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NEXT GENERATION OF FORMULATIONS FOR INTERIORS APPLICATIONS

Replacing Phenolics and Metals

Kyle Ingram
Strategic Marketing Manager
Aerospace
Huntsman Advanced Materials

Huntsman Corporation

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POLYURETHANES	PERFORMANCE PRODUCTS	ADVANCED MATERIALS	TEXTILE EFFECTS
MDI Polyols PO/MTBE TPU PU Systems	Amines Surfactants Maleic Anhydride Upstream Intermediates	Composites Adhesives Resins	Dyes Chemicals Inks Apparel Home & Institutional Technical Textiles

Huntsman – Advanced Materials

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Brands

Araldite ©
Aradur ©
Matrimid ©
Kerimid ©
Tactix ©
AroCy ©
Epibond ©
Epocast ©
Epocert ©
Fastweld ©
Uralane ©

Outline

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- Interior Application
  - Aerospace
  - Benchmark
- Commercial Products
  - FST 40002/3
  - FST 40002/6
- Development Products
  - FST 40010/11
- Summary

Interior Application
Aerospace Market

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Interior

Characteristics
- FST
- Heat release
- Mechanical requirements
- Cost

Materials
- Thermoset prepregs
- Honeycomb sandwiches
- Advanced engineered thermoplastics

Market
- New planes
- Refurbishing older planes
- Expanded to other segments in transportations

Parts
- Floor, ceiling and sidewall panels
- Galley
- Partitions
- Overhead stowage bin
- Lavatory

Interior Application
Market Benchmark

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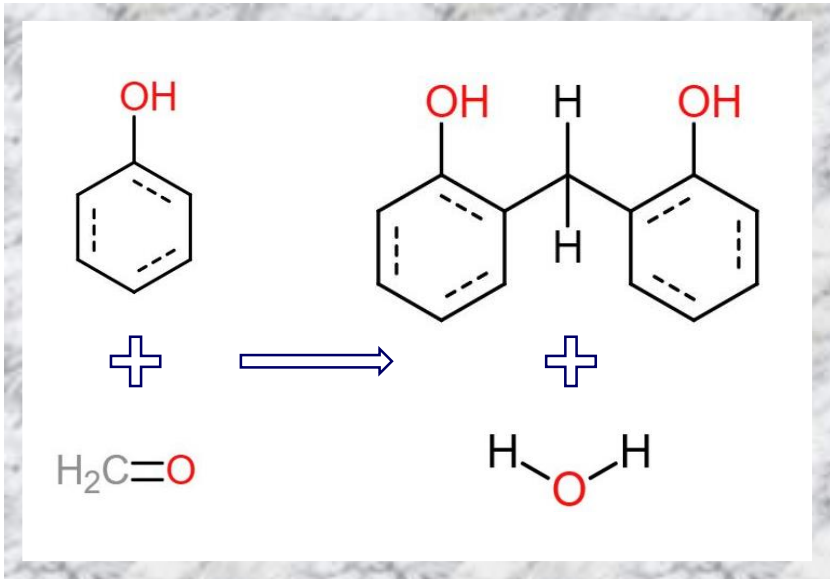

Phenolic Advantages

- Low cost
- Good FST
- Low coefficient of thermal expansion
- Good electrical properties
- Good chemical resistance

Phenolic Challenges

- High temperature cure required
- Limited shelf life (storage)
- Outgassing (void & surface pinhole)
- Hazardous chemical exposure
- Water absorption
- Mold making materials (acid catalyst)
- Color & appearance

Outline

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  - Industrial
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  - Benchmark
- **Commercial Products**
  - **FST 40002/3**
  - **FST 40002/6**
- Development Products
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- Summary

