Characterization of Prepreg Materials for Wind Turbine Blades

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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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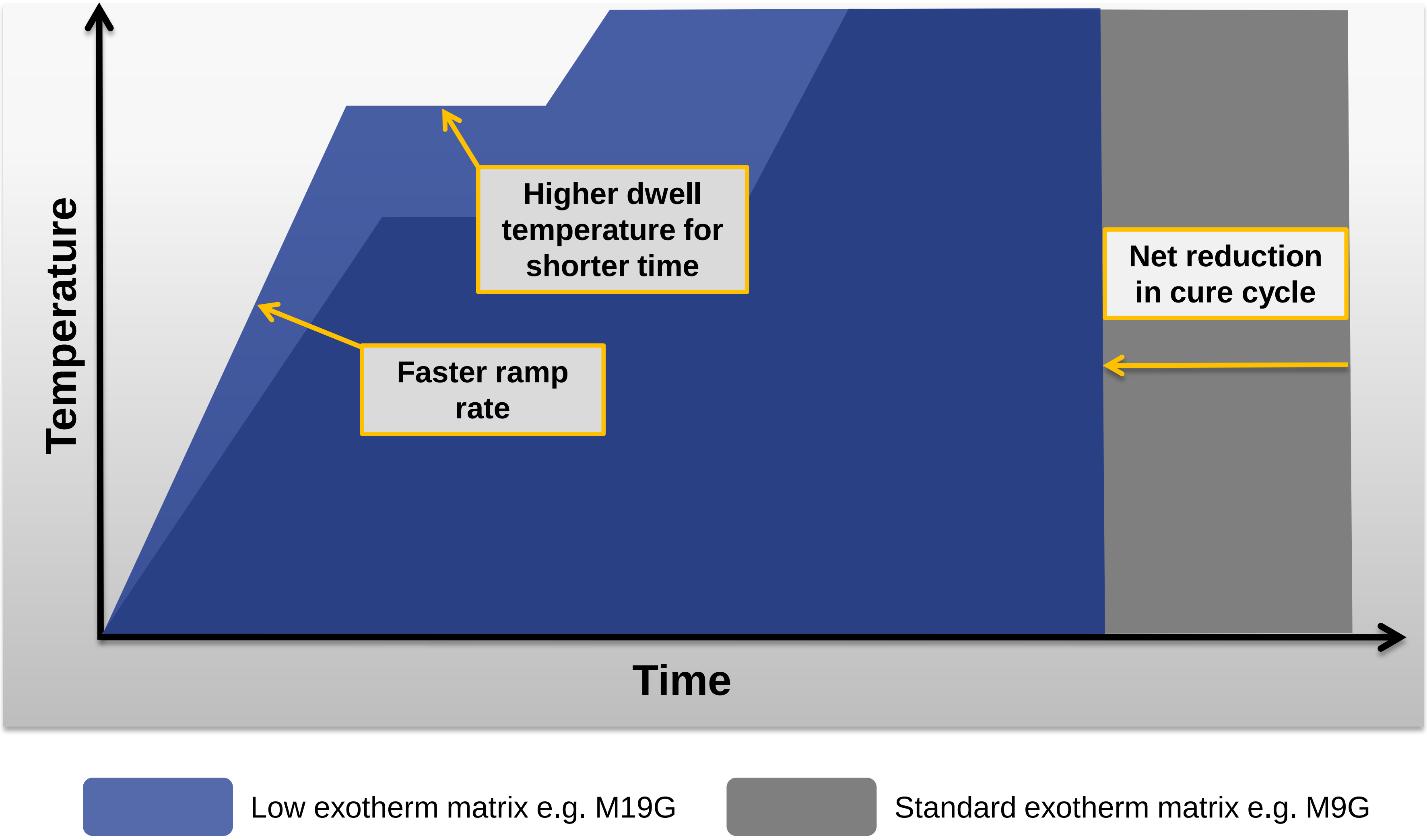
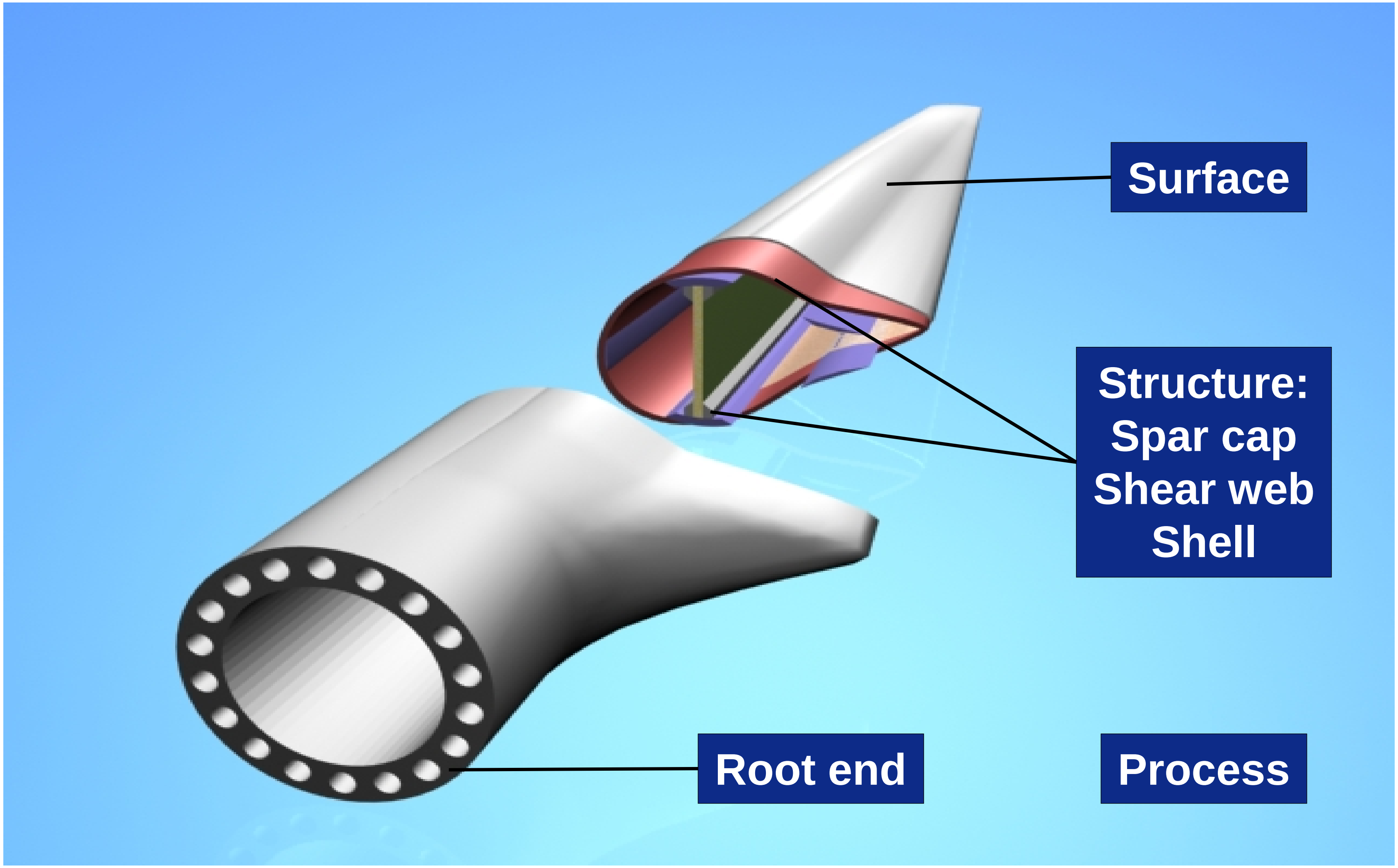
The Value of Low Exotherm in Thick Laminates



