Development of Improved Composites and Adhesives for Aircraft Structures and Interiors

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Henkel

Agenda

- **Henkel Background**
- **Development of Improved Products**
  - New Approach to development of FST products
- **Specific Examples:**
  - Structural Paste adhesive for Aircraft Interiors
  - Composites for structural aplications
- **Summary**

Henkel Areas of Competence

Henkel

A Brand like a Friend

Laundry & Home Care

Cosmetics/ Toiletries

Adhesive Technologies

Quality with Brands & Technologies

Henkel

Structural Adhesive Products

Hysol® Aerospace Products

Paste, Films, Primers, Wet Peel Ply

SynCore® Syntactic Films

Lightweight stiffening replacement

SynSpand® Expanding Syntactic Films

Lightweight core fill & potting

Jet engine abradable seal applications

SynSkin® Composite Surfacing Films

Superior surface for painting & lightning strike foil/screen protection

Frekote® Composite Release Polymers

World's standard semi-permanent mold release system

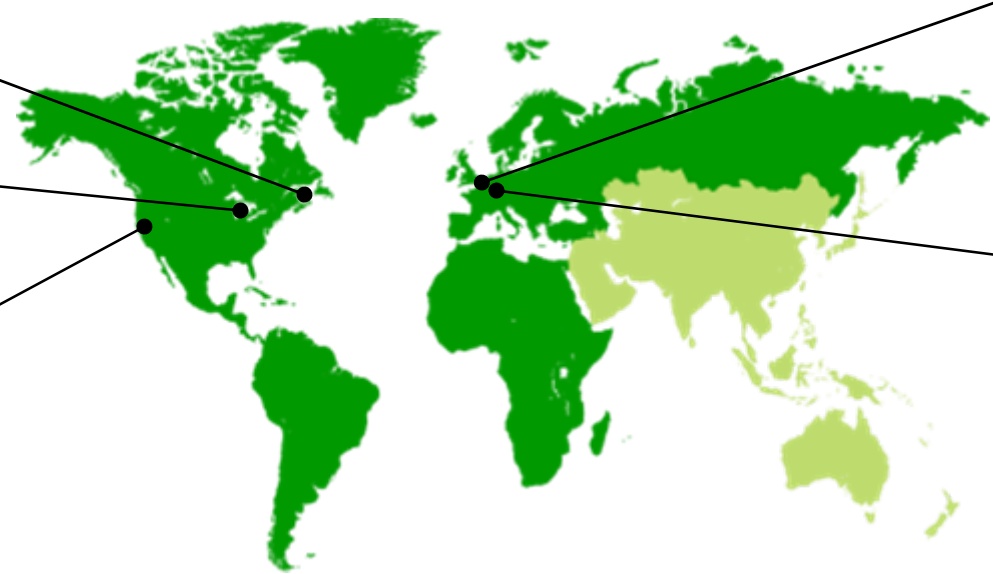
Aerospace Group of Henkel

- Henkel leverages R&D and PD laboratories over the world to serve the Aerospace market
- Henkel Aerospace covers the product range from pretreatment to the final bonding process

Rocky Hill, CT, USA

Madison Heights, MI, USA

Bay Point, CA, USA



Amersfoort, Netherlands

Dusseldorf, Headquarters, Germany

Development of Improved Products: Industry Needs

Industry Needs

- **Improved Flame, Smoke and Toxicity**
- **Performance criteria: mechanical, damage, temperature, ageing…..**
- **Meet current and future environmental standards**
  - Workplace exposure resins/flame retardants
  - In service exposure
  - End of life
- **Cost:**
  - Acquisition: material and fabrication
  - Total life cost
- **Ease of use:**
  - Storage, processability, working life, cure etc

Our Strategy for Sustainability: Five Focal Areas

Industrial Applications/Markets of Flame Resistant Materials

Aerospace Industry

- Interior (adhesives, core materials, acoustic materials, laminates)
- Composite structures

Railway and road transportation market

- Interiors (adhesives, foams, laminates)
- Composite structures

Naval Structures

- Interiors (adhesives, foams, laminates)
- Composite structures

Electronics, PCB, battery markets

- Low ignition materials, dielectrics

Offshore Oil & Gas Production Platform

Building & Construction Industry

Technical Analysis – Flame Resistance

Resins (+)	Resins (−)
Phenolics	Standard Epoxies
Benzoxazines	Polyurethanes
Cyanate Esters	Acrylics
Polyimides	Vinylesters
Specialty Epoxies	Vulcanized Rubbers
Bismaleimide Resins (BMI)	

