Characterization of Prepreg Materials for Wind Turbine Blades

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9 May 2013

Agenda

- Hexcel company profile
- Background to prepregs in wind energy
- Prepreg characterisation
  - Surface prepregs (XF2P)
  - Structural prepregs (matrix system, M79)
- Combinations of prepregs with infusion: co-infusion
- Conclusions

Company Profile

- Technology leader in advanced composites
- Serving commercial aerospace, space & defense and industrial
- Net Sales 2012: $1.58 Billion
- 5,000 employees worldwide
- 19 manufacturing sites (including JV in Malaysia)
- Headquarters in Stamford, CT, USA
- Listed on New York and Paris Stock Exchanges






Background

Prepregs in Wind Energy

Typical Prepreg Systems in Wind Energy

Typical resin systems

M9G	310 J/g	Cure temperature ~100-120°C
M9GF	230 J/g	
M19G	160 J/g	

UD Products

Carbon 500-600 g/m^2

Glass 1000-3000 g/m^2

Overall cure cycles

~4 to ~8 hours (optimisation is key)

Typical prepregs
high areal weight + moderate cure temperature + low reaction enthalpy

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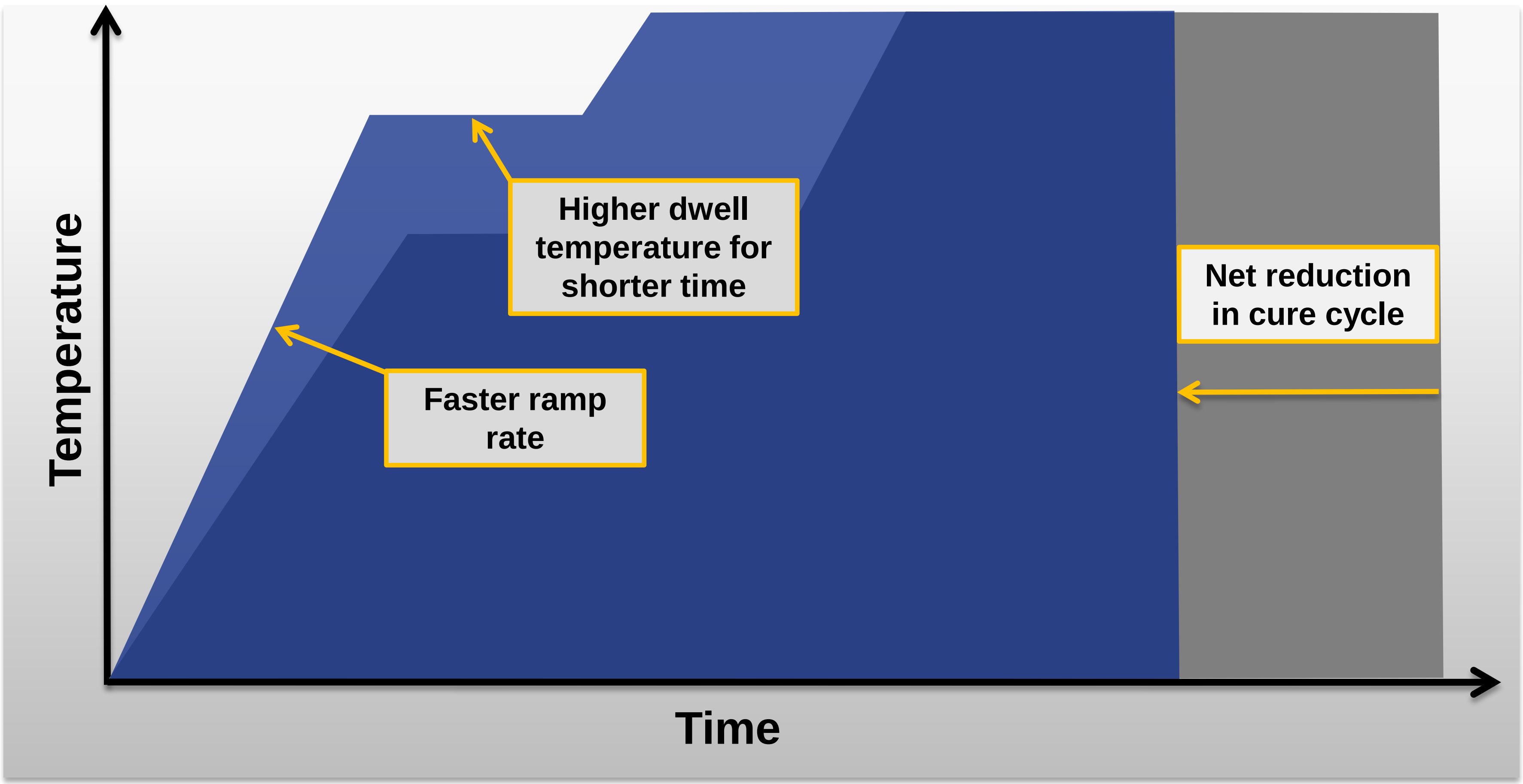
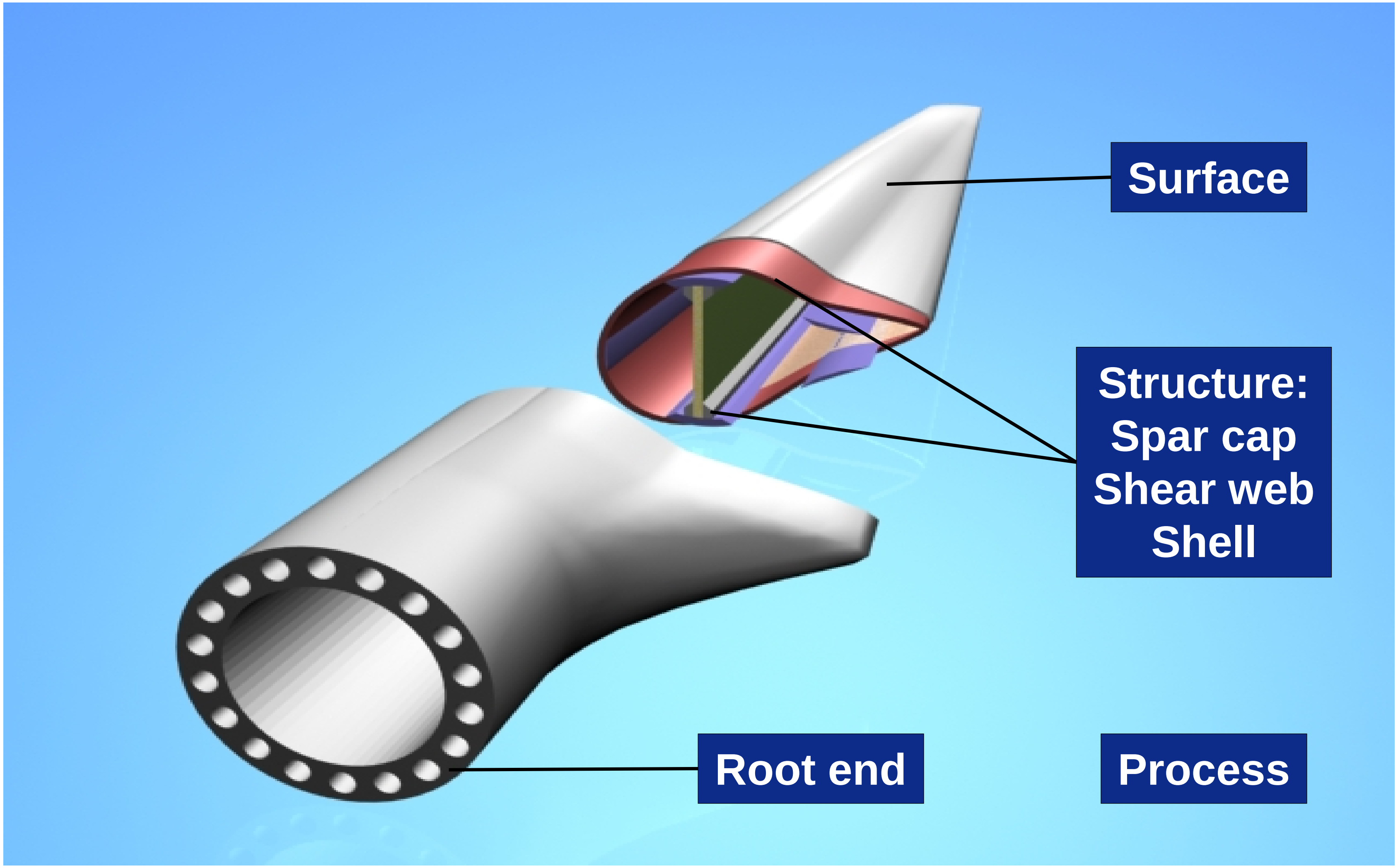
The Value of Low Exotherm in Thick Laminates