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

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Characterisation of a Shell Prepreg: HexPly XF2P

Prepregs for the Shell Surface

Shell prepregs are used for the aerodynamic shell

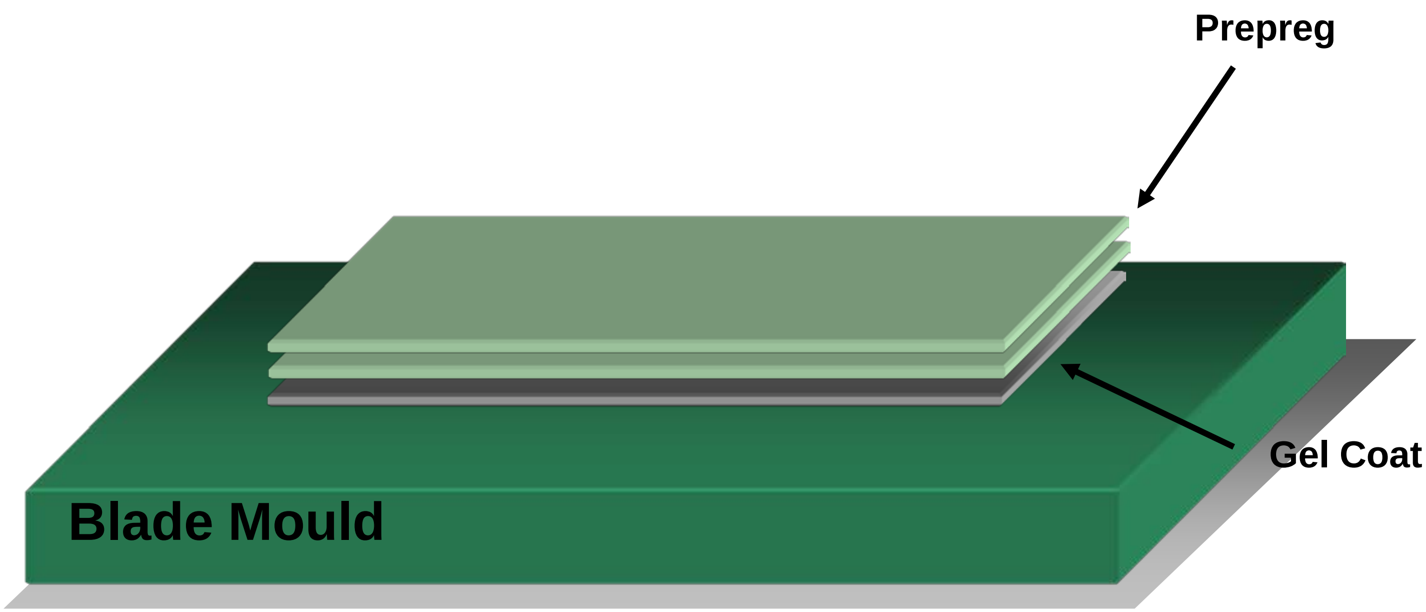
- Gel coats may be used to provide a good paint-ready surface
- Polyurethane paints may be used for the final surface