Curatives	Curatives
Phenolics	DICY
Cresol Novolacs	Acids
Amines + High Crosslink Density	Anhydrides
Melamines	Amines + Low Crosslink Density

Technical Analysis – Flame Resistance

"The thermal stability of epoxy resins, as well as their flammability, depends on the structure of the monomer, the structure of the curing agent and the crosslink density"

"*Thermal decomposition, combustion and flame-retardancy of epoxy resins – a review of the recent literature*"
S V Levchik, E D Weil Polym Int. 53 1901-1929 (2004)

General Trends

Higher Crosslink Density >> Lower Crosslink Density

→ *1-Part Heat Cure & High Tg >> 2-Part RT Cure & Low/Med Tg*

Higher Charring Tendency >> Lower Charring Tendency

→ *Phenolic Systems, Highly filled Systems better*

Paths to Improved Flammability Resistance

New Resin Chemistry

New Flame Retardants

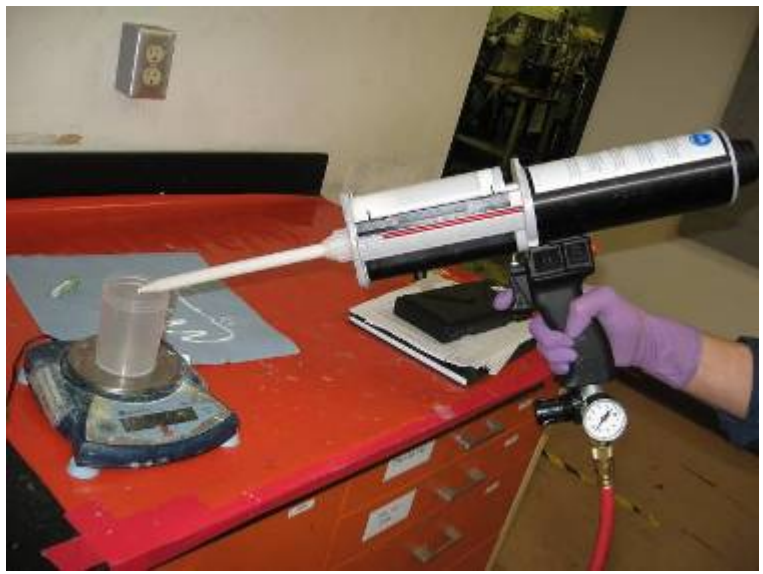
Formulation Design

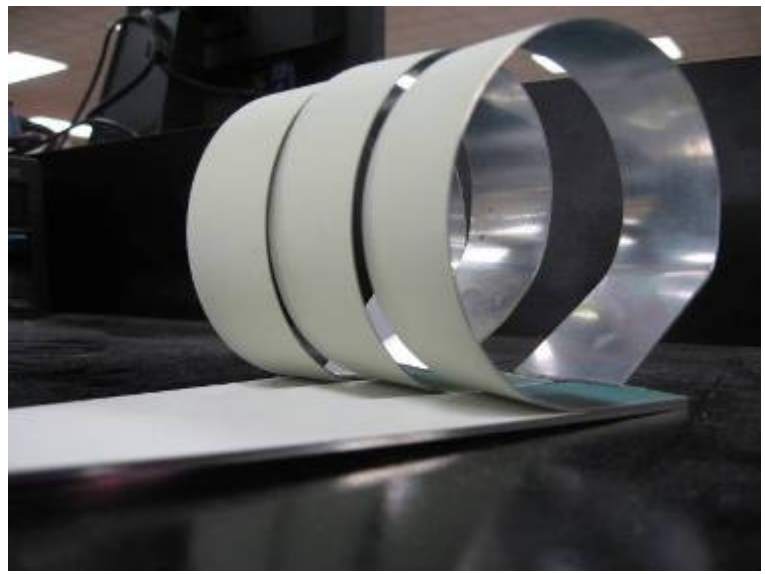
Use these approaches individually or in combination