Low exotherm matrix e.g. M19G

Standard exotherm matrix e.g. M9G

Features of Typical Wind Turbine Blades



Prepreg Characterisation

This presentation will focus on the following

Surface and shell prepreg

- **Characterisation of a surface prepreg that obviates an additional gel coat**

Structural prepreg for large/ thick sections

- **Characterisation of a new structural prepreg system, M79, that combines:**
  - Low temperature cure
  - Low exotherm

Characterisation of a Shell Prepreg: HexPly XF2P

Prepregs for the Shell Surface

Shell prepregs are used for the aerodynamic shell

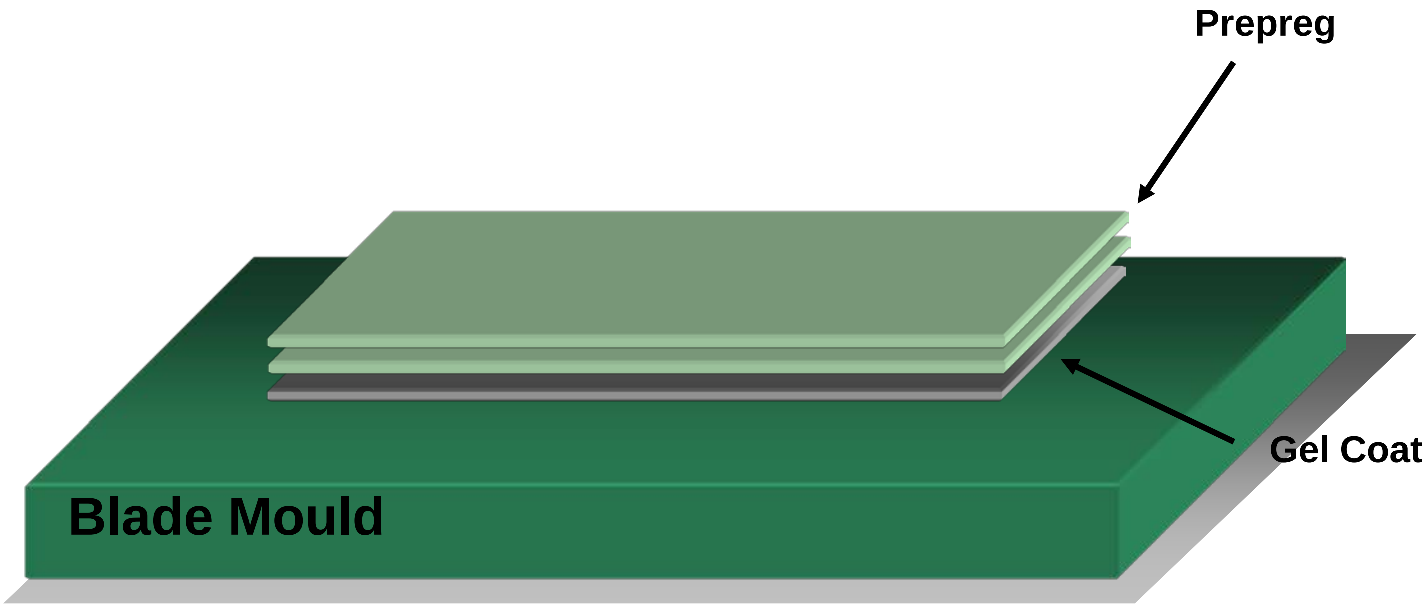
- Gel coats may be used to provide a good paint-ready surface
- Polyurethane paints may be used for the final surface

