High-Temperature, High-Density Epoxy-Urethane Foam:

An Economical Alternative for Tools and Molds

Presented by Mitch Johnson, Ph.D.
Senior Technical Director
Agenda

- Company Overview
- Soft Tooling vs. Hard Tooling
- What is HDU?
- HDU Tooling Board Properties
- HDU Applications
- Foam Tool Material Selection
- Foam Properties
- Cure Profile Considerations
- HexTOOL® Case Study
  - Making a Composite Tool
  - Summary
- Q&A
Company Overview

• Est. 1941 in Tacoma, WA
• Producer of flexible and rigid polyurethane foam since 1955
• Supplier to the Global Aerospace Industry
• Producer of low- to high-temperature tooling board 18-50 lb. densities
• On-site R&D staff and engineers
• On-site analytical/testing capability
• ISO 9001:2008/AS9100C

Where Great Ideas Take Shape
Soft Tooling vs. Hard Tooling

**Soft Tooling (Foam)**
- Low Cost of materials
- Easily machined into complex shapes
- Can be easily modified
- One-off or short run parts
- Larger thermal compensations
- Insulating materials
- Tight tolerances are difficult to maintain at higher temperatures

**Hard Tooling (Metallics)**
- Higher cost tooling
- Difficult to process into complex shapes
- Difficult to modify surface after machining
- High production rate parts
- Smaller thermal compensations
- Faster heat up and cooling
- Maintain tight tolerances
What is HDU?

- HDU stands for **High Density** Polyurethane Foam

- Polyurethane is a reaction product of isocyanates and polyols

- We consider HDU to include densities of 12 pounds per cubic foot (pcf) and higher.

- Can be manufactured in a batch or continuous process
High Density Urethane (HDU) Tooling Board Properties

- Extremely versatile in application
- Highly solvent and chemical resistant
- Wide range of block sizes available
- Easily bonded together
- Easily machined and sanded
- Dimensionally stable
- Consistent density throughout thickness
- Free of swirls and large voids
HDU Applications

- Modeling & Prototypes
- Mold making
- Vacuum holding fixtures
- QA check fixtures
- Tool proofing
Things to Consider When Selecting Foam Tooling Materials

- Must be able to withstand the curing conditions
  - Cure profile
  - Pressure
  - Exotherm of resin
- How many cure cycles must be performed?
- What is the desired surface finish?
- How large is the tool?
- Do you need to bond up foam blocks before or after machining?
- What are the tolerances of the design?
  - Are you machining post-cure?
Foam Properties

• Formulation will dictate CTE, $T_g$, strength, modulus, porosity, and density.

• $T_g$ and CTE are heavily influenced by filler type and polymer crosslinking.

• Within a resin system, higher density will:
  – Increase modulus and strength
  – reduced surface porosity
Cure Profile
Considerations
Foam Properties

Not all foam is created equal!

<table>
<thead>
<tr>
<th>Foam Properties</th>
<th>FR-3718</th>
<th>FR-4718</th>
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*FAR 25.853 (A) App. F (a)(i)(i) & (ii) tested vertically on ¼” thick specimen using 12- and 60- second ignition with a Bunsen burner
## High Temperature foam Properties by Density

### LAST-A-FOAM® FR-4700 HT Tooling Board

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<th>Property</th>
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<td>27 x 10^{-6}</td>
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**Where Great Ideas Take Shape**
Example of Cure Cycle – Metallic Substrate

HexTOOL® M61 Cure Cycle

- 191°C/375°F (240 minutes)
- Ramp at 1.7-2.8 °C/min (3-5°F/min)
- 135°C/275°F (30 minutes)
- 107°C/225°F (30 minutes)
- Ramp at 0.27-0.55 °C/min (0.5-1 °F/min)
- 7 bar/100 psi
- Ambient
- 0.75 bar/22 inHg
Modified Cool Down Cycle for Soft Tool Substrate
(Hexcel HexTOOL® M61)

Where Great Ideas Take Shape
CASE STUDY: Foam Masters with HexTOOL® M61

FR-4718 is an excellent choice as the substrate!

- High Tg, Compressive modulus and predictable CTE.
- Foam will not distort under required cure conditions.
- HexTOOL M61 Tooling Compound can be machined to the final dimensions.

Please reference the Hexcel HexTOOL user guide
Stringer HexTOOL® Fabrication Overview

- FR-4718 Foam Block
- Foam Master NC Machined
- HexTool Face Sheet Applied to Master over Tooltec, Cured, Post Cured
- Graphite Toolboard Bonded to Back of HexTool Face Sheet
- Tool Assembly Removed from Master
- Surface NC machined (.06” average stock removal)
- Surfaces benched and sealed

Diagram courtesy of Hexcel Corporation and HexTool®
• Epoxy adhesive bonding both vertical and horizontal surfaces
• Review service temp
• Ambient cure is best
• Low-sag viscosities are best
• Check pot life

• Machine with standard cutters
• Exiting climbing cuts will result in the best edge definition
• The material will machine fast and dust removal is recommended.
Surface Preparation

The most efficient and proven method to release a foam tool is to use Airtech Tooltec® fiberglass reinforced PTFE tape with high temperature PSA.
Layup and Thermal Couple Replacement

- Prepreg material is placed as required on the foam tool

- The prepreg plies are consolidated per manufacturer’s instructions

- Minimum Thermocouples placement
  - between foam surface and inner prepreg ply
  - At the bagging surface in the air stream of the autoclave

- Greater than 3” from tool edge

- For large tools (> 8 sq ft) multiple TC’s should be used

Instructions on the layup best practices are provided in the HexTool® User guide.
Final Steps

• Bag and cure per prepreg or resin manufacturer requirements.
• Once the final cure is complete, outer surfaces of foam may look darker.

Before

After
Demold | Machine | Polish

Graphite HexTool after post-cure and demolding

Finished tool after polishing

Where Great Ideas Take Shape
Case Study Process Review

- FR-4718 Foam Block
- Foam Master NC Machined
- HexTool Face Sheet Applied to Master over Tooltec, Cured, Post Cured
- Graphite Toolboard Bonded to Back of HexTool Face Sheet
- Tool Assembly Removed from Master
- Surface NC machined (.06” average stock removal)
- Surfaces benched and sealed

Diagram courtesy of Hexcel Corporation and HexTOOL®

Where Great Ideas Take Shape
Soft Tool Summary

- Used from ambient to high temperature and under pressure conditions.
- Blocks can be bonded to make large complex shaped tooling.
- Machinable and rapid surface preparation.
- Can be used several times with a controlled cool down rate.
Q & A