Structural Paste Adhesive: Aircraft Interior Applications

Flame Resistant Structural Paste Adhesive

- **Flame retardant paste adhesive designed for interior applications**
- **White, two-part paste**
- **High dispensability**
- **High Mechanical properties**
- **Meets FST requirements**





Flame Resistant Structural Paste Adhesive LP31007.0

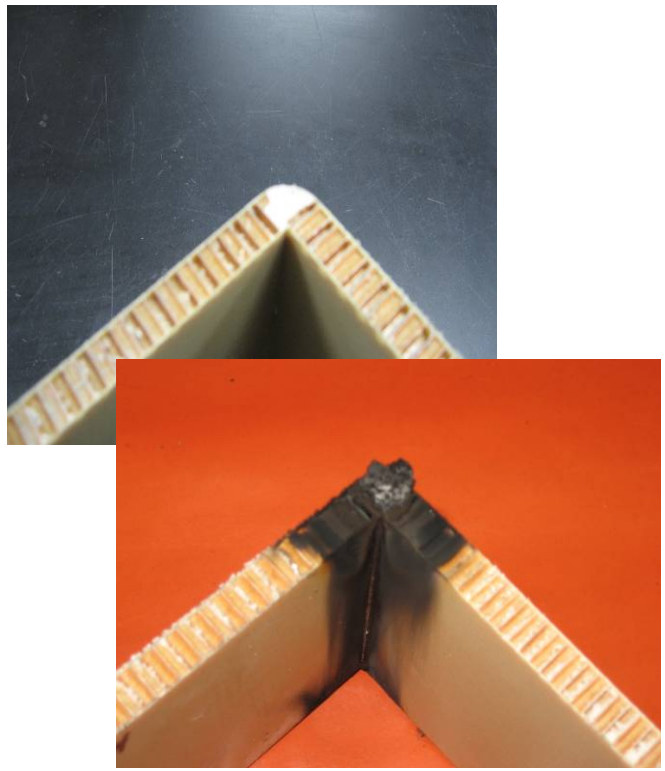
Components	Part A	Part B
Color	White	Straw
Specific Gravity	1.43	1.35
Characteristic	Moderate Viscosity Liquid	Thixotropic Paste

Mixed Adhesive	Units	Temperature	LP31007.0
Mix Ratio A/B	volume/volume	---	2/1
	weight/weight		2.12/1
Dispensability[1]	gpm	23°C (75°F)	91
		37°C (99°F)	300
Flow	inches / 10 min cm / 10 min	23°C (75°F)	0.85 2.2

1. Dispensability determined using 200 ml side-by-side cartridges

Typical Flammability Results

Extinguishing Time (seconds)	Burn length (cm / in)
~1	2.5 – 3.8cm (1 – 1.5inch)



- Corner exposed to flame for 60 Seconds
- Extinguish time is time to extinguish after ignition source is removed
- Burn Length is the distance the surface skin was eroded from the edge of specimen

Flame Resistant Structural Paste Adhesive Mechanical Performance

Cured Properties	Units	Test Temperature	LP31007.0
Lap Shear Strength	MPa	23°C (75°F)	23.6
		71°C (160°F)	19.1
Working Life after 1 hour at 23°C (75°F)	MPa	23°C (75°F)	23.6
Working Life after 1 hour at 37°C (99°F) (300 gpm)	MPa	23°C (75°F)	21.8
Modified Bell Peel	N/cm	23°C (75°F)	34.7
'Ditch and Pot' Mechanical Strength	N	23°C (75°F)	133
'Ditch and Pot' Burn (extinguish time)	sec	NA	<1

Flame Resistant Structural Paste Adhesive Conclusions

- **Using new Technology Approach Henkel has develop a new Structural Paste Adhesive which:**
  - Exceeds flammability requirements
  - Has improved mechanical performance
  - Meets dispensability requirements
  - Long working life
  - Self colored white