Painting makes the gel coat redundant as a surface finish system

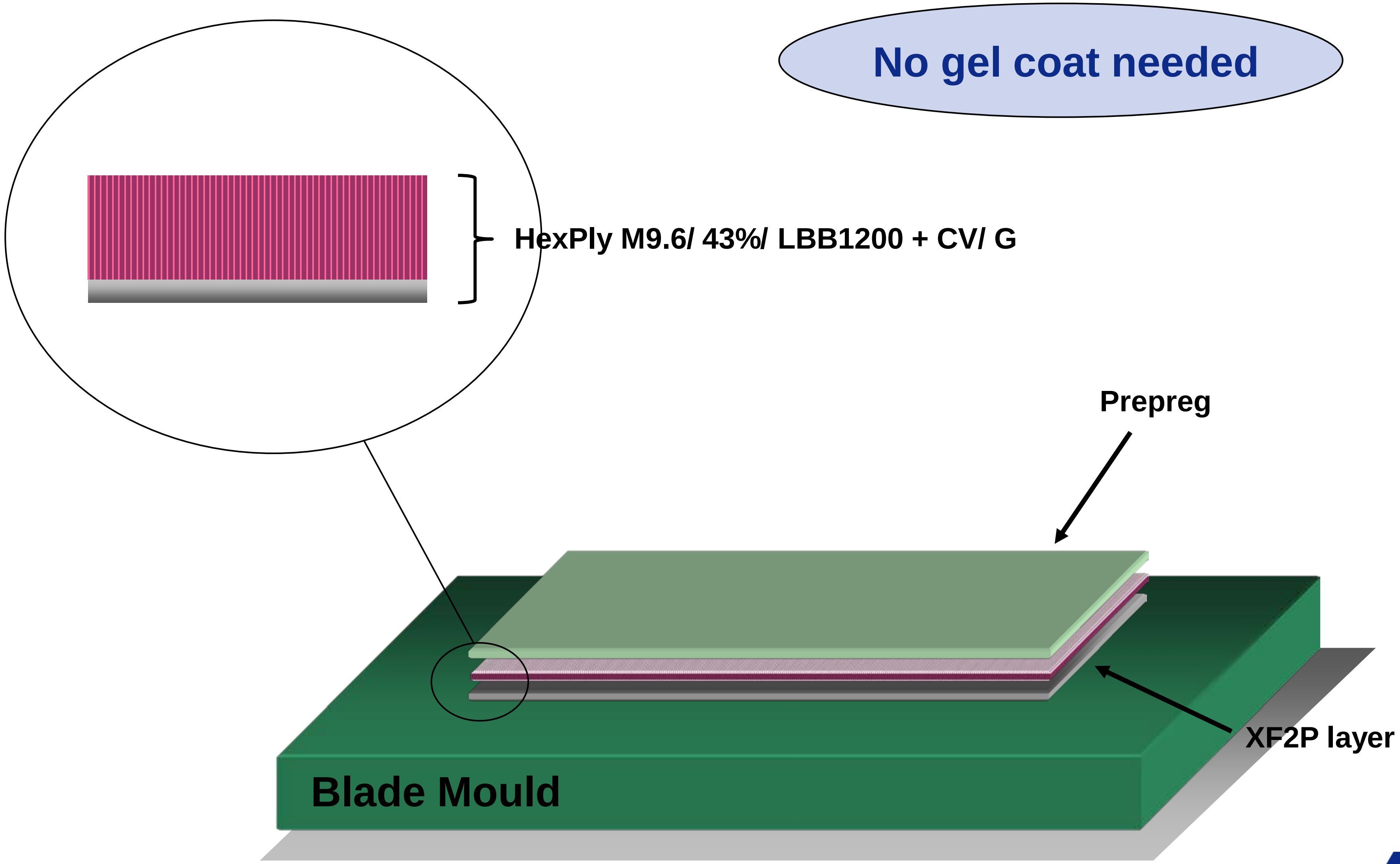
This process can be simplified by using specific shell prepregs such as HexPly XF2P