Unique combination of performance

Araldite® FST 40002 platform

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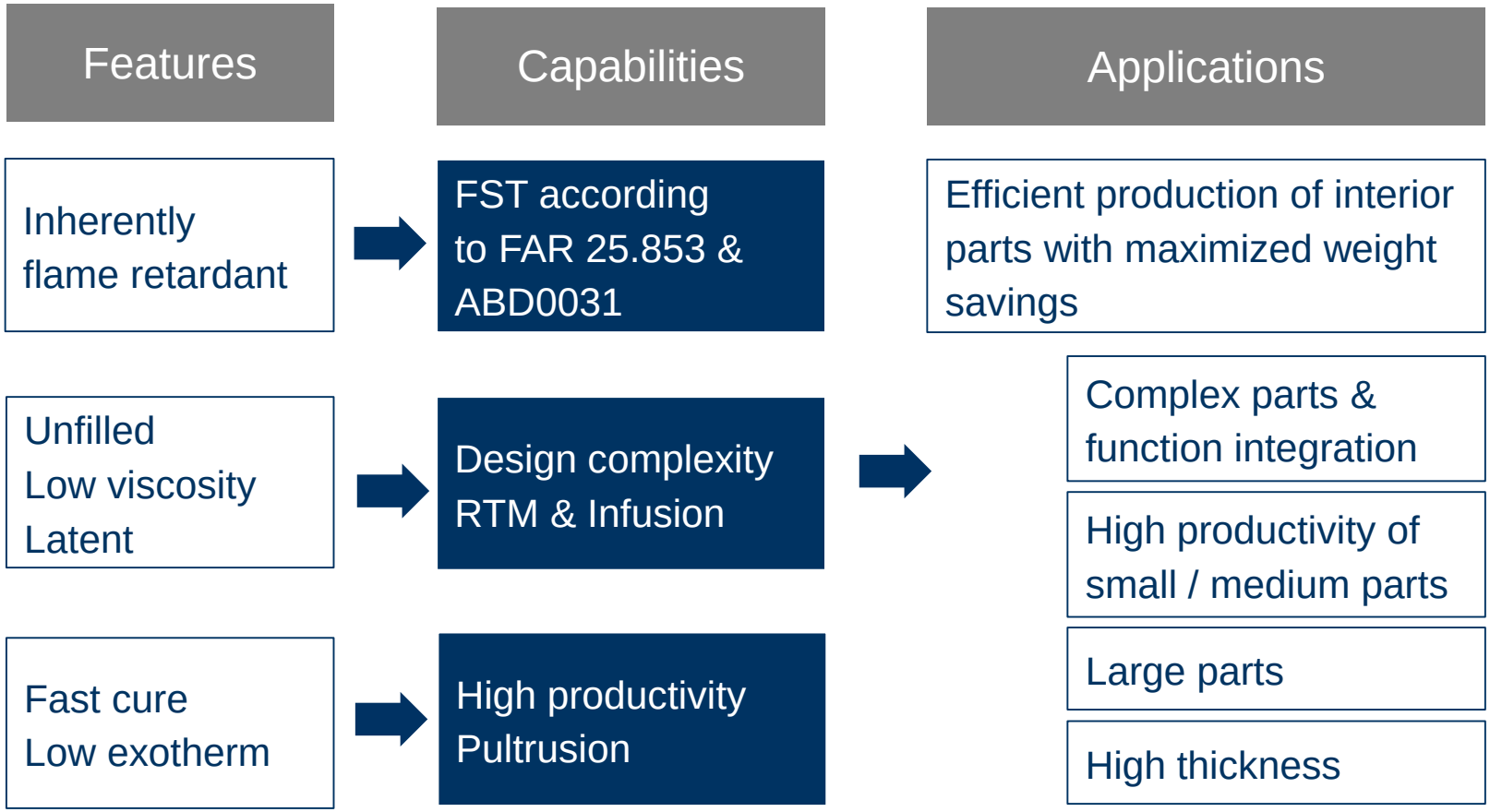

Araldite® FST 40002 platform

Structural and heat release performance differentiation

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	Araldite® FST 40002 / 40003	NEW Araldite® FST 40002 / 40006
Structural performance	High	Medium
Heat Release performance*	Low	Medium