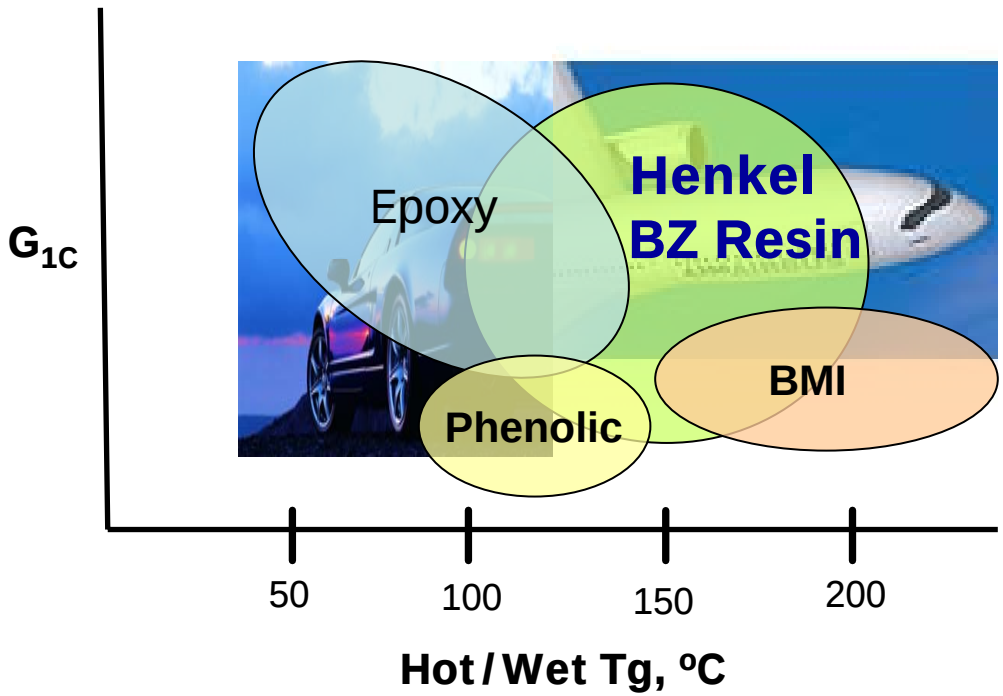
Structural Composites: Benzoxazine Matrix Resins

Structural Composites Industry Needs

- **Structural Composites used for many years:**
  - Commercial Aircraft – secondary structures
  - Military Aircraft – primary structures
- **Main Resin Systems:**
  - Epoxy
  - Bismaleimide
- **Increasing use of composites in commercial aircraft**
  - Structure:
    Fuselage, Wings
  - Engines and nacelles
  - High temperature areas:
    APUs
    Engine pylons
    Wheel wells
    Leading edges (de-icing)

Henkel Benzoxazine Resin

- Ambient shipping and storage
- Material costs comparable to Epoxy
- Process equivalent to Epoxy
- Excellent FST performance



Compared to epoxy resins

- Lower cure shrinkage and heat release
- Higher hot/wet performance
- Inherent FST characteristics

