NOVEL FST THERMOSET SOLUTION FOR COMPOSITE STRUCTURE

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Abstract
Huntsman Advanced Materials has developed an entirely new high-performance and inherently flame resistant, halogen free, solution for RTM and infusion composite processes. The matrix resin is radically different from current commercially available materials. It provides a unique combination of very high mechanical, fire, smoke and toxicity (FST) performance alongside high quality, user-friendly composites processing conditions enabling efficient production of interior carbon and glass composites parts with maximised weight savings. The article will describe the development process and resulting thermo-mechanical properties of material and demonstrate that for RTM and infusion processing, mechanically superior parts offering improved security functionality can be cost-effectively produced for the first time.

1. Introduction

With operating costs continuing to rise and the need to improve the revenue potential on each and every new aircraft being commissioned, both the OEM and supply sectors of the aerospace industry are evaluating all aspects of design and weight optimisation with a focus on the role of advanced composite materials. Most recently the attention has shifted somewhat from the airframe to aircraft interiors in the continuous drive for weight reduction. For many commercial aircraft, interior use of composites is just as crucial to the cost : revenue equation, as the weight of materials for interiors actually exceeds that of the airframe. From overhead bins and ceiling panels to cabin dividers, galleys and bulkheads, the use of interior composites in the pursuit of weight reduction vies with lighter textiles and leathers on seating, lighter food carts, the elimination of in-flight magazines and thinner display screens to achieve the desired results.
Huntsman Advanced Materials has developed an entirely new high-performance and inherently flame resistant, halogen free, solution for RTM and infusion composite processes. The matrix resin is radically different from current commercially available materials. It provides a unique combination of very high mechanical, fire, smoke and toxicity (FST) performance alongside high quality, user-friendly composites processing conditions enabling efficient production of interior carbon and glass composites parts with maximised weight savings. The inherent FST properties of the system come from the chemical nature of the network and its high cross-link density. The new system (Araldite® FST 40002 / 40003) meets the FAR 25.853 vertical burn, smoke and toxicity requirements with both carbon and

glass fibres. Surprisingly for a system with such high glass transition (Tg) (>250C) and high crosslinking density, it also exhibits high tensile elongation and appreciable toughness, enabling the possible substitution of metal in semi structural applications. The development process, chemistry, and resulting thermo-mechanical properties of material will be described. Finally it will be demonstrated that for RTM and infusion processing, mechanically superior parts offering improved security functionality can be cost-effectively produced for the first time.

2. Processing

The newly developed Araldite® FST 40002 / 40003 system based on hybrid chemistry, exhibits a low viscosity at working temperatures above 50°C (Figure 1). The latency range from 50°C to 150°C provides the ability to produce complex parts in small and large dimensions (Figure 2). In addition, the low reaction energy of about 220 J/g which eliminates bulk exothermic safety issues as well as exotherm in the composites enables both large thickness composite part production and fast production of small to medium parts at high injection temperature.

