “One, a lattice structure would be very print-friendly and two, it might allow us to tailor-fit heat transfer in a better way. The motor we were working with is designed to be used in drones, where extra mass can take a particularly heavy toll on payload, range and performance.”

The Solution

> *"The possibilities that nTopology's nTop Platform software opened up were virtually endless. The fact that the generation of hundreds and thousands of different lattice shapes is mathematical, accomplished without having to create discrete, surface-based models like you'd see in traditional CAD packages, meant we could be a lot more adventurous with our designs for 3D printing."*
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> - **Kevin Brigden, DfAM expert at Renishaw**

Using nTop Platform's automated capabilities, Cobra was able to quickly generate different sizes of lattices and varying wall thicknesses of struts, filling-in the lattice inside their cylinder geometry, and terminating it on a highly undulating surface. Through every configuration, the software handled all data generated by lattice iterations with ease, automatically filling in fillets to broaden and smooth strut intersections and connections to the part skin. This distributes stress more uniformly, reducing concentrations that can lead to delamination, and promoting both manufacturability and durability.

Hilbert notes, "The issue we were exploring is that the amount of pressure drop across the cooling duct is directly related to the amount of drag on the airframe. We needed to find that sweet spot where we're getting enough heat pulled away from the cylinder but we're not adding a tremendous amount of drag onto the entire structure so the UAV can fly longer, more efficiently."

"By the time we were done, our models had evolved to the point where they were simply beautiful!" he recalls. "Apart from the lattice, we soon realized there were many other advantages to using nTopology software besides no longer needing support structures. We were able to integrate the cooling duct with the cylinder itself, consolidating parts into a single piece. Overall the design is just cleaner, simpler, a tighter package that prints perfectly and presents itself a lot nicer on the engine."

A trio of final cylinder designs was achieved, ready for 3D printing and real-world testing. nTop Platform then produced the engine cylinder part-geometry data in the sliced format required to drive the path of the laser in the layer-by-layer process of metal additive manufacturing.

> *"Testing showed that the new lattice structure design with nTopology was more efficient at cooling than our fin design. In every case, at every different RPM, less cooling air was required to maintain proper engine temperature. What this means to design going forward is that we can now make a smaller inlet to the cooling duct, which in turn makes*

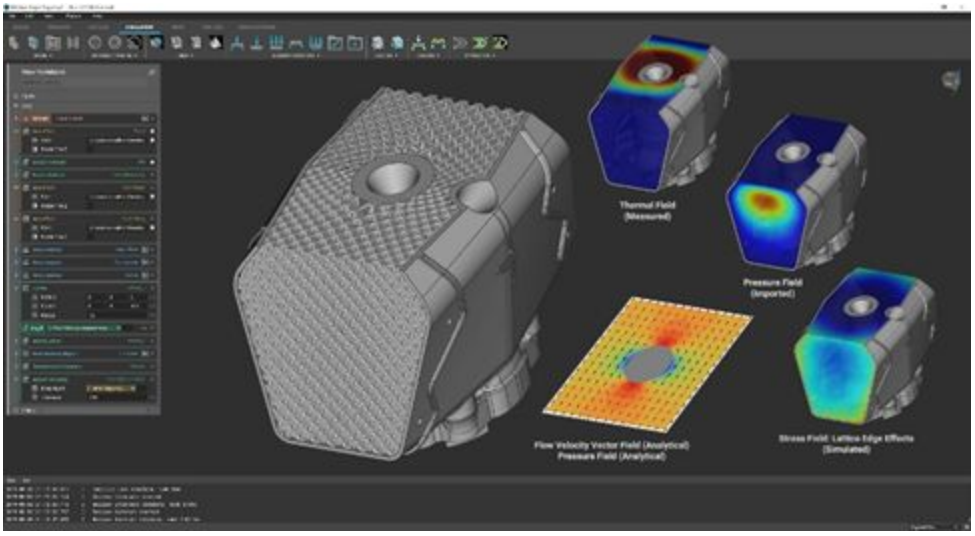
a smaller frontal area on the aircraft, so we have less drag on the aircraft for the same amount of cooling—exactly what we were hoping for."

- **Sean Hilbert, Cobra Aero**

Moving Design Forward with Multiphysics in nTop Platform

With their cylinder test results in hand, Cobra Aero is now in a position to take further advantage of other advanced capabilities available in nTop Platform as they refine their design towards commercial production.

The next round of testing will measure inlet and outlet pressures across the cooling structure to help determine which lattice density is optimal for the final production part. From those results the lattice geometry might be redesigned in nTop Platform to be progressively thicker or thinner depending on where it is in relationship to the cylinder walls.



Screenshot demonstrates the effects on the design of a broad range of multiphysics fields, here being simulated, explored and evaluated through a hypothetical engine cylinder model in nTop Platform.

The software's field-driven simulation capabilities can drive how a model is generated based on a wide range of multiphysics inputs--including temperature, flow velocity and stress as well as pressure. Reusable workflows allow designers to regenerate models without having to start from scratch each time and the software's implicit algorithms slash computational run times dramatically.

"We've definitely come to the conclusion that our new lattice-cylinder design is a better mousetrap than our fin cylinder—which is a big deal," says Hilbert. "We now know we're in the ballpark in terms of lattice density. From here on out it's a matter of using nTop Platform to

fine-tune all the design parameters we need and make the final tweaks of what we want to go to production with.”

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