Compared to phenolics

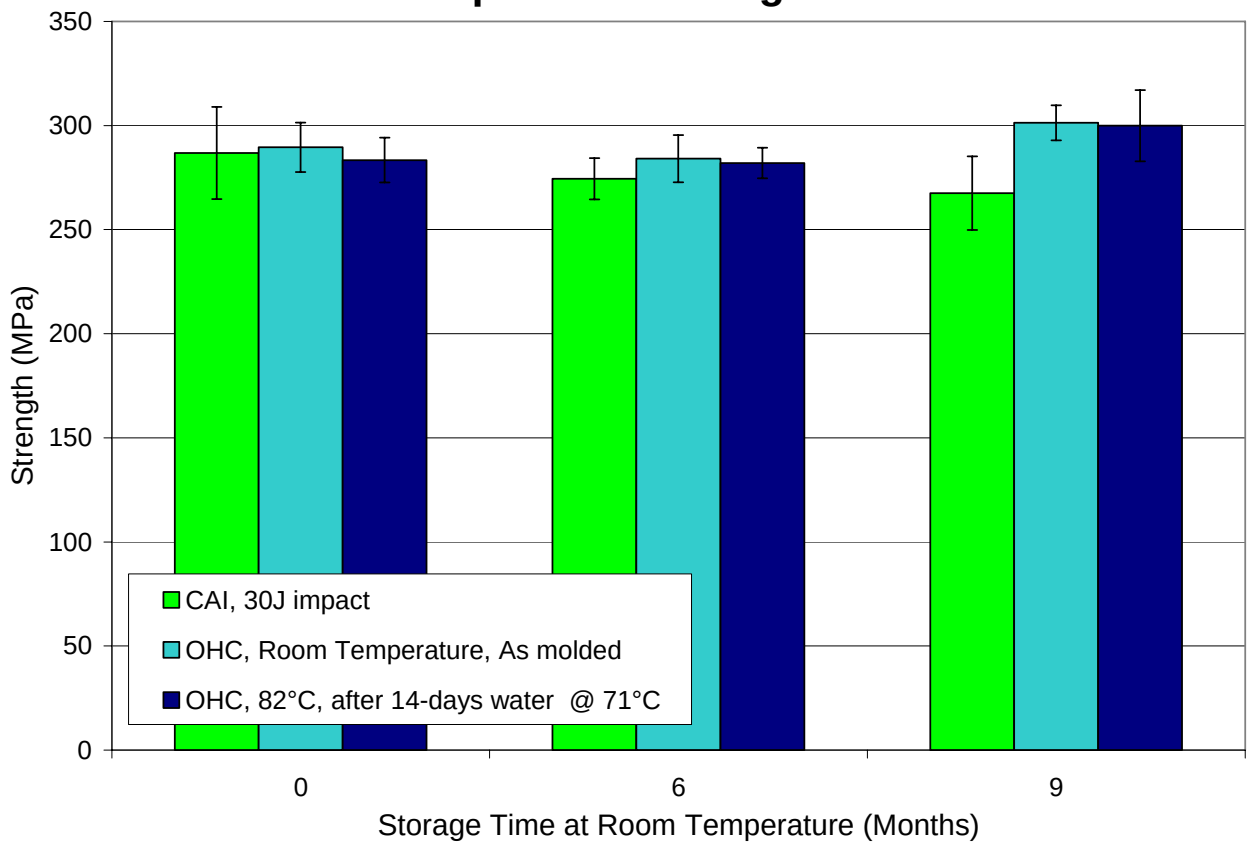
- No microcracks
- No water generated

Compared to BMI

- Lower cure temp and shorter cure time
- Lower cost
- Higher toughness

Epsilon Benzoxazine Prepreg Resins

- **High retention of hot/wet properties**
- **Damage tolerance equivalent to toughened epoxy prepregs**
- **Meets flammability and burn-through requirements**
- **Extended room temperature storage**