Painting makes the gel coat redundant as a surface finish system

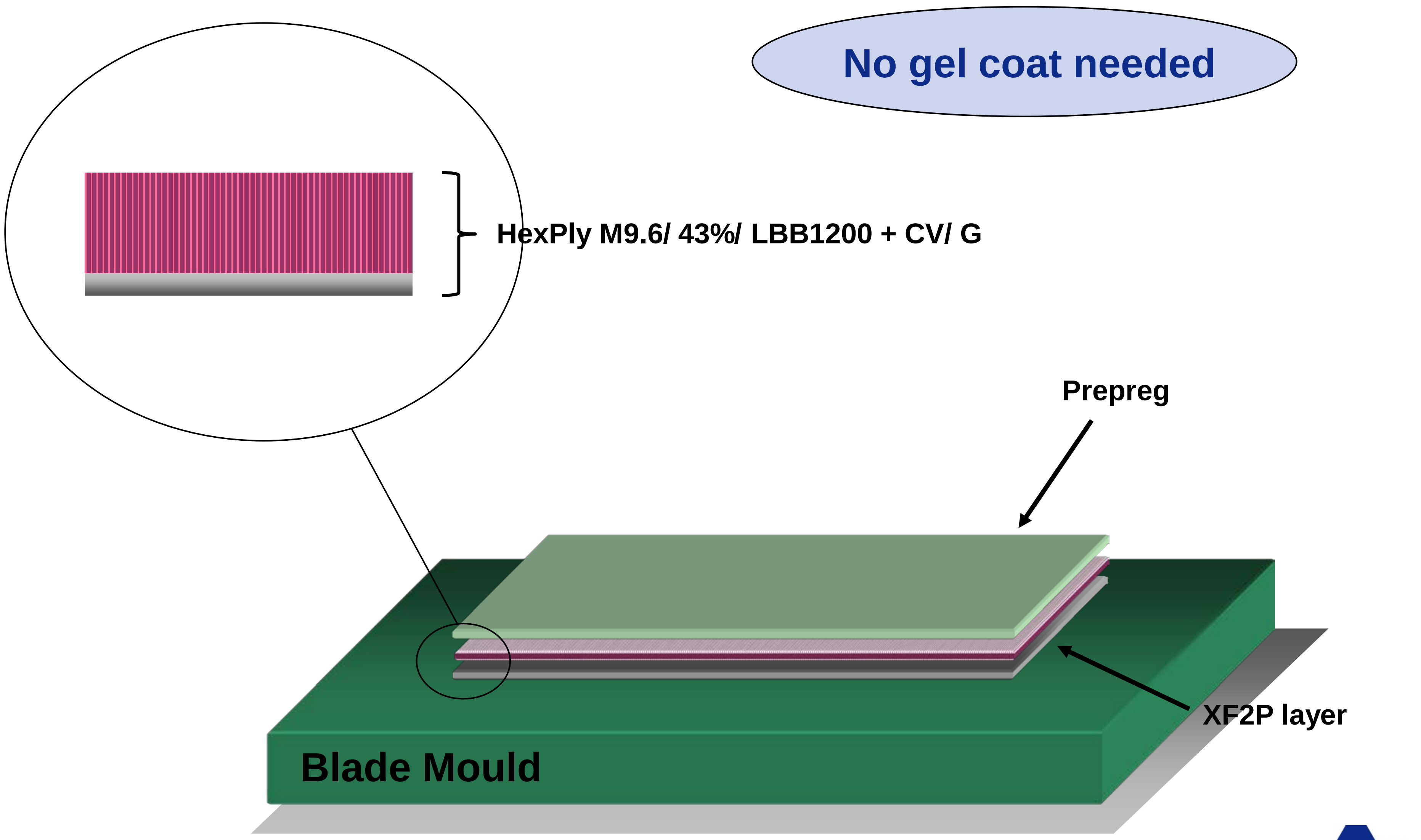
This process can be simplified by using specific shell prepregs such as HexPly XF2P

- To build the aerodynamic shell surface
- To eliminate the gel coat

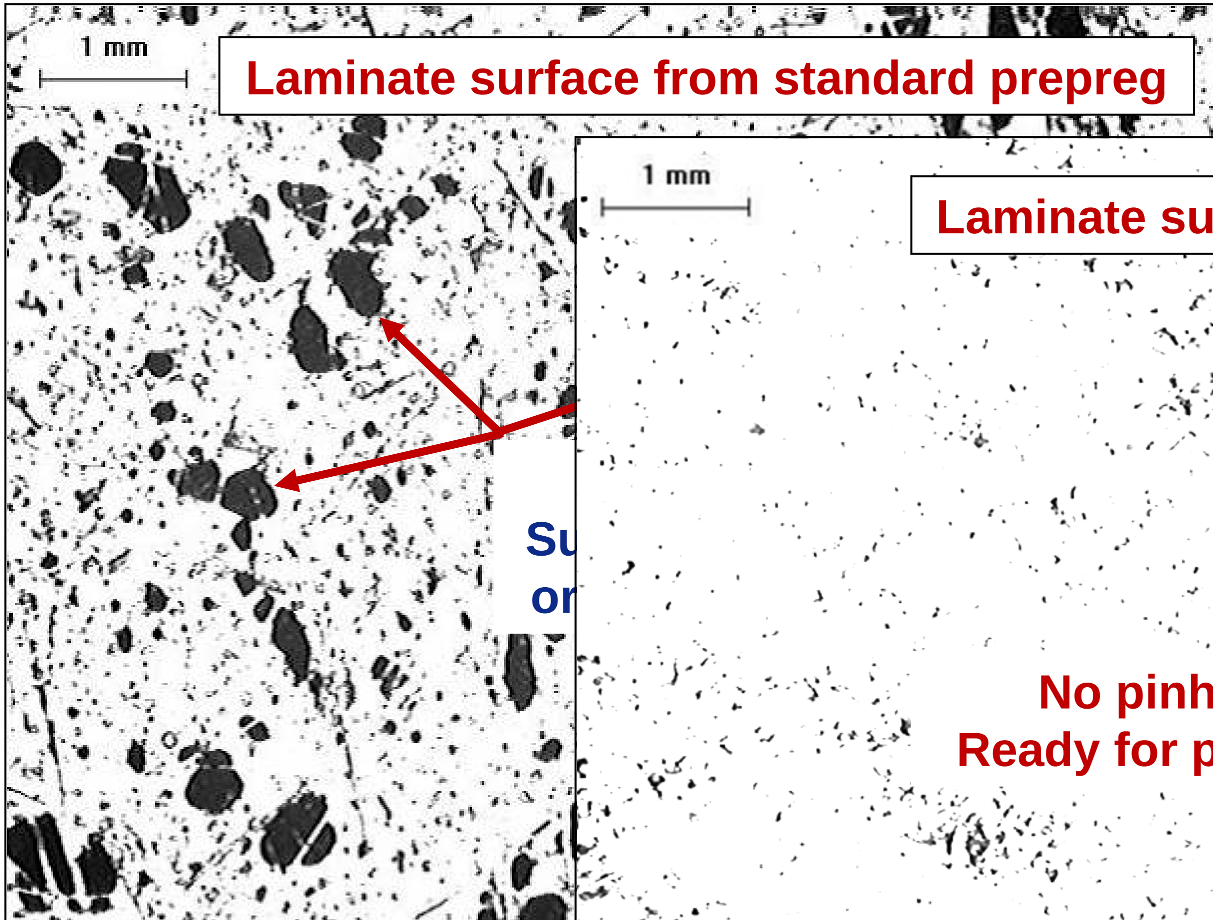
Conventional Shell Construction, with Gel Coat