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

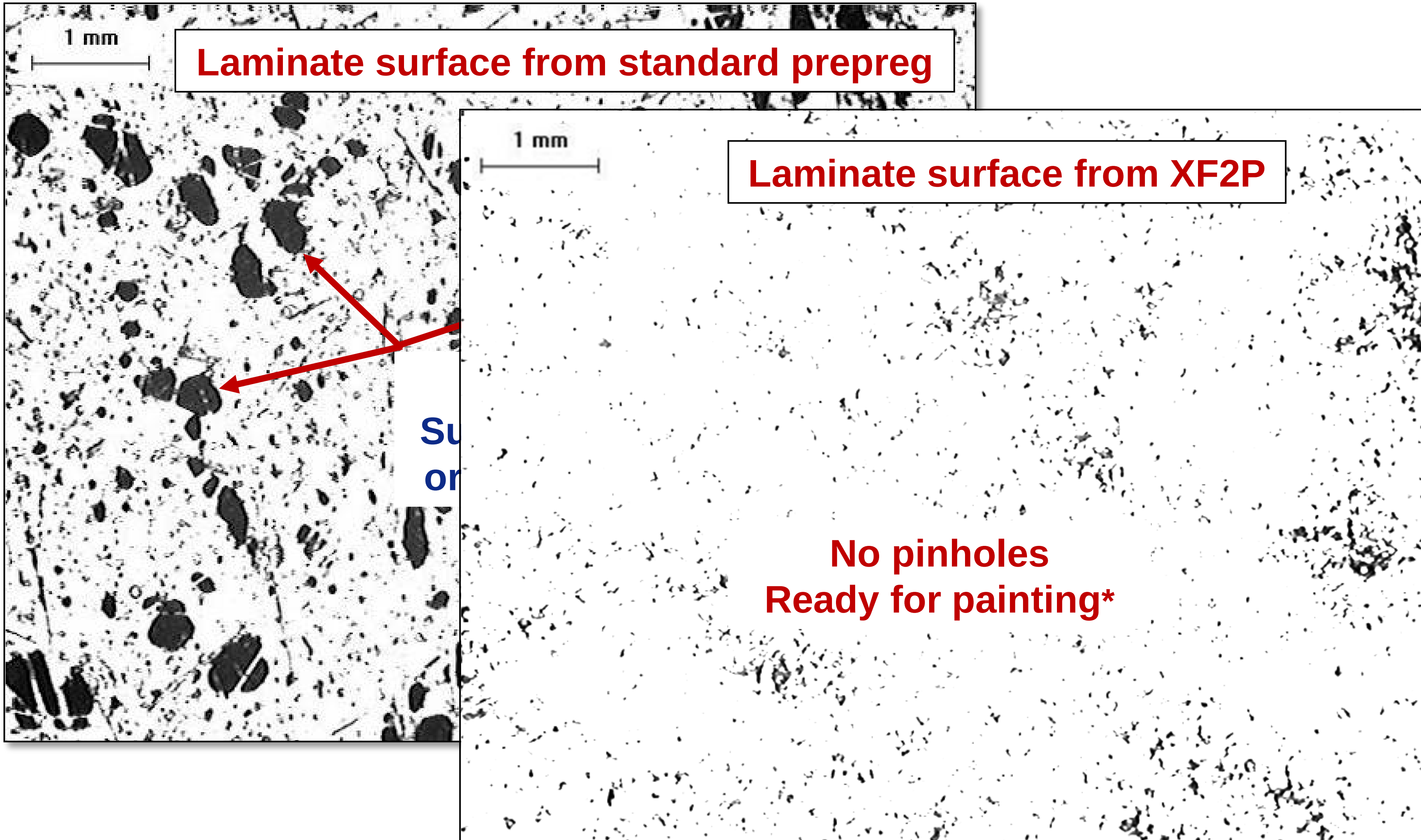
Conventional Shell Construction, with Gel Coat



