FDM ECS Ducting

Overview

Environmental control system (ECS) ducting, used in both the aerospace and automotive industries, provides a climate-controlled air supply and regulates cabin airflow. These ducts are usually lightweight and not exposed to high pressure or harsh chemicals. ECS ducting often involves complex geometries, which usually requires custom designs. They have traditionally been made from aluminum, composite layups and rotationally molded thermoplastics. These methods can be costly and time-consuming, often requiring post-production assembly to achieve the desired configuration. In addition to long lead times, diminishing supplies of spares make 3D printed replacement parts a faster and more economical solution.

Benefits of FDM

- Reduced cost and lead time
- Completely customizable designs
- Resilient to pressure and temperature changes
- Lightweight but durable

FDM is a best fit for

- Reducing part count in multipart assemblies
- Relatively low part volumes (10s – 100s vs. 1000s)
- Complex duct geometries

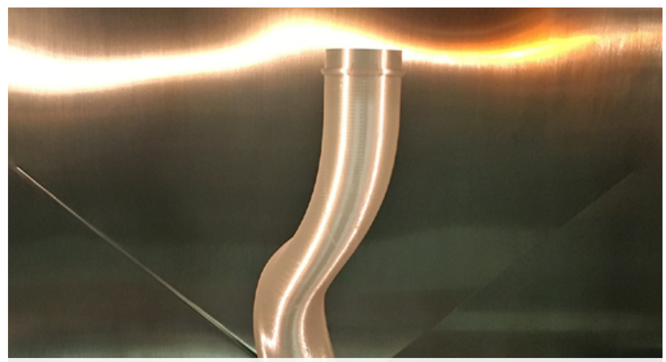
Application Outline

Fused Deposition Modeling (FDM®) provides an effective alternative for manufacturing ECS ducting. Compared to the complex and time-consuming traditional methods, FDM technology offers a straightforward, time- and cost-efficient process.

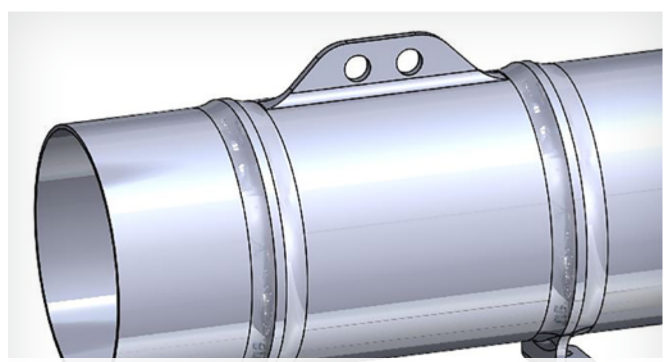
3D printing's freedom from conventional manufacturing constraints makes it well suited for ducts with complex geometries. Also, because the FDM process requires no additional tooling, it's much more cost-effective than traditional manufacturing methods and makes low-volume production economically feasible. If an airtight duct is required, there are multiple post-production techniques available that effectively seal the duct. The fastest and easiest method of sealing simply requires brushing on a coat of epoxy.

Stratasys® ULTEM™ 9085 resin is an ideal material for ECS ducting. It is a high-performance thermoplastic, flame retardant and has a high strength-to-weight ratio, making it perfect for ducts that must be both lightweight and resilient. Functional testing of FDM ECS ducts made with ULTEM™ 9085 resin demonstrated excellent resilience under pressure and mechanical loads as well as in temperature changes. In tests performed by Stratasys, non-sealed ducts showed no degradation in leak rate through 10,000 pressurization/depressurization cycles and 250 thermal cycles. The addition of an epoxy sealer completely sealed the ducts up to 15 psi.

ECS duct designs often involve thin walls combined with severe curves or angles, traditionally making the design process difficult. The FDM design process allows for vertical building, which reduces sharp angle changes and improves sealing and overall surface finish. For thin-walled cross sections, a special fill algorithm, remnant fill, automatically detects areas not supported by contours or rasters and fills them to the exact width necessary. FDM materials also allow for self-supporting angles, thus minimizing the use of support material. This reduces build time and overall material cost.



A duct built in a vertical orientation to improve sealing and surface finish.



FDM ECS ducts with integral mounting flanges can be produced as a single-part design.

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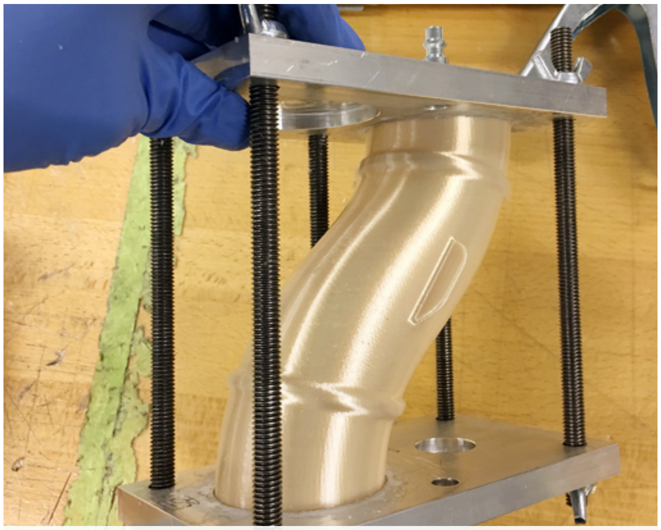
Customer Story

The US Air Force is increasingly using parts printed with FDM technology, both for prototyping and for production parts. In the aerospace industry, where time efficiency and customizable design are critical, FDM is an ideal method for producing tooling and non-structural interior parts such as window fixtures and latrine covers. Air ducting systems produced with FDM technology are currently being evaluated as part of the Boeing C-17 system. The parts were printed using ULTEM™ 9085 resin and are an effective option for the Air Force use due to their FST (flame, smoke, and toxicity) characteristics.

Like the Air Force, United Launch Alliance (ULA) is also exploring applicability of FDM for their spacecraft. ULA provides launch systems to both government and commercial customers, including the US Air Force and NASA. According to Andrea Casias, a materials processing engineer at ULA, producing parts from plastic makes the entire process simpler. “You can build really complex geometries, and reduce weight,” she said. “We’re actually replacing a lot of metallic applications with plastic applications, because it’s substantially less expensive.”



An S-shaped duct used for remnant fill testing.

ULA has already used FDM for tooling and is now applying the technology to flight hardware. Kyle Whitlow, a structural engineer at ULA, said “We are fully qualifying the material through testing and getting to the point where we can qualify the process, and not the part.” In fact, an ECS duct for the Atlas 5 is now being manufactured with FDM. ECS ducting is critical to the function of the Atlas 5, as it provides cooling airflow to the hot avionics equipment on the launch pad. When produced via traditional manufacturing techniques, the duct required over 140 separate components. With FDM technology, the duct is made up of just 16 pieces that fit easily around the nose of the rocket. Whitlow added, “This makes installation and assembly significantly easier.”

A finished custom duct showing the complex shapes made possible with FDM technology.

Standard automotive or aerospace paint can be used as a sealant for low-pressure applications.

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