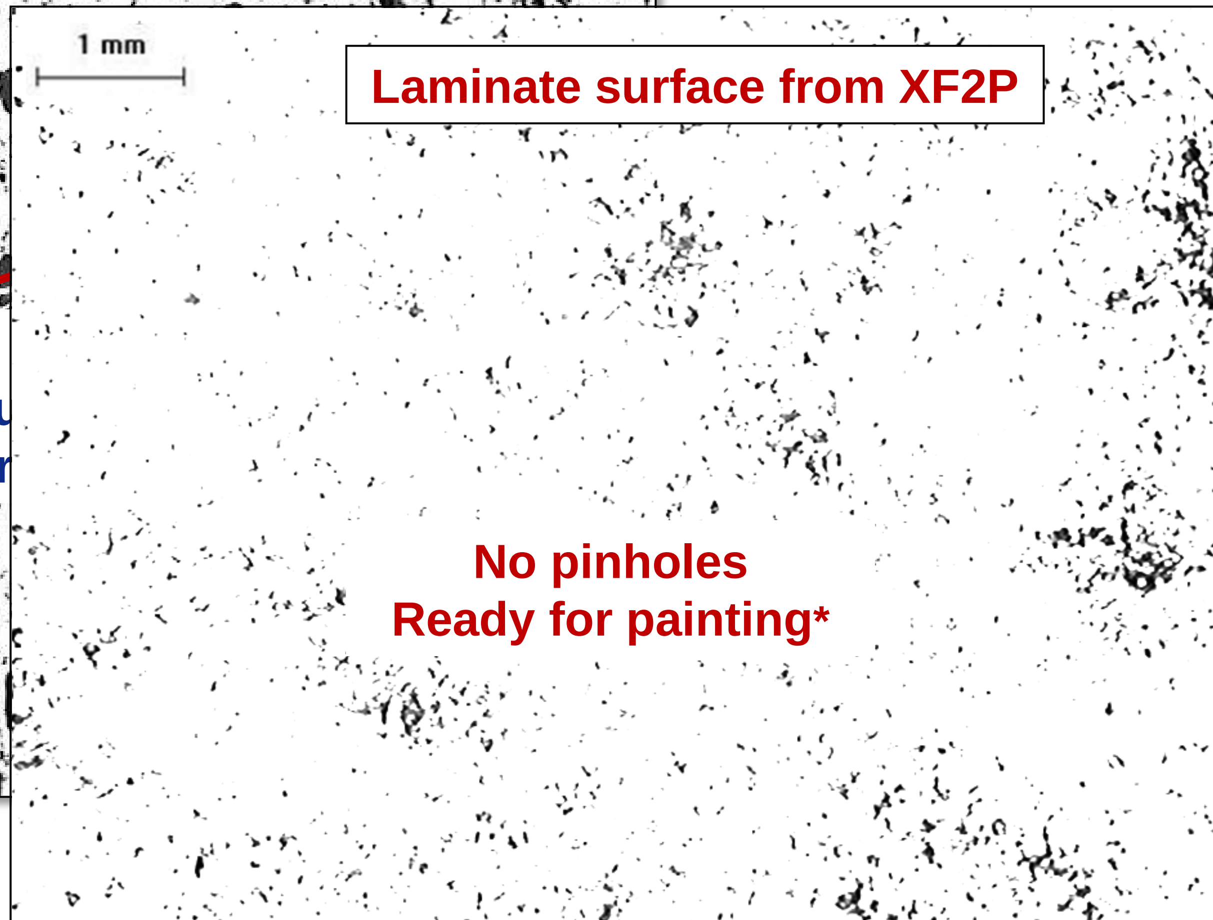


XF2P – Gel Coat-free Surface Finish



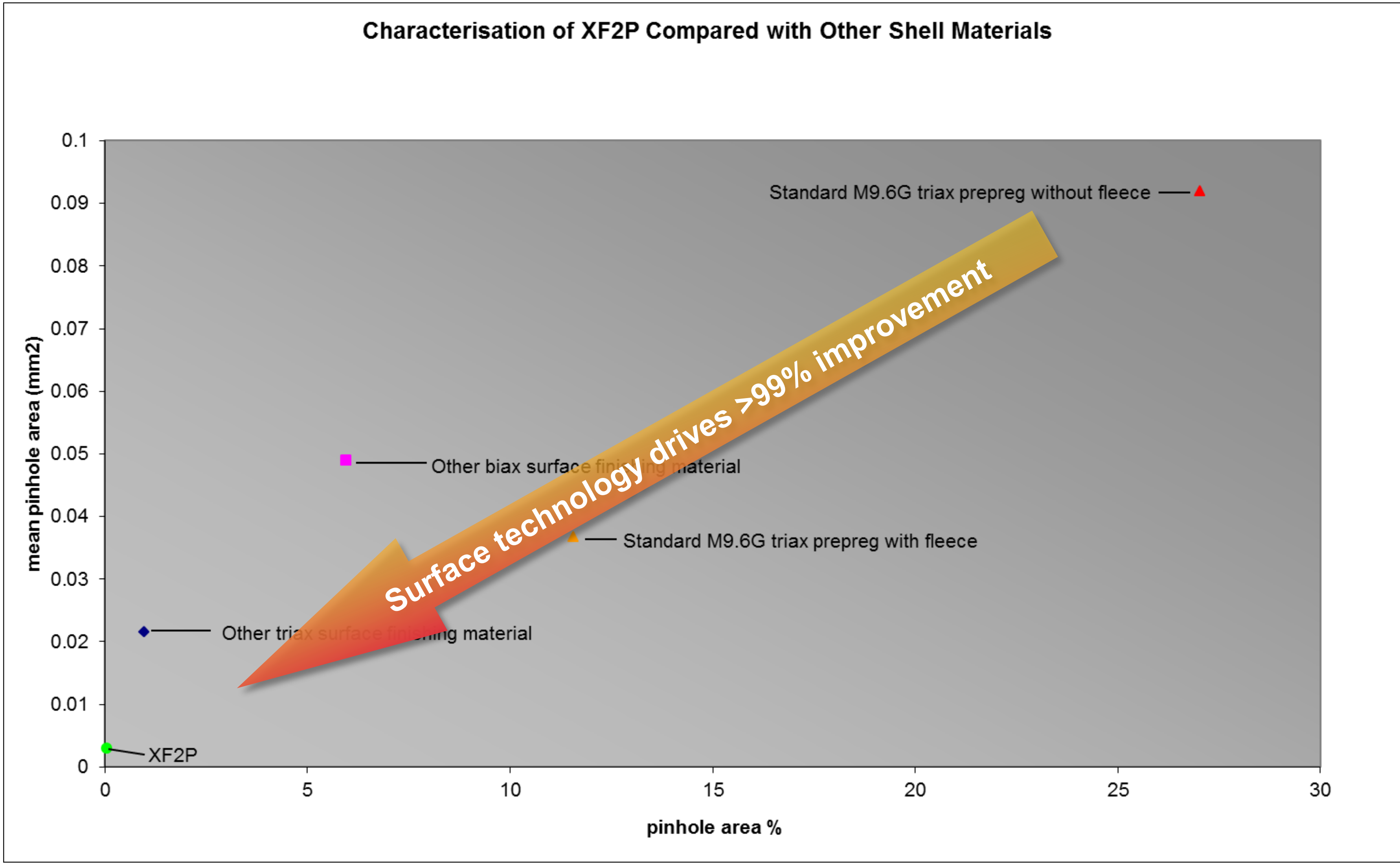
XF2P: Surface Characterisation



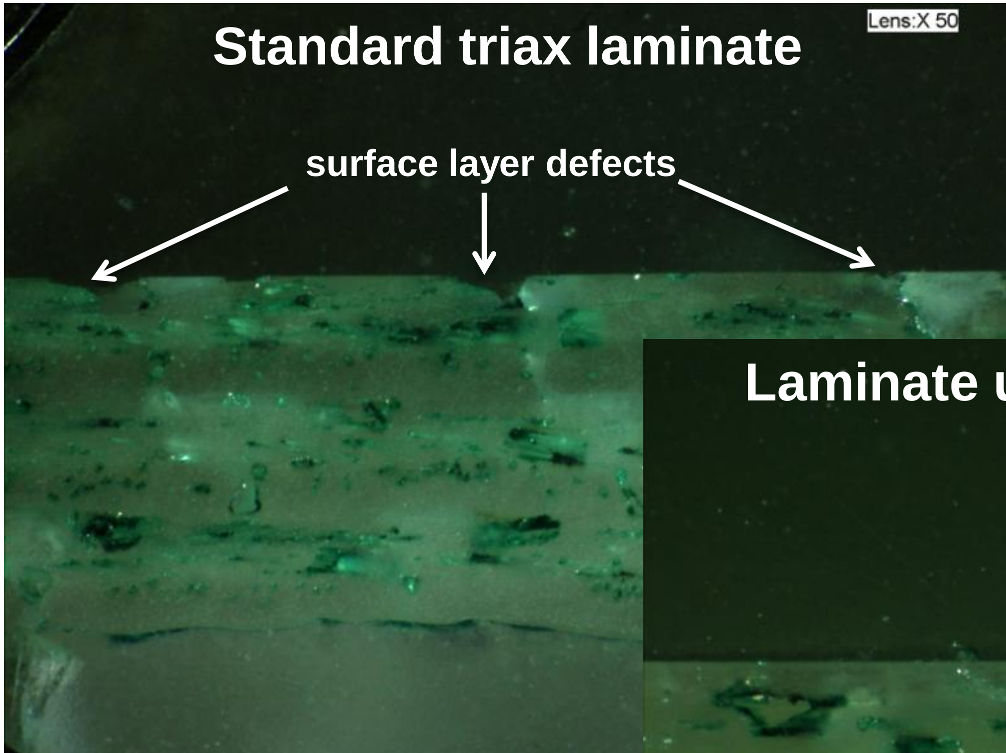