XF2P – Gel Coat-free Surface Finish

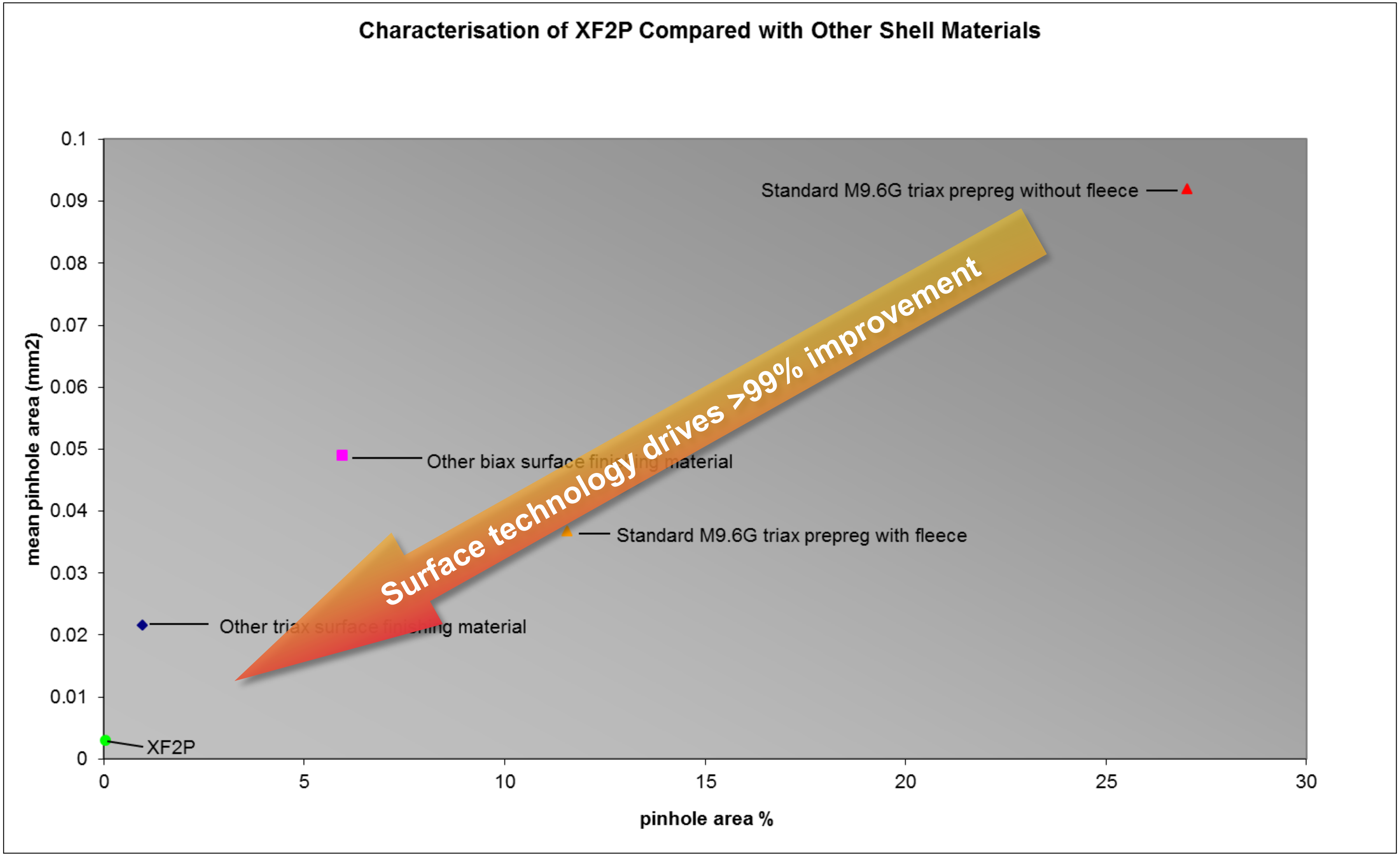


XF2P: Surface Characterisation

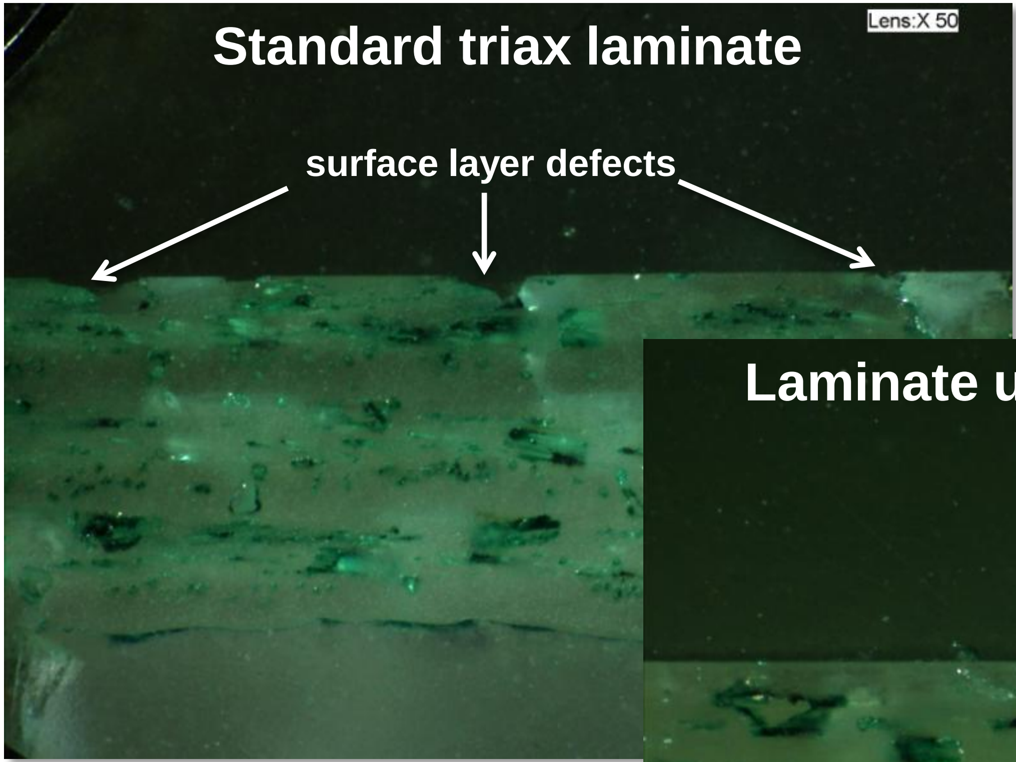


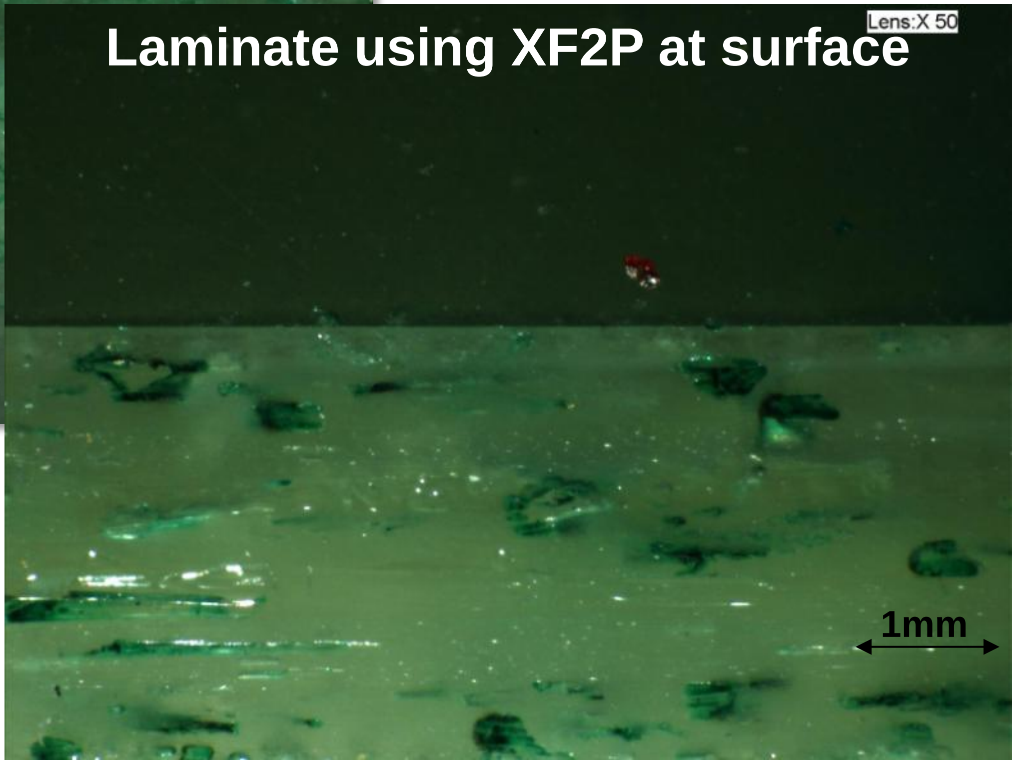
* After removal of release agent

Surface Porosity from Shell Materials



XF2P: Cross-sectional Analysis





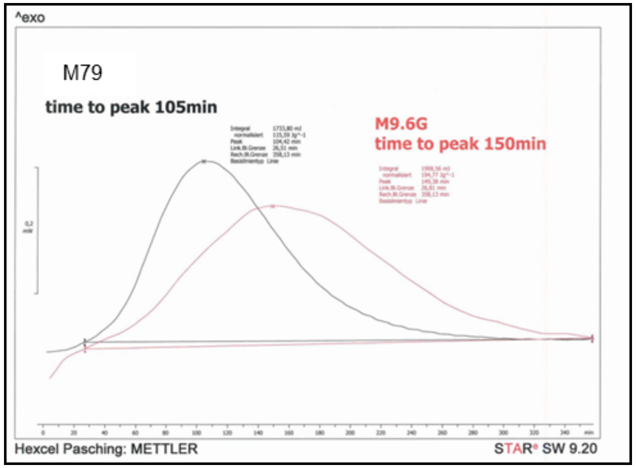
Characterisation of Prepreg Matrices: M79