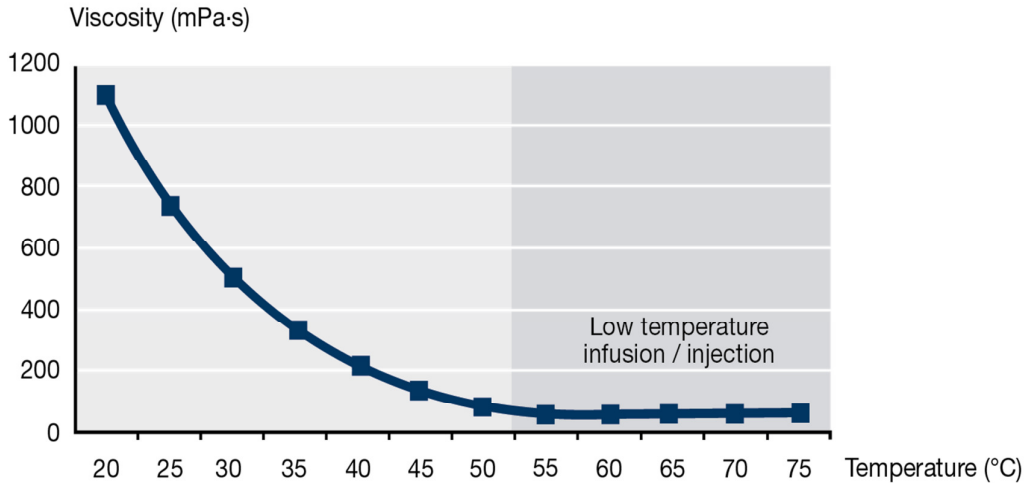

Figure 1. Viscosity versus injection temperature

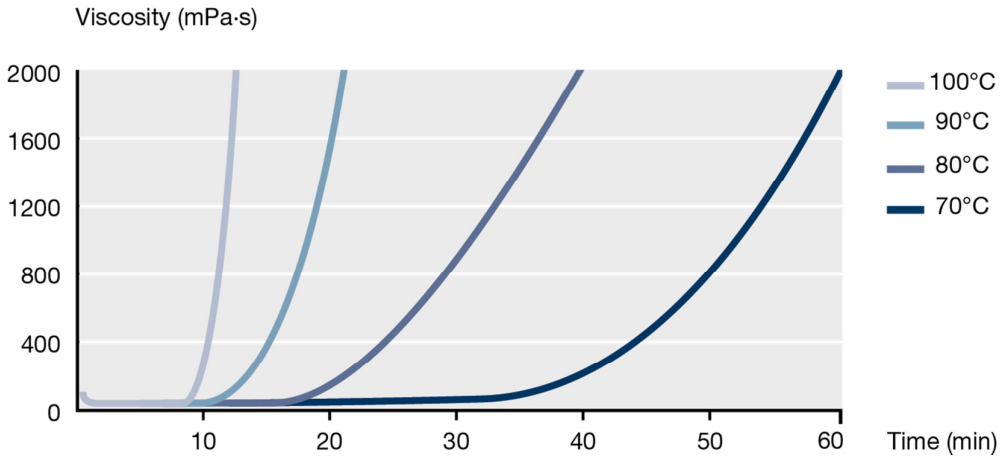

Figure 2. Viscosity build-up versus temperature

By comparison with traditional RTM and infusion systems, its viscosity and reactivity profile shows snap-cure behaviour which allows fast Tg and interlaminar shear strength (ILSS) development.
Large parts requiring low temperature injection can be demoulded after pre-cure conditions of approximately one hour at 100°C followed by one hour at 120°C, resulting in mold cost optimization (Table 1). The system also allows small to medium part production with very high output as parts can be demoulded after 5 min at 150°C.
After both in-mold pre-cure conditions, the system develops 85-90% of its ultimate ILSS – when measured on carbon fabric reinforcement. In-mold pre-curing is followed by two-hour free-standing post-curing at 180°C, to enable development of ultimate performance. Post-curing can be optional depending on in-mould cure conditions and composite requirements.

	In-mould cure	**Free-stand post-cure (1)**
Large part	**1H 100ºC 1H 120ºC**	**2H 180ºC**
ILSS 23ºC CFRP (2)	56 MPa	64 MPa
Small / medium part	**5 min 150ºC**	**2H 180ºC**
ILSS 23ºC CFRP (2)	54 MPa	65 MPa

(1) optional depending on in-mould cure conditions
(2) 5H Satin, 370 gsm, TVf 50%

Table 1. Cure cycle examples

3. Properties

3.1. Thermo-mechanical properties

Araldite® FST 40002 / 40003 develops dry and wet Tg of 260°C and 185°C (measured by DMA) with very high ILSS performance of 97 MPa and 55 MPa at 23°C and 120°C respectively – when measured on unidirectional carbon reinforcement (Table 2). Surprisingly for a system with such high Tg and high crosslinking density, it also exhibits high tensile elongation and appreciable toughness, enabling the substitution of metal in highly structural applications.

Dry DMA Tg	260ºC	ISO 6721
Wet DMA Tg	185ºC	
K_{1C}	0.9 MPa.√m	ISO 13586

G_{1C}	270 J/m^2	
Tensile modulus	3000 MPa	ISO 527
Tensile strength	100 MPa	
Tensile elongation	5 %	
ILSS at 23ºC	97 MPa	ASTM D2344 (CFRP UD[3])
ILSS at 120ºC	65 MPa	
ILSS at 160ºC	55 MPa	

(3) UD, 6K, 270 gsm, TVf 60%

Table 2. Thermal and mechanical performance

3.2 Fire Smoke Toxicity properties

In contrast to other materials used in interiors, Araldite® FST 40002 / 40003 is an unfilled system. As described in paragraph 1, the inherent FST properties of the system come from the chemical nature of the network and its high cross-link density, and is not based on halogenated chemistry. The new system meets the FAR 25.853 vertical burn, smoke and toxicity requirements with both carbon and glass fibre in all thickness configurations (Table 3).

The heat release performance of the system is dependent on composite thickness, hence Araldite® FST 40002 / 40003 is ideally suited for non-visible structural parts in the interior which do not have direct contact with potential ignition sources as well as cockpit parts that currently do not need to pass heat release.

For applications requiring heat release performance, it is possible to build on the new thermoset platform and formulate in order to meet heat release requirements in any configuration. This is shown in table 3 comparing a recent development to Araldite® FST 40002 / 40003.

	Araldite® FST 40002 / 40003				Latest development	
Fiber type	CFRP[4]		GFRP[5]		GFRP[5]	
Thickness (mm)	0.3	2	0.3	4	4	Standard 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/m^2) HR (kW.min/m^2)	 63 32	 85 90	 45 25	 74 16	 32 11	AITM 2.0006 65 65
Toxicity (flaming mode) Components toxicity level	pass					AITM 3.0005
Smoke After 4 min	 23	 12	 16		 46	AITM 2.0007A 200

(4) 5H Satin, 6K, 270 gsm, TVf 50% (5) 8H Satin, 300 gsm, TVf 50%

Table 3. FST performance according to FAR 25.853 / ABD 0031

4. Conclusion

Advanced composites processes and materials are essential for high-performance fibre reinforced composites to realize their full potential in the interior aerospace market. The new thermoset platform, first illustrated by Araldite® FST 40002 / 40003, takes RTM and infusion processing into a new dimension, enabling for the first time, production of structural parts without limitation in part complexity and function integration by comparison with current composites solutions, and with fast curing capability for small to medium RTM part production.

This first innovative high-performance solution, creates a radically new and much improved value proposition for aerospace designs, providing a preferred alternative to metal in structural applications. In addition further developments are planned which will complement and extend the offer.