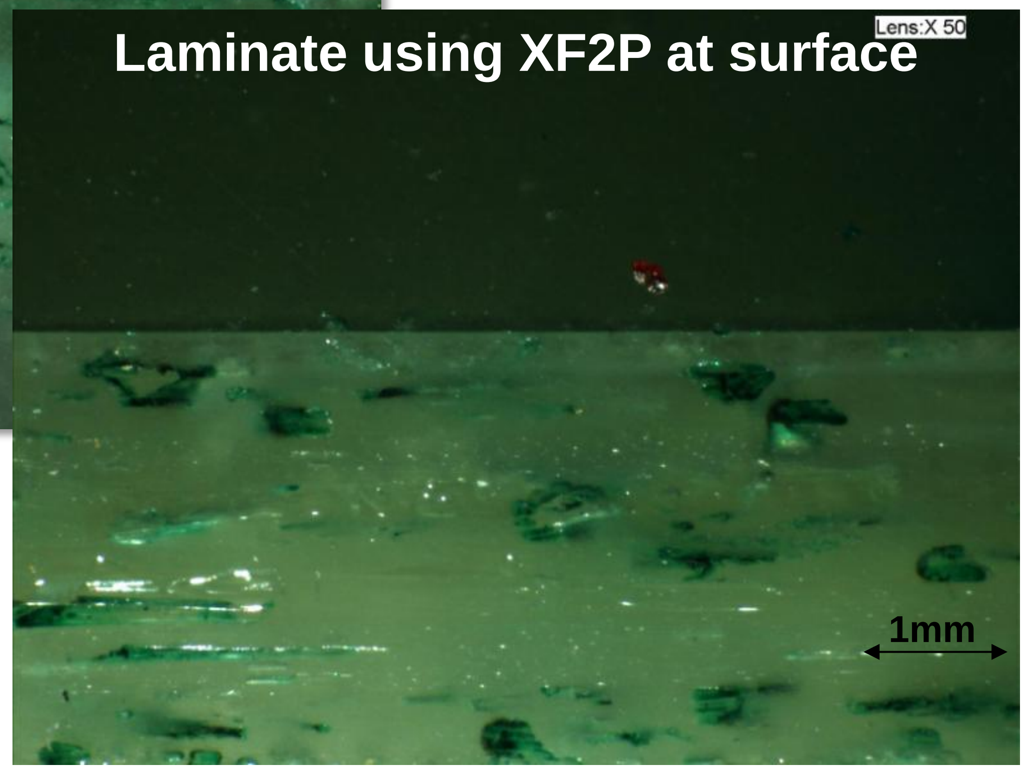
* After removal of release agent

Surface Porosity from Shell Materials



XF2P: Cross-sectional Analysis





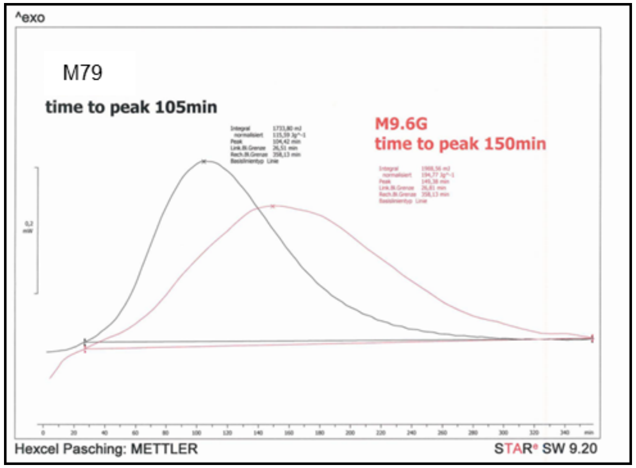
Characterisation of Prepreg Matrices: M79