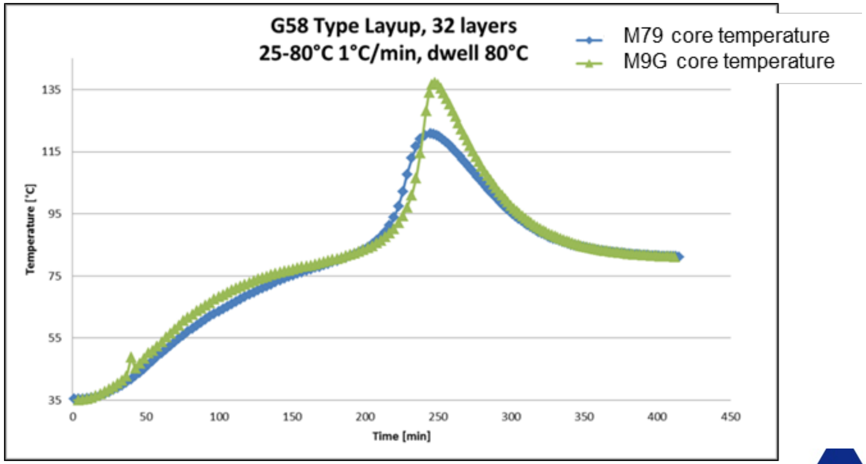
Designed for Structural Applications

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





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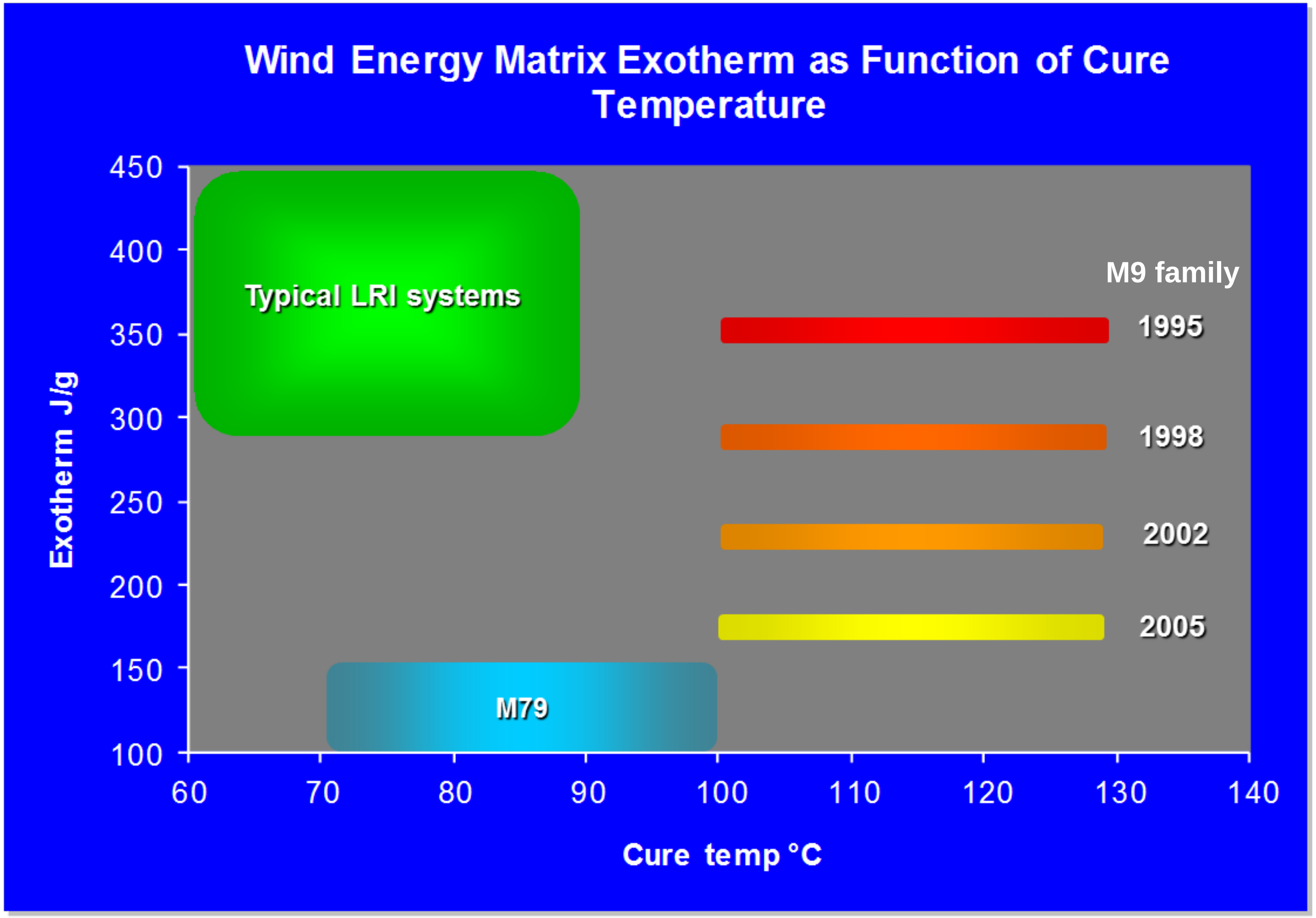
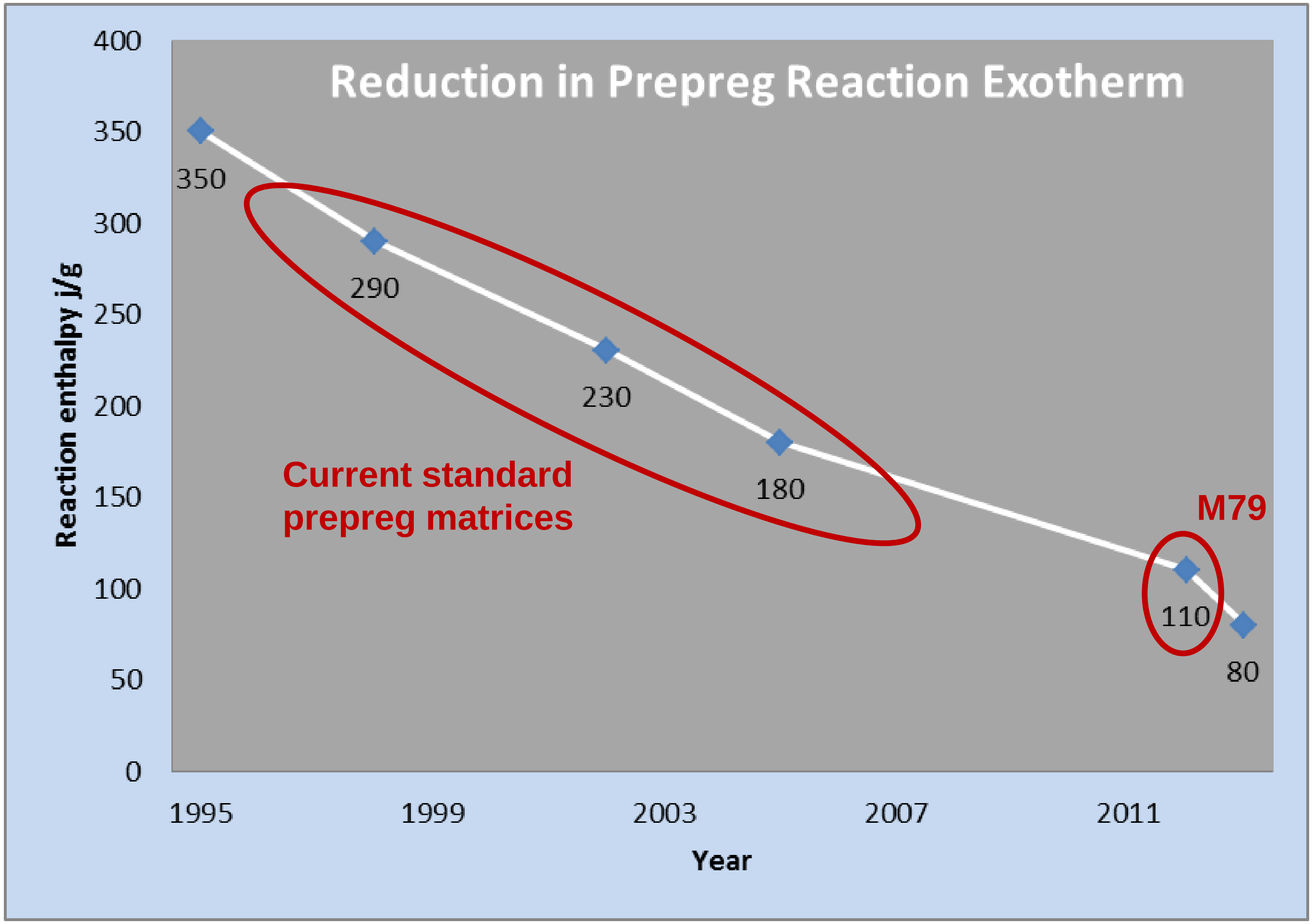
M79 Compared with Conventional Systems