* Meeting heat release is part design dependent

Qualified for an economy class visible seat back

Araldite® FST 40002 platform
Processing

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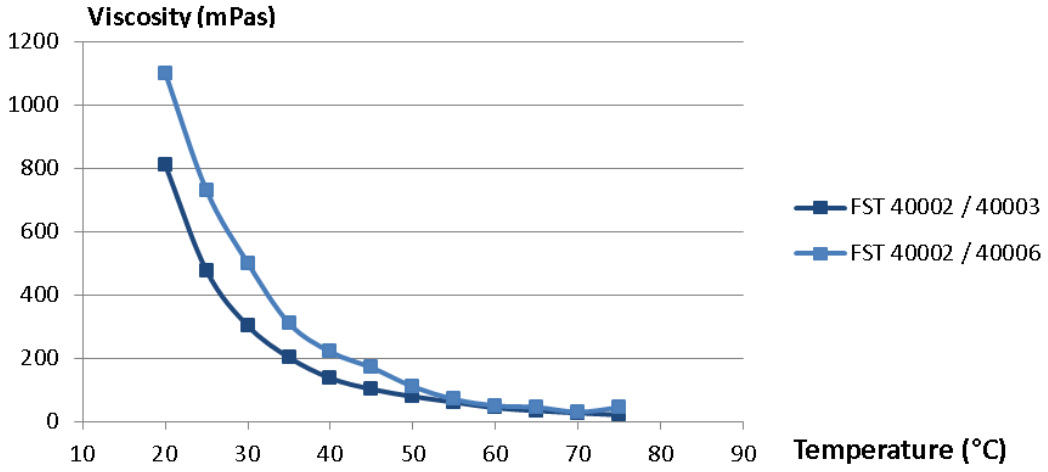
High quality versatile processing

- 2-component liquid system
- Injection capability 50 -150°C
- Very low reaction energy (ca. 220 J/g):
  - no risk of exotherm
  - high temperature injection of high thickness parts

Viscosity versus injection temperature



Araldite® FST 40002 platform
Processing

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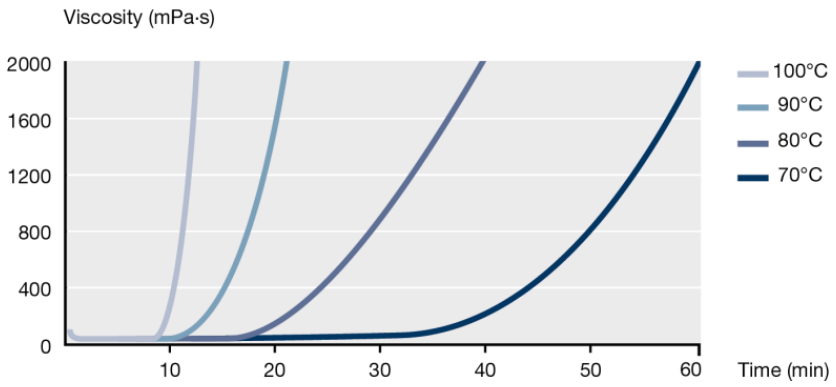
High quality versatile processing

- Large part production with low cost / low temperature resistance molds
- High productivity of small / medium part (pre-cure of 5 min 150°C or 20 min 120°C)
- Pultrusion speed of ca. 10 meters / hour

Viscosity build-up versus temperature (FST 40002 / 40003)



Production cycle examples

	In-mold cure	Free-stand post-cure
Large part	**1H100°C + 1H120°C**	**2H180°C**
ILSS 23°C CFRP (1)	56 MPa	64 MPa
Small / medium part	**20 min 120°C or 5 min 150°C**	**2H180°C**
ILSS 23°C CFRP (1)	54 MPa	65 MPa

(1) 5H Satin, 370 gsm, FVF 50%.
Measured with FST 40002 / 40003

Araldite® FST 40002 platform
Mechanical Performance

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		High performance	Medium performance	
	Test	**Araldite® FST 40002 / 40003**	**Araldite® FST 40002 / 40006**	**Standard**
NEAT	**Dry DMA Tg**	260ºC	210ºC	ISO 6721
	Wet DMA Tg	185ºC		
	K_{1C}	0.9 MPa.√m	0.6 MPa.√m	ISO 13586
	G_{1C}	270 J/m^2	100 J/m^2	
	Tensile modulus	3000 MPa		ISO 527
	Tensile strength	100 MPa		
	Tensile elongation	5 %		
	Flexural modulus		3400 MPa	ISO 178
	Flexural strength		135 MPa	
	Flexural elongation		4 %	
CFRP UD (1)	**ILSS at 23ºC**	97 MPa		ASTM D2344
	ILSS at 120ºC	65 MPa		
	ILSS at 160ºC	55 MPa		

