APPLICATION BRIEF:
FDM Sacrificial Cores and Mandrels for Composite Layups

OVERVIEW
Hollow, composite parts present a unique manufacturing challenge. Cores are used to create the hollow features in composite structures when smooth internal surface finish and seam-free construction are required. Some cores can be easily removed because of the part’s design geometry, but any configuration that traps a core or mandrel inside it requires special, often sacrificial tooling (Figure 1).

Typically, sacrificial cores are made from eutectic salt, ceramic or urethane. These options present several challenges:

- Can limit part geometry
- Requires machined tooling to make
- Uses harsh removal procedures
- Difficult to handle, particularly fragile components

BENEFITS OF FDM
- Average lead time savings: 50% – 85%
  - From design to final part
- Average cost savings: 75% – 95%
  - From design to final part
- Reduced labor:
  - Less tooling and setup
  - No bonding of composite sections
  - Hands-free core manufacturing
- Improved composite parts:
  - Single-piece construction
  - More features, including integrated hardware
  - Control over surface finish and accuracy
    - Core only: part’s internal surfaces
    - Core and mold: part’s internal and external surfaces
- Lower risk:
  - Minimal investment
  - Easier to modify
  - Greater durability
  - Improved consistency
  - Higher part yield

FDM IS A BEST FIT
- Part geometry:
  - Complex, hollow parts
    - Requires multi-piece molds
    - Bonding that yields a seam
    - Replace other core/mandrel production methods
- Part requirements:
  - Quantities: 1 to 100s
  - Seamsless
  - Wrinkle-free
  - Good internal surface finish and accuracy
- Composite manufacturing:
  - Initial cure temperature:
    - < 121 °C (250 °F)
  - Can post-cure to higher temperature
  - Consolidation pressure:
    - < 550 kPa (80 psi)

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APPLICATION OUTLINE

Sacrificial cores yield several performance advantages when used in place of clamshell tooling. For example, because the composite fabric is laid up on a male core, it can be favorably oriented and overlapped to create a seam-free part with optimal mechanical properties (Figure 3). Using a male tool also eliminates interior wrinkles, and provides control over interior accuracy and surface finish.

ULTEM® 9085 RESIN SUPPORT FOR SACRIFICIAL CORES

ULTEM 9085 resin is a strong, high-temperature thermoplastic that uses a support material which may be used for sacrificial cores. Exposing it to acetone embrittles the material, allowing it to be extracted. This option is ideal when molding or curing temperatures exceed the limits of FDM soluble support materials, or when parts contain aluminum inserts that may be corroded by the support removal solution.

For these reasons, composites are more commonly laid up in clamshell tooling. If there is sufficient access to the interior of a closed clamshell tool, composite material is put into the mold and pressed against the cavity walls (Figure 2). For more complex geometries where access is a problem, the part must be cured in two halves and bonded together. This results in a seam that weakens the part.
FDM® is an additive manufacturing process that builds plastic parts layer by layer, using data from computer-aided design (CAD) files.

Sacrificial cores made with FDM technology use the same soluble material that’s used as support structure for FDM parts. However, unlike other core materials that require harsh methods for removal from the composite, FDM soluble cores are easily washed away in a detergent solution (Figure 4). This reduces the risk of damaging the part during core extraction. Additionally, FDM provides a much higher level of design freedom than other types of technologies. This allows the creation of more robust, complex cores that result in composite parts with improved performance and functionality (Figure 5).

FDM soluble cores are strong enough to withstand the temperatures and pressures associated with composite manufacturing processes. And, because the core is produced in an automated process and the composite can be laid up directly on the soluble core, much of the tooling and labor is eliminated. This yields substantial reductions in lead time and cost.

**PROCESS OVERVIEW**

The first step is to design a 3D model of the core geometry. During pre-processing of the digital data, there are two modifications required to ensure ease of core removal. First, the core is produced with an internal structure that makes it mostly hollow. Second, the soluble material normally used for support structures replaces the standard FDM thermoplastic.

Integrating FDM soluble cores into the composite manufacturing process is straightforward with minimal modifications. The composite curing
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cycle is unchanged as long as the cure temperatures and pressures are within the specifications of the FDM material. After curing, simply wash away the core by soaking the part in a support removal bath.

“We substantially improved the quality of carbon fiber turbo inlet ducts and other aftermarket parts by making them with FDM soluble cores,” said Chris Lyew, lead mechanical engineer for Champion Motorsport.

Lyew adds, “The use of FDM soluble cores makes it possible to mold the duct in a single piece that is much stronger than parts produced by bonding. Every FDM soluble core is exactly the same so it’s easy to maintain the internal finish of the duct. Also, FDM soluble cores are produced in less time and at a lower cost than sand cores because they don’t require a mold.”

CUSTOMER STORY
Champion Motorsport’s legacy of performance on the racetrack drives the performance of its aftermarket products. The Le Mans-winning team develops, perfects and proves its technology on the track and then leverages it to create aftermarket Porsche equipment.

When manufacturing a turbo inlet duct for the Porsche 997 Turbo, Champion used sacrificial FDM cores to overcome the challenges of making this high-performance carbon fiber part (Figure 6).

Figure 6: Carbon fiber turbo inlet duct (black) for Porsche engine with matching soluble core (SR-30).
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Application compatibility:
(0 – N/A, 1 – Low, 5 – High)

- FDM: Idea (0), Design (0), Production (5)
- PolyJet™: Design (0), Production (0)

Companion and reference materials:

- Technical application guide
  - Document
- Application brief
  - Document
- Video
  - Commercial
  - Success story
  - How It’s Used
- Referenced processes
  - Best Practice: Removing Soluble Supports
  - Best Practice: Bonding
  - Best Practice: CAD to STL

CUSTOMER PROFILE

Forward-thinking designers, engineers and manufacturers of composite parts for:
- Aerospace, automotive, marine, robotics
- Performance sports
- Medical prosthetics/orthotics

Characteristics:
- Low-volume manufacturing
  - Challenging, hollow composite parts
  - Open to change or seeking innovation

Traditional technology obstacles:
- High labor demands
  - Limited design freedom
  - Configured to allow core removal
- Tooling
  - High cost
  - Long lead time
  - Many mold components
  - Cores hard to work with
  - Inconsistent core features
  - Difficult core removal processes
  - Reduced part strength with clamshell molding

REFERENCE COMPANIES

ASTON MARTIN
CHAMPION
M
JOE GRASS RACING
GIANT
TENNANT
CONTACT:

To obtain more information on this application, contact:

Stratasys Application Engineering
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