Reduction in Prepreg Exotherm, 1995-2013



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

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

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M79 and Co-infusion

Co-infusion

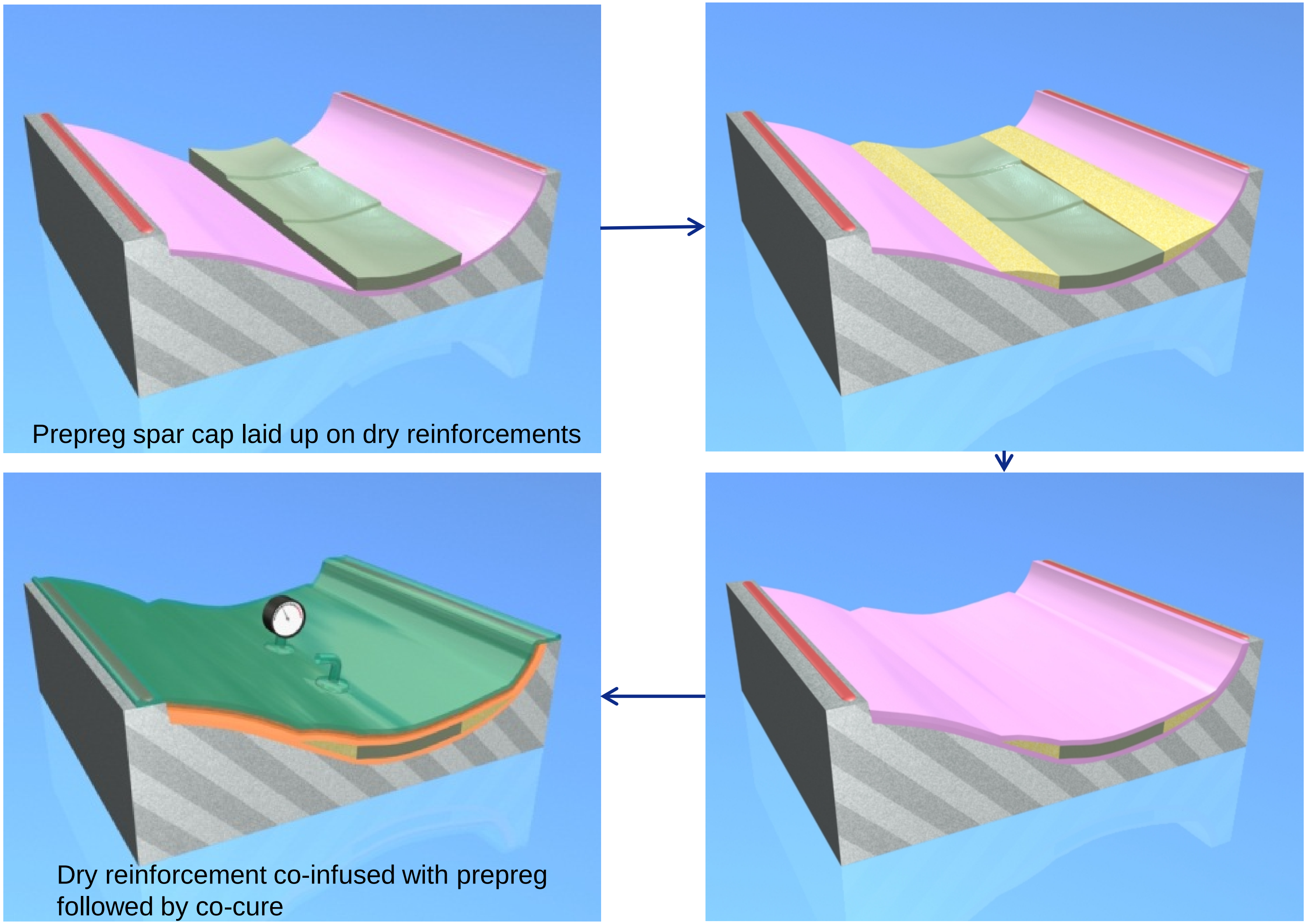
The use of prepreg and infusion technologies in the same laminate with co-cure

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



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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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