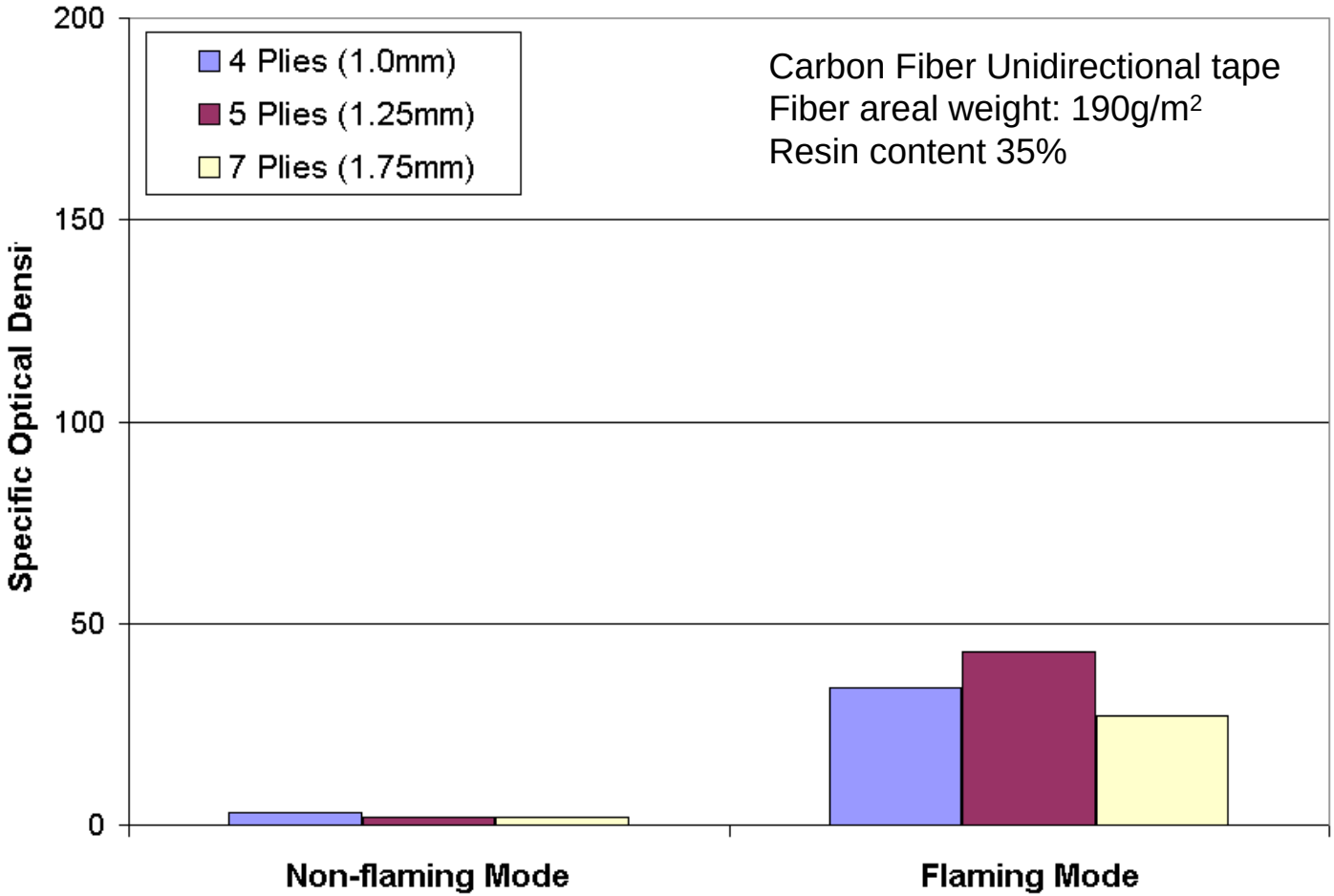


Epsilon Benzoxazine Prepreg Composite: Flame, Smoke and Toxicity

Property	Units	Limit	Epsilon Composite	
Vertical Burn: 60secs				
After burn length	inch	6	0.91	
After flame time	secs	15	2	
After flame time of drips	secs	3	No Drips	
			Non-Flaming Mode	Flaming Mode
Smoke Density				
Specific Optical Density	N/A	200	3	34
Toxicity				
HCN	ppm	150	0	0
CO	ppm	1000	2	40
NO/NO_2	ppm	100	0	2
SO_2/H_2S	ppm	100	0	2
HF	ppm	100	0	0
HCl	ppm	150	1	1

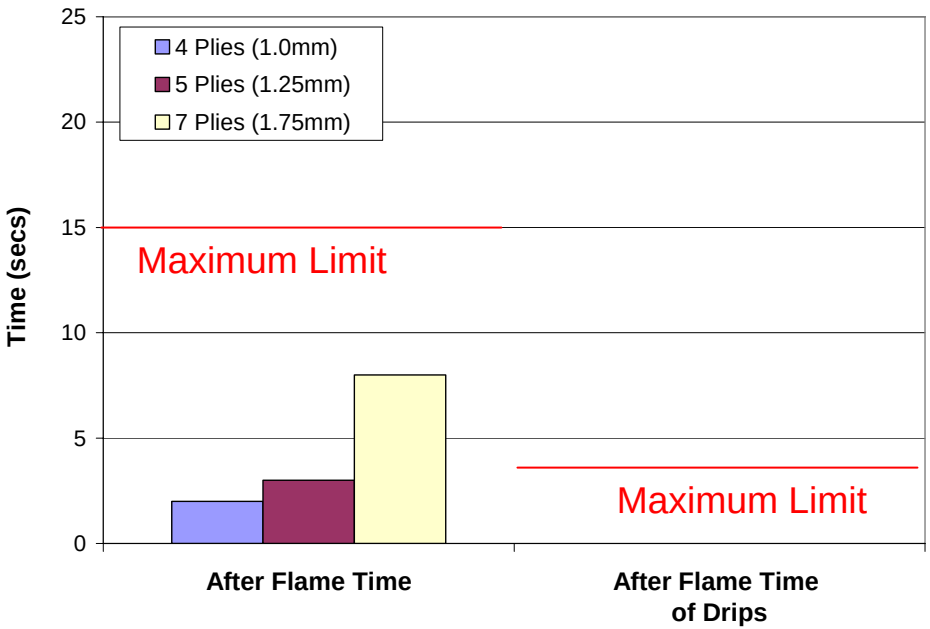
4-ply Carbon Fiber Composite Unidirectional Tape: 1mm thick

