Covestro PUR Infusion resin

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Covestro PUR infusion resin

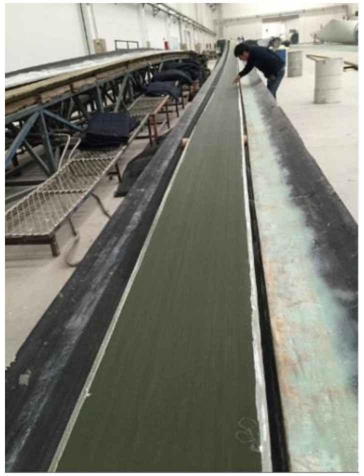
Main characteristic

- **Low viscosity**
- **Fast curing**
- **Color change indicating degree of cure**
- **Low exotherm**
- **Excellent mechanical properties**

Proven industrial feasibility

In April 2016, 1.5MW wind blade (37.5m, ~5800kg) was made with Covestro polyurethane resin

Blade components



Spar cap
PU resin
44 layers
UD1200

+

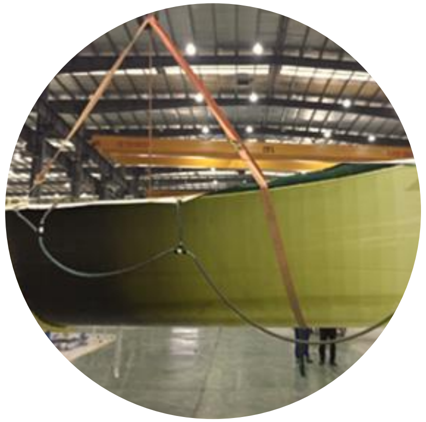
Shear web
PU resin
PVC Foam
Biax l800

+

Blade shell
PU resin
max.110 layers
UD, Biax, Triax
PVC foam
Balsa wood

Full blade

14 Wind Blades made – 2 Wind up running



1 x Blade
37.5m
World First
PU Blade

4 x Blades
55.2m
Passed all
blade tests

1 x Blade
59.5m
Passed
static test

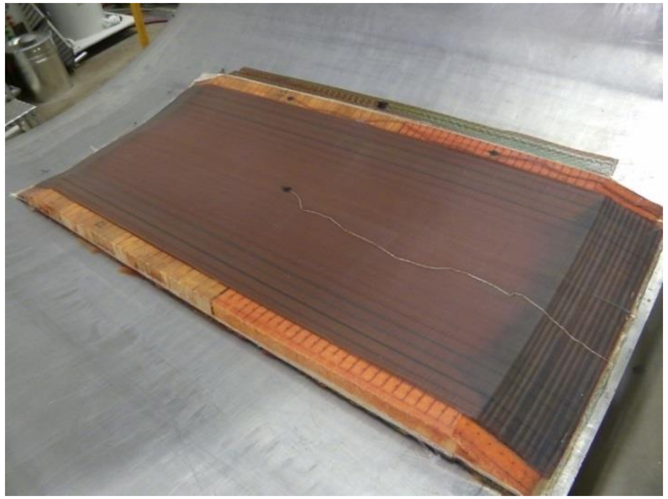
4 x blades
59.5m
Passed all
blade tests

1 x Blade
63,5m
Passed
static test