(1) UD, 6K, 270 gsm, FVF 60%

Araldite® FST 40002 platform
Flame, Smoke & Toxicity / Heat Release

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FAR 25.853 FST compliant solution

- Meets FST in all configurations: glass & carbon in all thickness
- Meets Heat Release only in low thickness

	Araldite® FST 40002 / 40003				
Fiber type	**CFRP(1)**		**GFRP(2)**		
Thickness (mm)	**0.3**	**2**	**0.3**	**4**	**FAR 25.853 requirements**
Vertical burn 12s Burn length (mm) After flame time (s) Drip flame time(s)	 88 9 0		 48 15 0		AITM 2.0002B <203 <15 <5
Vertical burn 60s Burn length (mm) After flame time (s) Drip flame time (s)	 82 0 0	 47 6 0	 65 0 0		AITM 2.0002A <152 <15 3
Heat release HRR max (kW/m²) HR (kW.min/m²)	 63 32	 85 90	 45 25	 74 16	AITM 2.0006 <65 <65
Toxicity (flaming mode) Components toxicity level	pass				AITM 3.0005
Smoke After 4 min	23	12	16		AITM 2.0007A <200

(1) 5H Satin, 6K, 270 gsm, FVF 50%
(2) 8H Satin, 300 gsm, FVF 50%

Araldite® FST 40002 platform
Heat Release

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Araldite® FST 40002 / 40006 as a **higher heat release performance** hence it increases the chance to pass heat release on any part design since heat release on final part is dependent on thickness, fiber type, core, fiber volume fraction and decoration.

	Sandwich application (customer confidential)	
	Araldite® FST 40002 Araldite® FST 40003	Araldite® FST 40002 Araldite® FST 40006
HRR (KW/m^2)	48	29
HR (KW*min/m^2)	32	28

	Monolithic application 2 mm CFRP, 60% FVF	
	Araldite® FST 40002 Araldite® FST 40003	Araldite® FST 40002 Araldite® FST 40006
HRR (KW/m^2)	64.7	48.7
HR (KW*min/m^2)	43.4	27.6

Araldite® FST 40002 platform

Case study # 1

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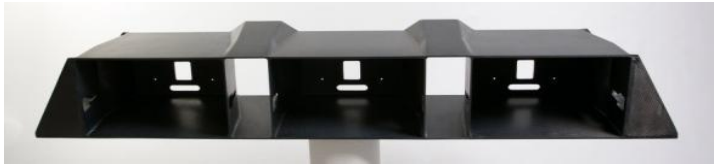
Description
Main control panel for commercial aircraft

Metal 13.7 kg



Composites 5.25 kg

Prototypes developed by
Hutchinson SA (France)

HUTCHINSON®

Process
RTM

Main benefits for the customer

- Significant cost saving (one shot molded part)
- 60 % weight saving compared to current metal
- Safety and Airworthiness: the composite Main Control Panel meets latest FAR 25 / ABD 031 Fire Smoke and Toxicity requirements

Araldite® FST 40002 platform

Case study # 2

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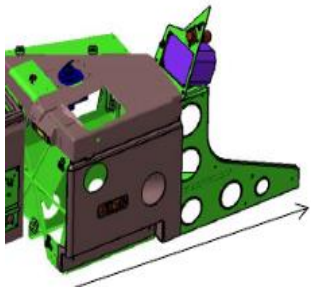
Description
Side stick console
for commercial aircraft

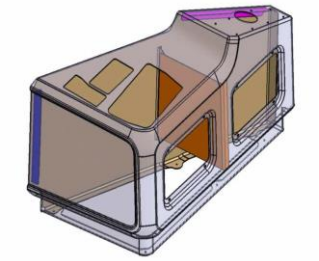


Metal
7.22 kg

Prototypes developed by
Hutchinson SA (France)

Process
RTM

HUTCHINSON



Composites
3.88 kg

Main benefits for the customer

- Styling improvement: round edges, Modularization: equipment pre-assembled
- Significant cost saving (one shot molded part)
- 46 % weight saving compared to current metal
- Safety and Airworthiness: the composite Main Control Panel meets latest FAR 25 / ABD 031 Fire Smoke and Toxicity requirements