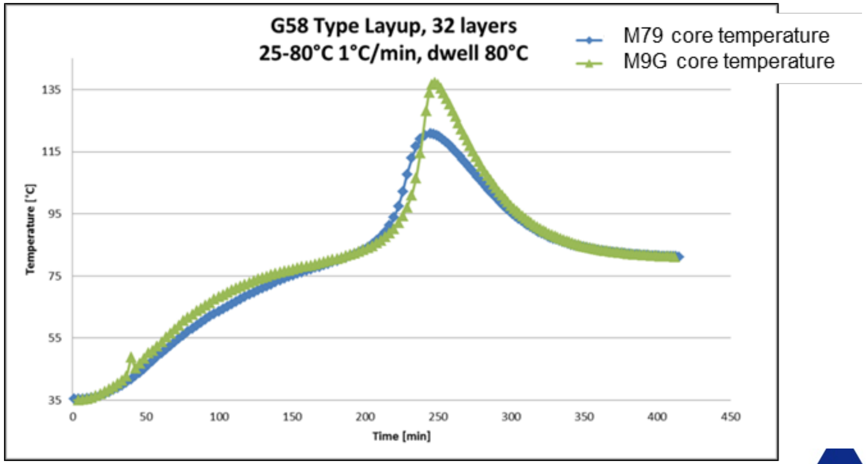
Designed for Structural Applications

M79

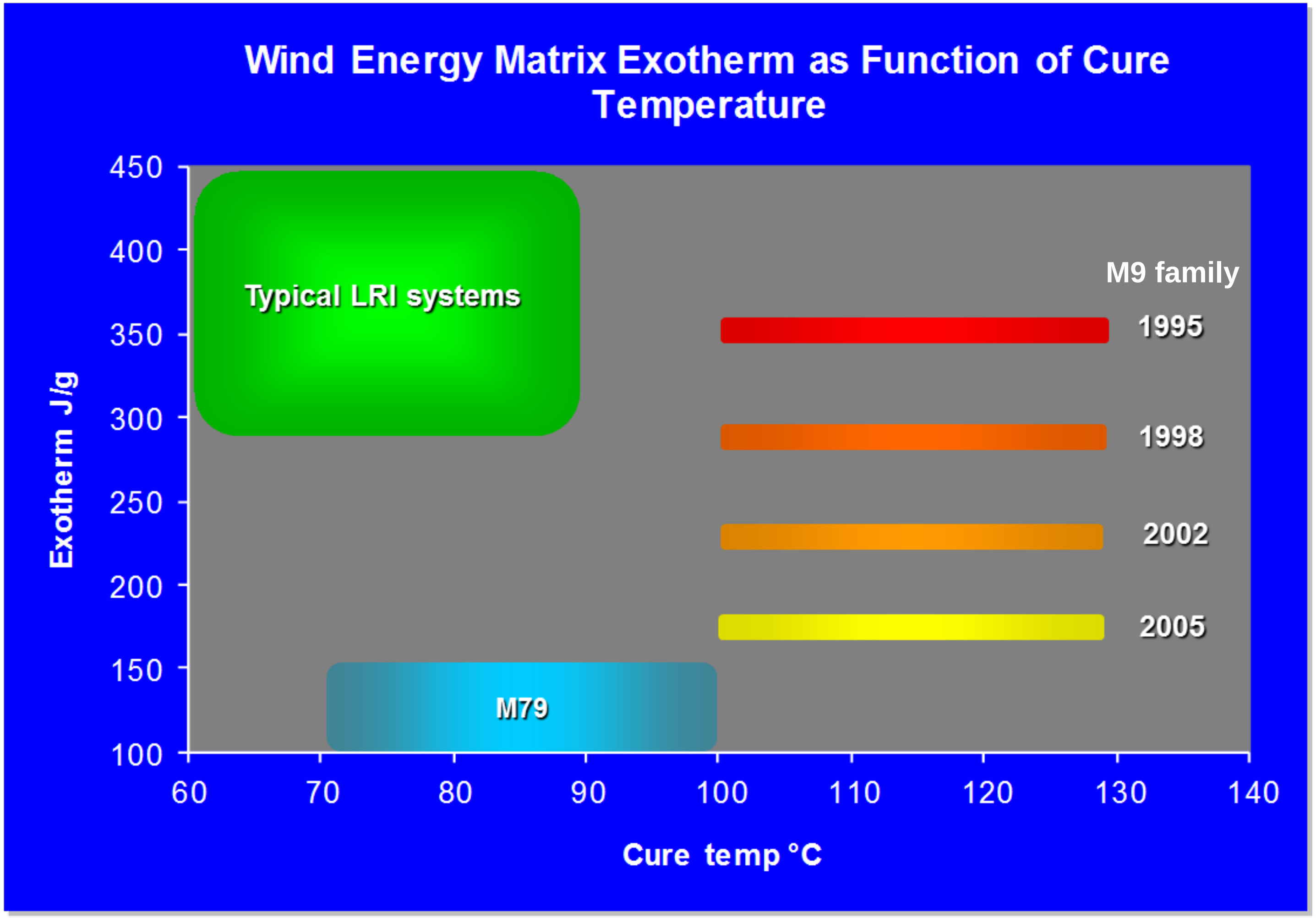
New generation prepreg system for large industrial structures (e.g. wind turbine blades)