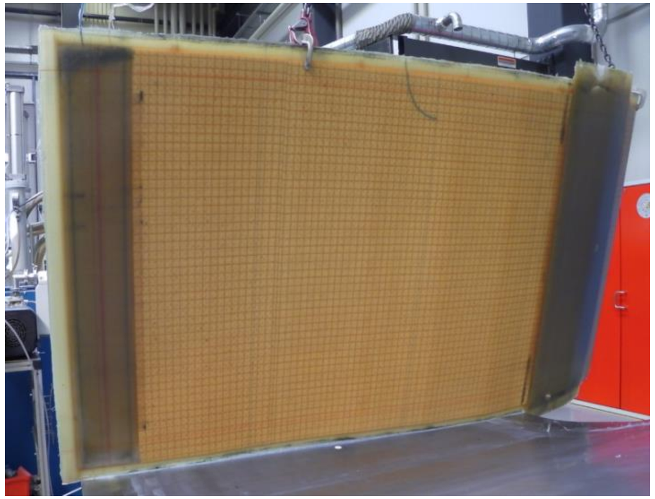
3 x Blade
68.5m

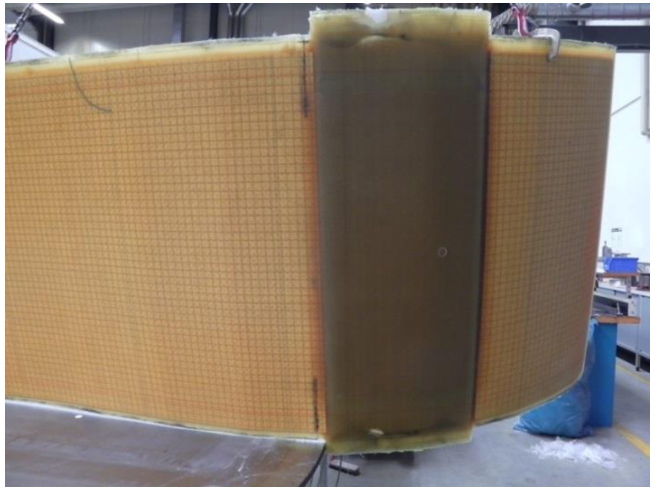
Section trials

Spar Cap



Widest Chord

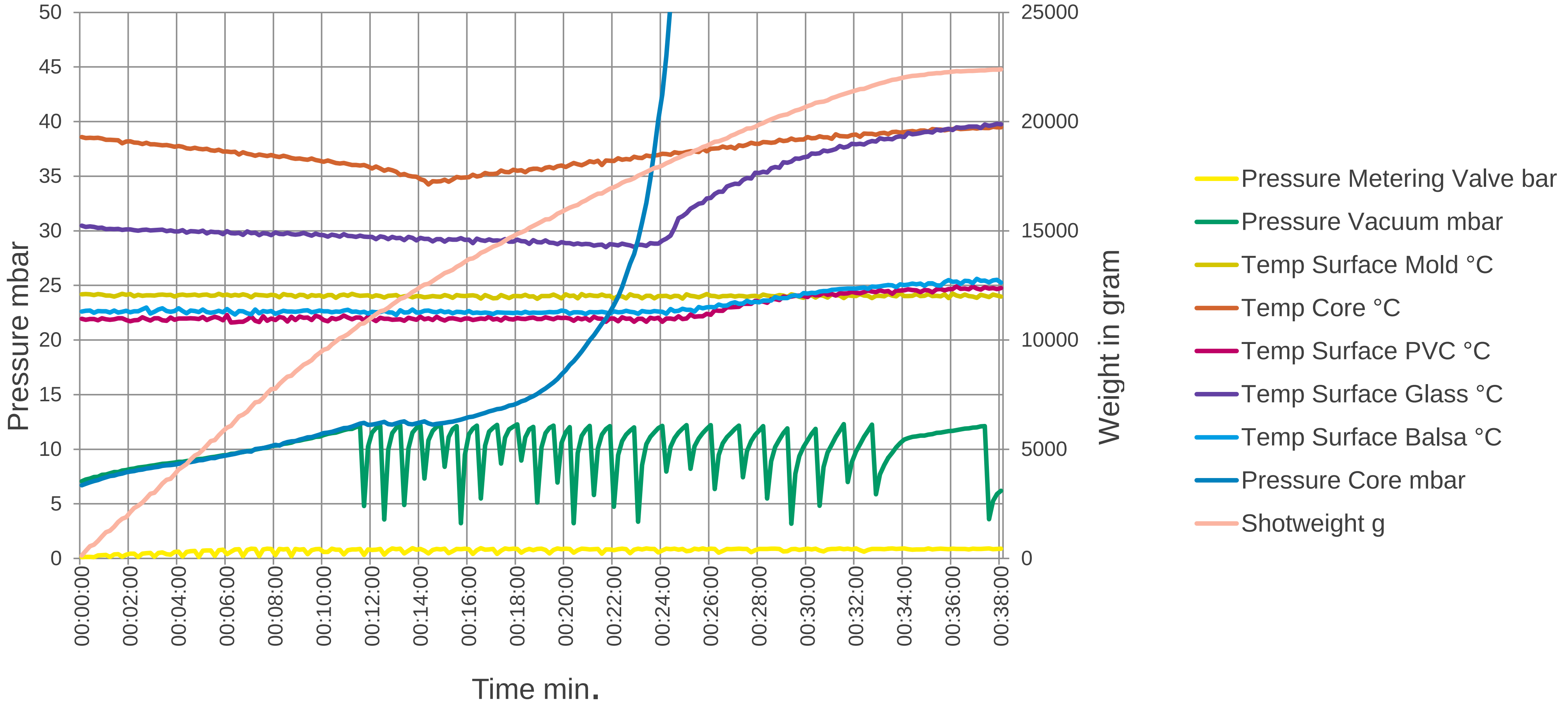




- Testing of lay up
- Testing of compatibility with other materials like:
  - Glass
  - Flow mesh
  - Core materials
  - Peel ply
  - Vap membrane
- Processing parameters

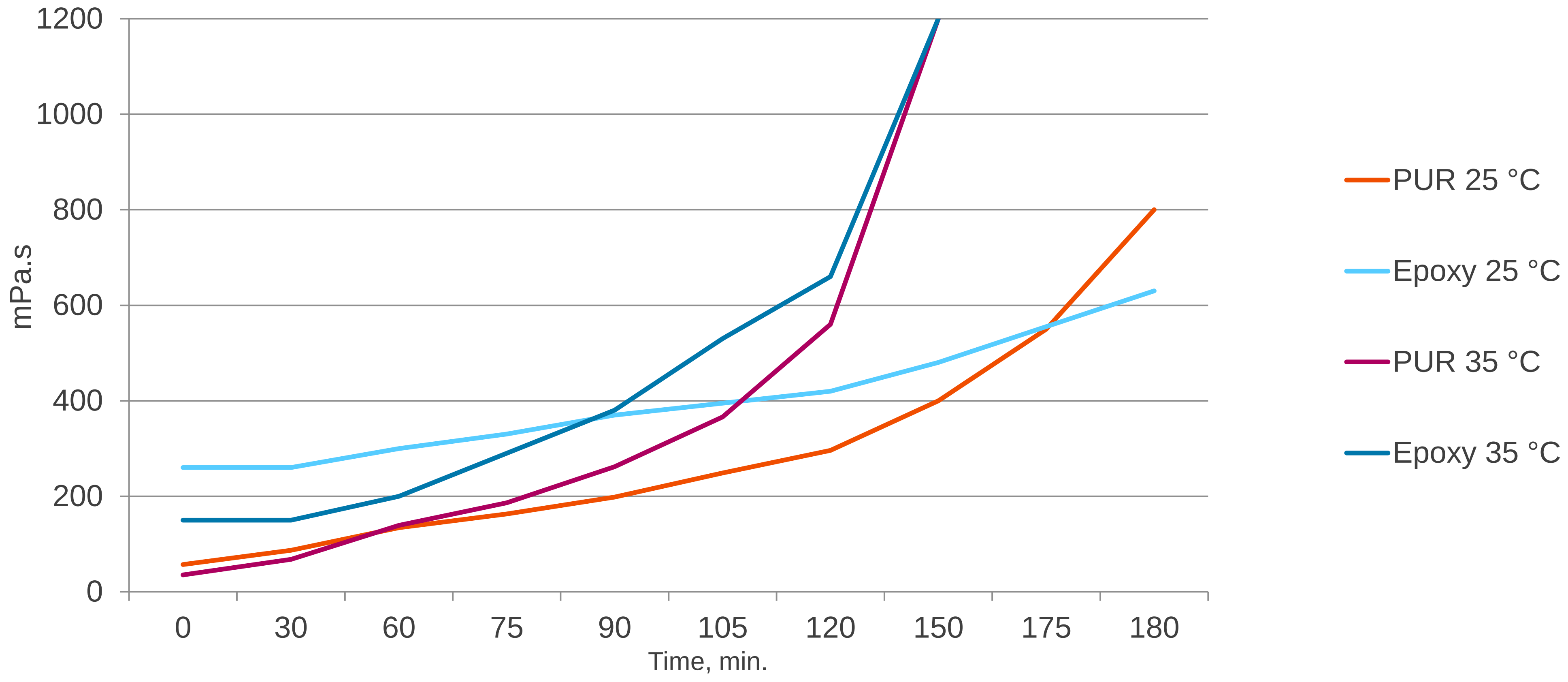
Spar Cap Section Trial

Record of infusion. Total infusion time 38 minutes.