Araldite® FST 40002 platform

Case study # 3

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Description

Ultra-light Z-reinforced FST & HR sandwich panel

Produced by

VDL (Netherlands)

VDL Fibertech Industries

Process

VDL's stitched sandwich technology & Press Molding

Main benefits for the customer

- Fulfill FST and Heat Release on VDL design
- Provide high mechanical resistance for ultra-light panels (<2 kg/m^2 - 3/4'' panel)
- EHS friendly compared to current Nomex / phenolic technology
- Increased galley storage capacity

Araldite® FST 40002 platform
Summary

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- **Good Mechanical Properties**
- **Very Good FST Properties and low heat release tested at multiple thicknesses**
- **Cost Saving Advantage: Lower production cost compared to phenolic parts due to flexible processing envelope and better part quality**
- **Design Advantage: Can be used in manufacturing of secondary structure part where FST performance is also required (due to good mechanical properties and low heat release)**
- **Processing Advantage: Versatile processing characteristics across a wide range of temperatures and times**

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Araldite® FST 40010 platform
Chemistry

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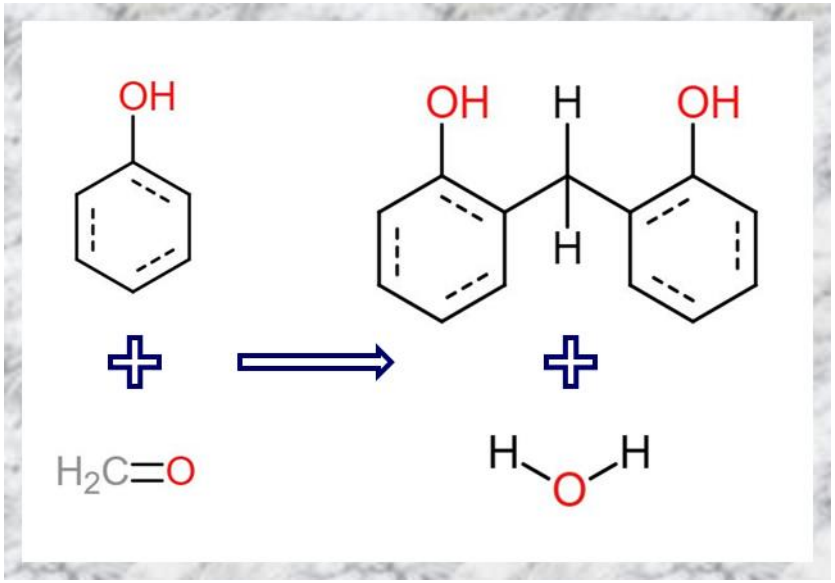