Structural Composite: Smoke Test Results



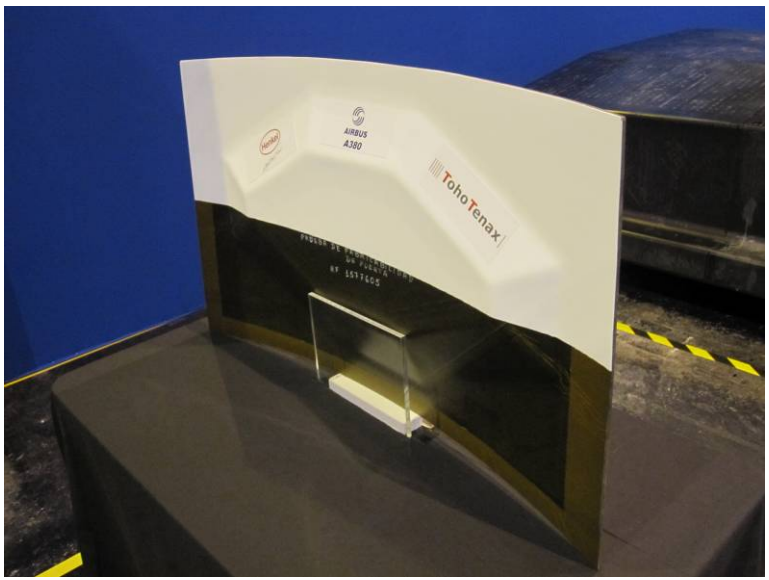
Structural Composite: 60sec Vertical Burn

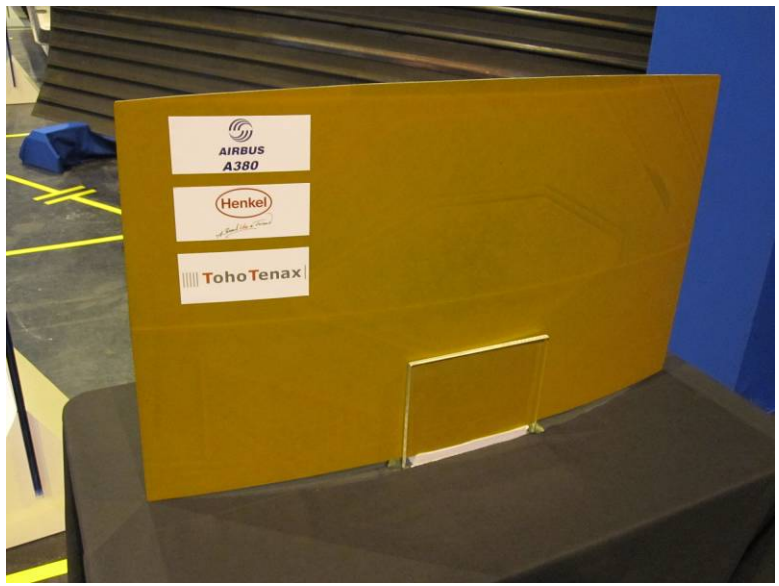
Carbon Fiber Unidirectional tape
Fiber areal weight: 190g/m^2
Resin content 35%



Structural Composite Application

- **A380 APU Housing & Duct:**
  - Carbon fiber, Glass Fiber Prepreg and Film Adhesive
  - Meets Structural Performance requirement
  - Meets standard FST requirements: OSU, Vertical Burn, Smoke, Toxicity
  - Meets oil burner 15min, 1100°C burn-through requirement





Summary

- **Requirements becoming more demanding:**
  - Flame, smoke and toxicity requirements
  - Health, safety and environmental requirements
  - Service performance
  - Processability
  - Cost: Acquisition and total life cycle

- **New approach needed to materials development:**
  - Resin chemistry
  - Flame retardants
  - Formulation design

- **Initial Product Developments**
  - Flame retarded paste adhesive for structural bonding
  - Structural composites using Benzoxazine matrix resin

THANK YOU