- Cure: 70°C ~10 hrs; 80°C ~6 hrs; 120°C <1 hr
- Outlife > 2 months
- Exotherm ~100-120 j/g
- Static mechanical properties as current M9G family prepregs
- Product form as current prepregs/ semipregs
- Manufacture: standard process, as current M9G family prepregs

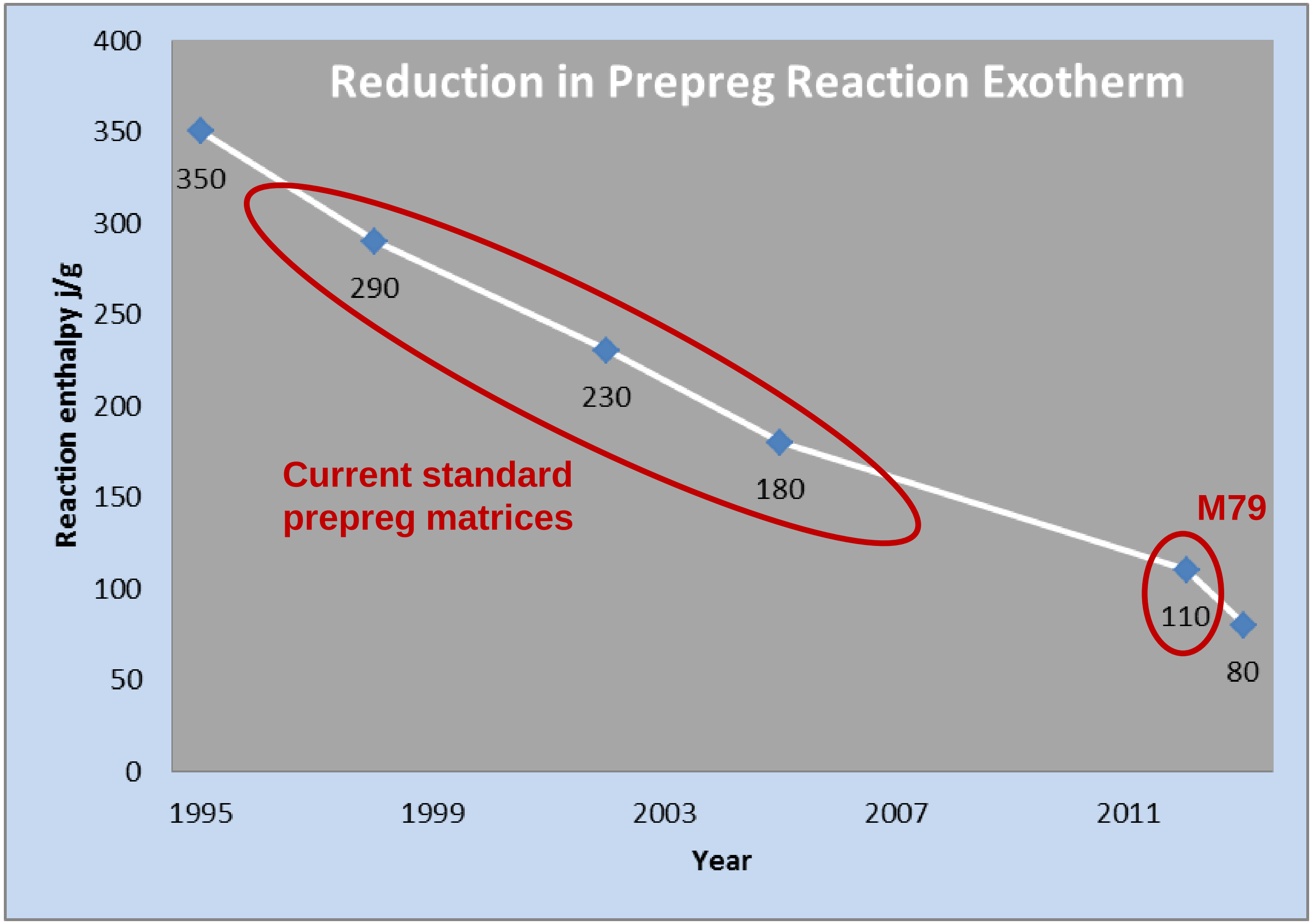




M79 Compared with Conventional Systems



Reduction in Prepreg Exotherm, 1995-2013



Latest prepreg matrices minimise reaction exotherm allowing short cure cycles of thick structures

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M79: Example of Mechanical Test Data

Test & Direction	Measurement	70 ° C Cure				M9 Historical
		No. of specimens	Mean	SD	CV (%)	
Tensile 0°	Strength (MPa)	8	**469**	9.4	2.0	**445**
	Modulus (GPa)		**21.2**	0.5	2.5	**18.2**
Compression 0°	Strength (MPa)	10	**413**	20	4.9	**333**
	Modulus (GPa)		**21.0**	0.3	1.4	**19.5**
ILSS (45° , 4-ply)	Strength (MPa)	20	46.7	1.9	4.0	43.6