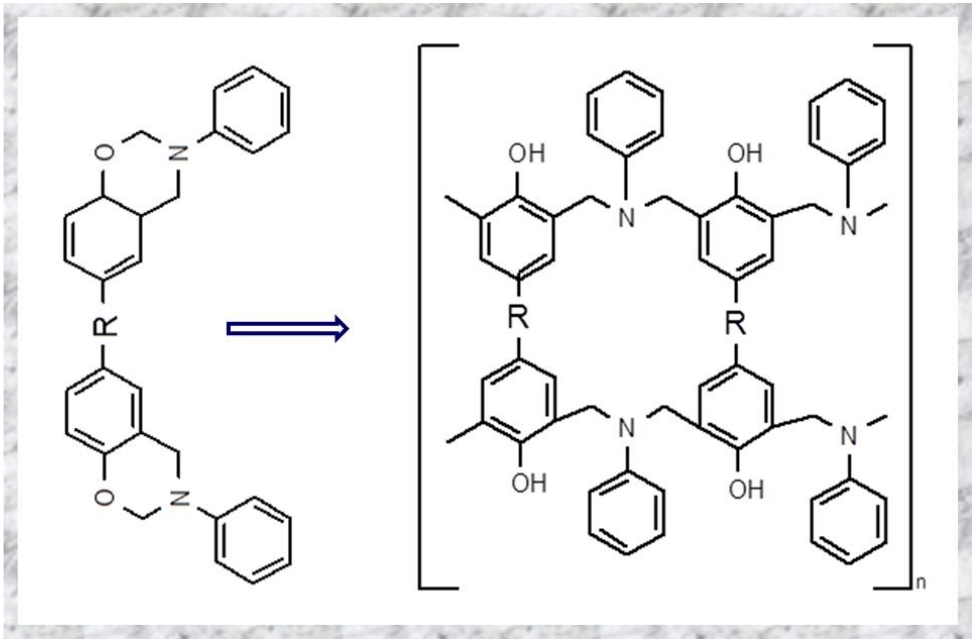

- **By products (low quality; surface & microstructure)**

Araldite® FST 40010 platform
General Benzoxazine Chemistries

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Box Advantages

- High Tg materials
- Can react with epoxies
- Near zero shrinkage
- Low moisture absorption
- Better flammability resistance
- Storage stable at room temperature
- Latent materials
- Low coefficient of thermal expansion
- Excellent electrical properties
- Good chemical resistance
- High modulus materials

Box Challenges

- High temperature cure required
- Solvent solubility issues
- Limited viscosity range

Araldite® FST 40010 platform
Processing

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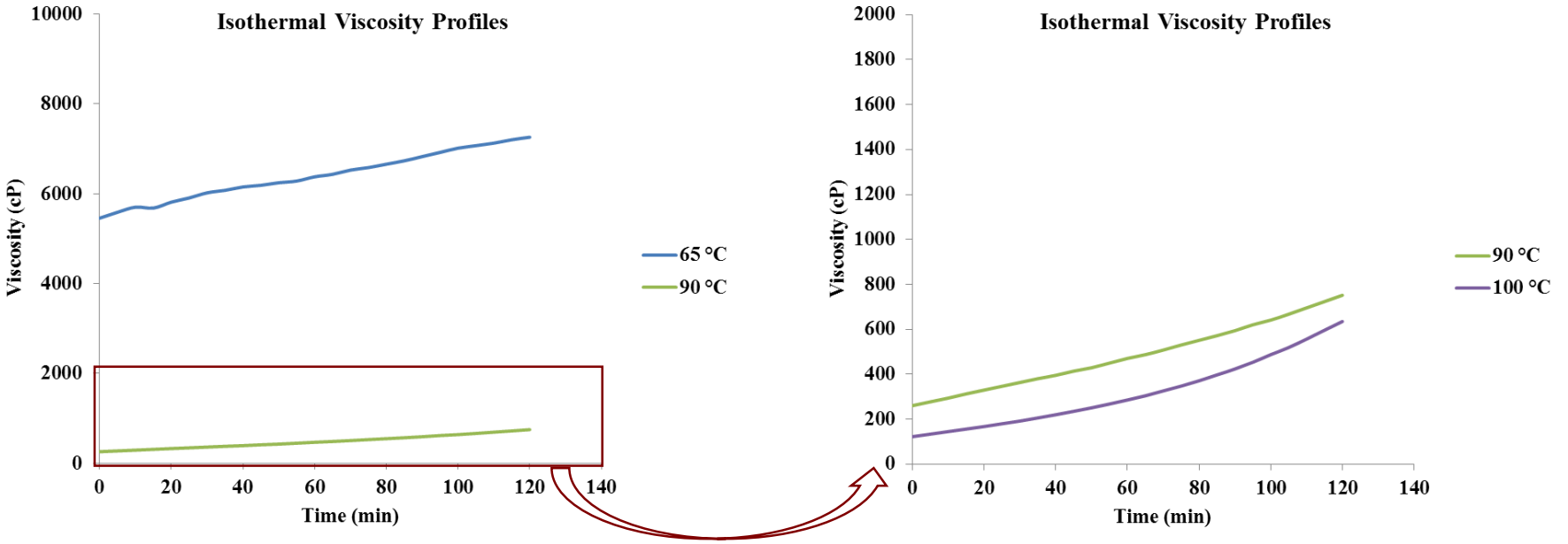

Processing robustness;

- **Prepreg**
- **Liquid processing (2 hr pot life)**

Araldite® FST 40010 platform
Cure

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DSC cure	Value
Onset Peak Temperature (°C)	172
Peak Temperature (°C)	200
Total Enthalpy (J/gr)	385

Low exotherm

Cure robustness

Low weight loss (no volatile)

Cured Neat Resin Properties			
Cure Schedule	1hr at 160°C	1hr at 160°C + 1hr at 170°C	1hr at 160°C + 1hr at 180°C
Tg (°C) (DMA, Storage modulus inflection)	122	122	122
Degree of Cured, %	87	90	90
Weight loss by TGA at:			
179°C	0.18%	No out gas	No out gas
200°C	0.30%		
220°C	0.50%		
Weight loss by oven at: 180°C	0.26%	NA	NA

Araldite® FST 40010 platform
Resin Properties

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Compositions	Units	Huntsman PF
Thermal Properties		
Cure Schedule		1 hrs @ 160°C
% cure	%	87
Condition		Dry, 23°C
DMA, Storage Modulus, Tg	°C	120
Mechanical Properties		
Tensile Strength	MPa *(psi)*	65.7 *(9,537)*
Tensile Modulus	GPa *(ksi)*	5.3 *(768)*
Tensile Elongation	%	1.36
Flexural Strength	MPa *(psi)*	82 *(11,893)*
Flexural Modulus	GPa *(ksi)*	5.6 *(820)*
Flexural Strain	%	4

Relatively fast cure with Tg of 120 °C.

Good mechanical properties for interior applications.

Araldite® FST 40010 platform
Composite Processing

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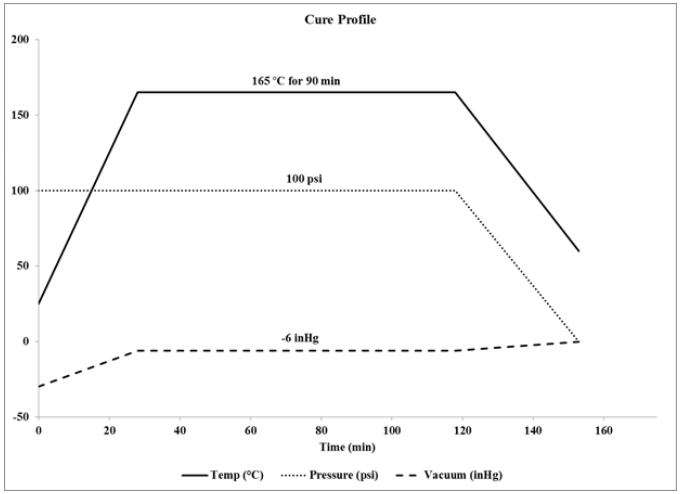

7781 style 8HS
300 GSM
E-glass fabric

AS4 Twill 2×2
380 GSM
Carbon fabric

Araldite® FST 40010 platform

Part Quality

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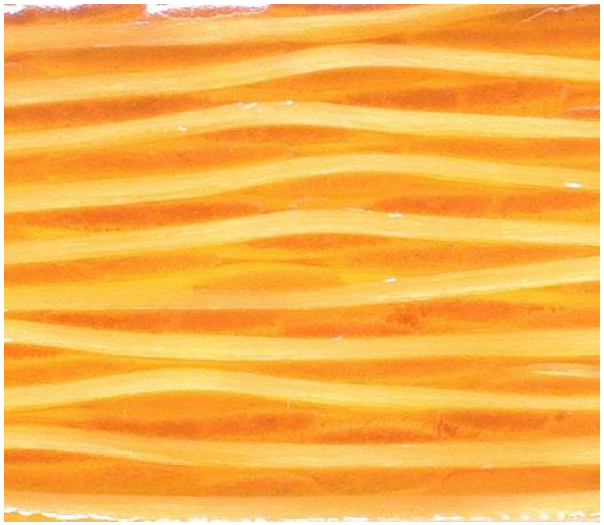
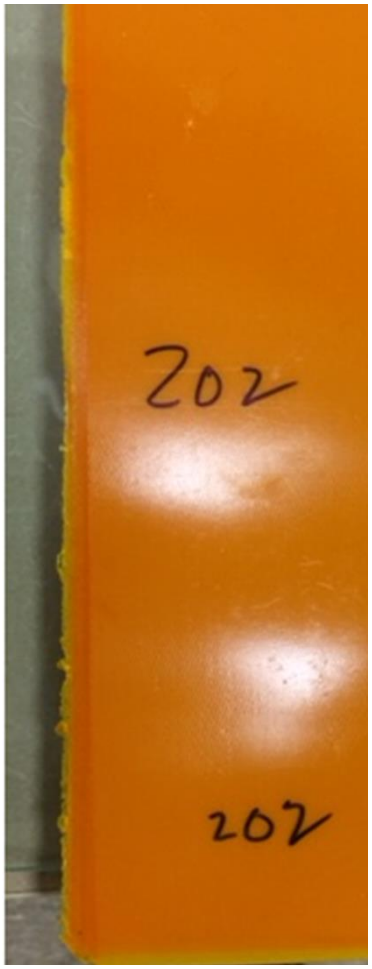
- **Surface quality**
- **Volatile (<0.3%)**
- **Void content (0.43%)**