Normalized results are in bold

Test results for HexPly M79/43%/LBB1200+CV/G cured at 70 ºC

Overall, M79 mechanical test data compares favourably with conventional (M9) systems

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M79: Example of Mechanical Test Data

Test & Direction	Measurement	80 ° C Cure				M9 Historical
		No. of specimens	Mean	SD	CV (%)	
Tensile 0°	Strength (MPa)	20	**456**	16	3.6	**445**
	Modulus (GPa)		**19.1**	0.3	1.7	**18.2**
Compression 0°	Strength (MPa)	10	**394**	30	7.5	**333**
	Modulus (GPa)		**20.5**	1.0	4.7	**19.5**
ILSS (45° , 4-ply)	Strength (MPa)	20	39.5	1.1	2.7	43.6

Normalized results are in bold

Test results for HexPly M79/43%/LBB1200+CV/G cured at 80 ºC

Overall, M79 mechanical test data compares favourably with conventional (M9) systems

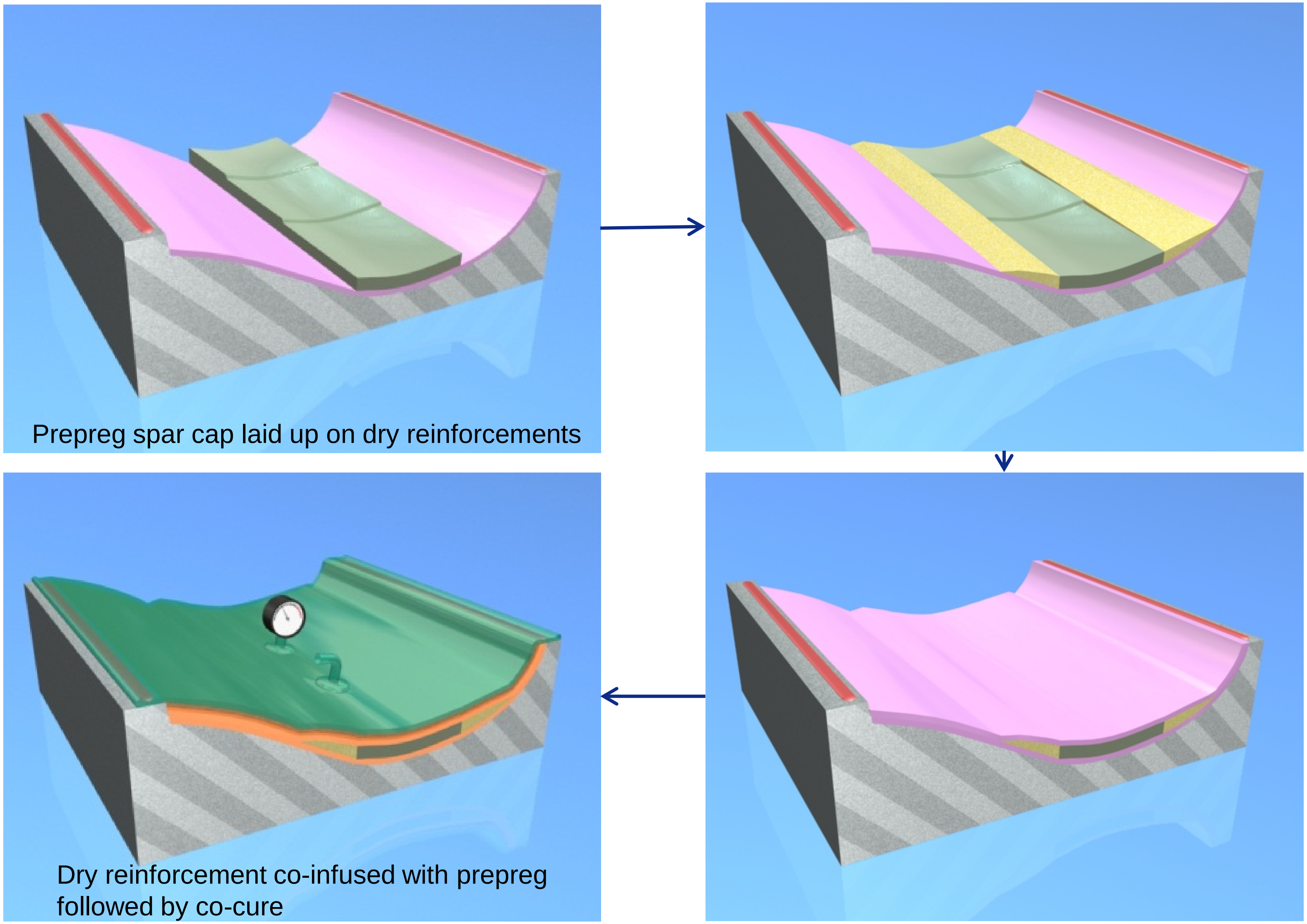
M79 and Co-infusion

Co-infusion
The use of prepreg and infusion technologies in the same laminate with co-cure

Typical configuration
UD prepreg for the heavy load-carrying structure
Infusion of dry reinforcement for the remainder of the structure
Cure of the whole assembly at the same time and temperature

M79 simplifies co-infusion when making large structures because it cures at 70-80°C (i.e. same temperature for both infusion and prepreg matrices)

Wind Blades: M79 co-cured in an Infused Shell



Co-infusion: Case Study after Demoulding

The finished 4x2m laminate

Low porosity, high Tg

FV (%)		50
Porosity (%)	Side	0,7
	Middle	1,5
Tg (°C)	Top	75
	Middle	120
	Bottom	75
Cure cycle		6hrs 90°C

Co-infusion simplifies the production process, combining the strengths of prepreg and infusion materials

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Conclusions

- Prepregs are used for both structural and surface applications in wind blade construction
- The surface of XF2P laminates have been characterised for surface defects
  - Defects can be reduced by >99% to give a paint ready surface
- M79, a new matrix for wind blades, has been characterised after cure at 70° and 80°C
  - Cure reaction enthalpies are 100-120 j/g, reducing from 350 j/g over the last 15 years
  - Static mechanical properties compare favourably with standard materials
- The low cure temperature of M79 helps enable co-infusion of prepreg with dry reinforcements, thus combining the best features of each process

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