Microstructure



Tool Surface

Top Surface

Araldite® FST 40010 platform
Laminate Properties

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Test	Units	Typical Phenolic	Huntsman PF	
Fiber		E-glass 7781	E-glass 7781	AS4 2×2 twill carbon
Fiber Aerial Weight	g/m^2	301	301	380
Fiber Volume Fraction	%	50 ± 1	50 ± 1	60 ± 1
Tensile Strength	MPa (*ksi*)	450 – 520	556 (*80.6*)	787 (*114.1*)
Tensile Modulus	GPa (*msi*)	20 – 27	34 (*4.95*)	75 (*10.9*)
Tensile Elongation	%	-	2.6	1.21
Flexural Strength	MPa (*ksi*)	490 – 650	693 (*100.5*)	894 (*129.7*)
Flexural Modulus	GPa (*msi*)	20 – 29	29 (*4.2*)	59 (*8.5*)
Flexural Elongation	%	-	3.54	1.8
Compression Strength	MPa (*ksi*)	365 – 480	575 (*83.4*)	648 (*94*)
Compression Modulus	GPa (*msi*)	29	31 (*4.45*)	68 (*9.8*)
ILSS	MPa (*ksi*)	25 – 45	78.6 (*11.4*)	60 (*8.7*)

Superior mechanical properties compared to phenolic based products available in the market for FST applications.

Araldite® FST 40010 platform

FST Results

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FAR 25.853		Glass fiber Hexcel 7781		AS4 twill Carbon
Fv%		50%	50%	60%
Thickness (mm)		0.38	2.25	2.2
Extinguish time	< 15 seconds	0	0	0
Burn Length	< 6 inches	< 5	< 5	< 5
Drip Extinguish time	< 3 second	0	0	0
Smoke Density				
Specific Optical Density	< 200 (Ds)	< 20	< 50	< 50
Heat Release				
Total Heat Release	<65 kW.min/m^2	< 25	< 60	< 50
Peak Heat Release	<65kW/m^2	< 35	< 50	< 55
Toxicity	HCN < 150	< 5	< 10	< 10
	CO Ref	38	114	103
	NOx < 100	< 5	< 25	< 20
	SO2 < 100	< 5	< 15	< 15
	HF < 200	< 5	< 5	< 5
	HCL < 500	< 5	< 5	< 5

Very good FST and heat release properties for thin and relatively thick laminates.

Araldite® FST 40010 platform
Summary

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- **This is a development system**
- **Good Mechanical Properties**
- **Very Good FST Properties and low heat release tested for 0.4 and 2.2 mm thick laminates**
- **Cost Saving Advantage: Lower production cost compared to phenolic parts due to high quality of finished surface**
- **Design Advantage: Can be used in manufacturing of secondary structure part where FST performance is also required (due to good mechanical properties and low heat release)**
- **Processing Advantage: Can be used in both RTM and prepreg fabrication processes (due to good viscosity range)**

Huntsman FST Systems

Economical alternative for metals and phenolics

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Epoxy Based

- 40002/40003
- 40002/40006
- Epoxy-based 2-part systems
- Ideal for liquid processing
- Wide processing envelope

BOX Based

- 40010/40011
- Benzoxazine-based 2-part system
- Can be prepregged or liquid processed
- Robust cure cycle

- Design freedom from excellent mechanical performance, and improved processing capabilities, lead to an overall reduction in final part cost while reducing weight and improving performance
- Huntsman materials for interior applications provides an economical replacement for metallic assemblies and phenolic-based composites


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Questions?

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