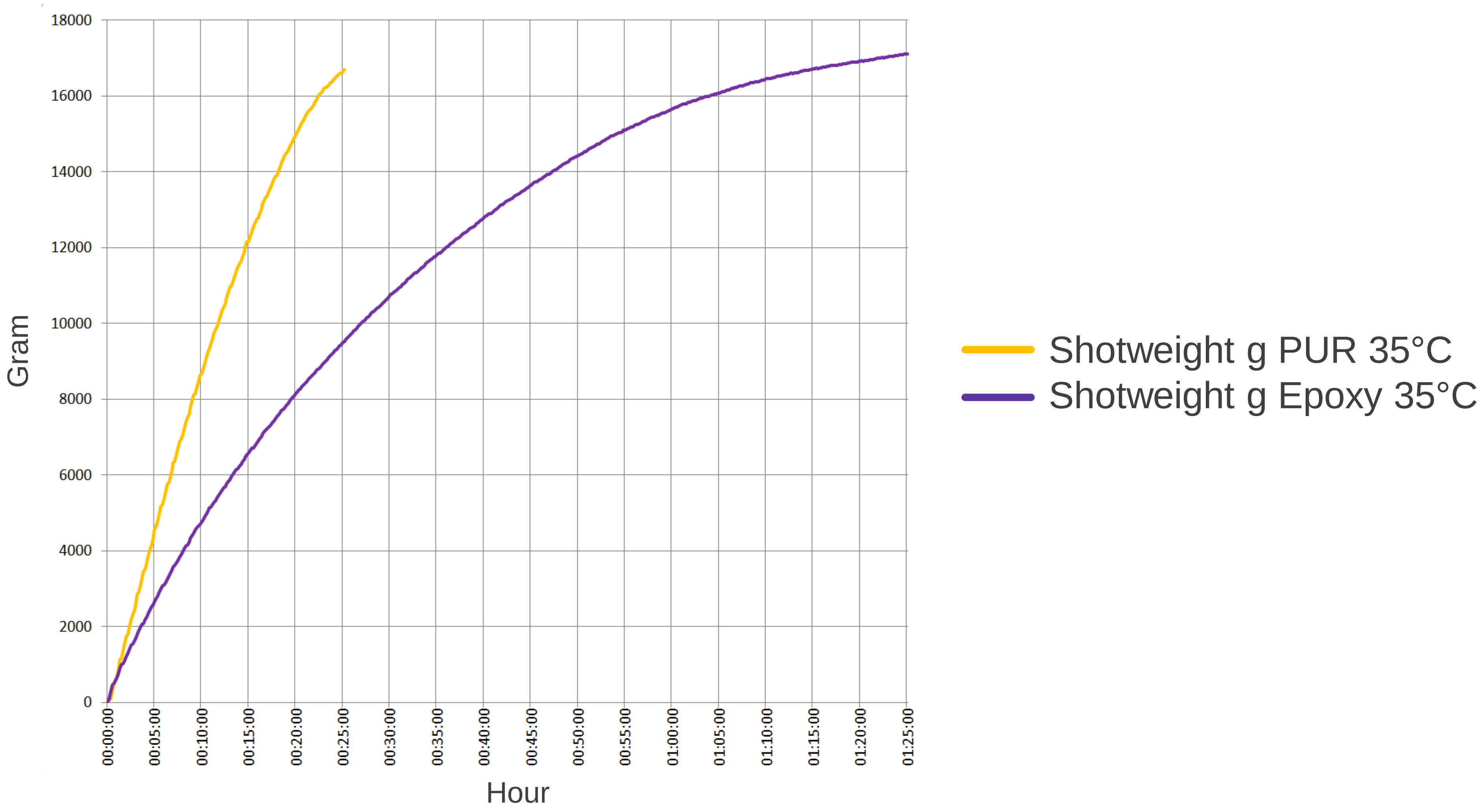


Viscosity

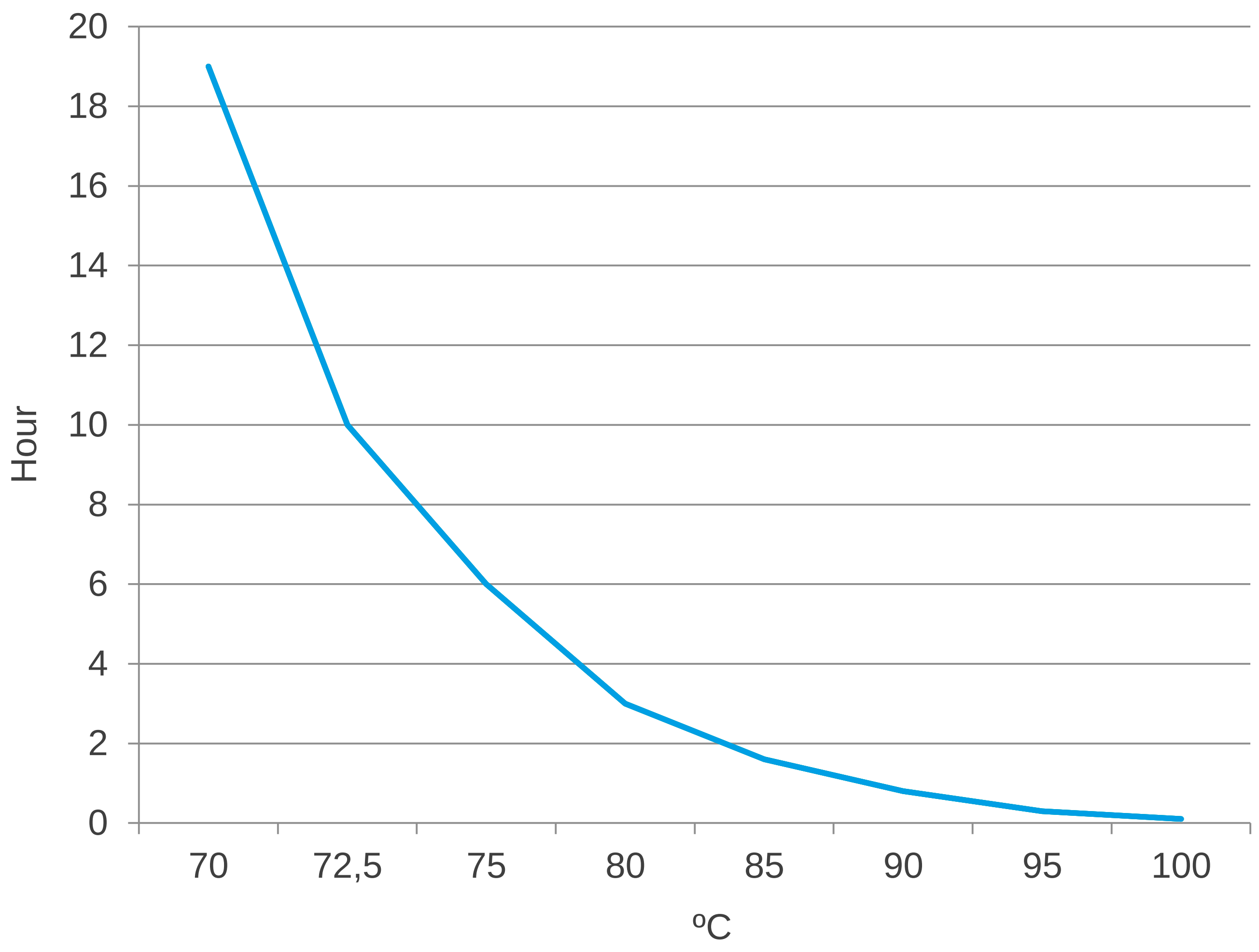
100 g. resin in constant water bath



Infusion time with PUR is in general less than 50% of Epoxy

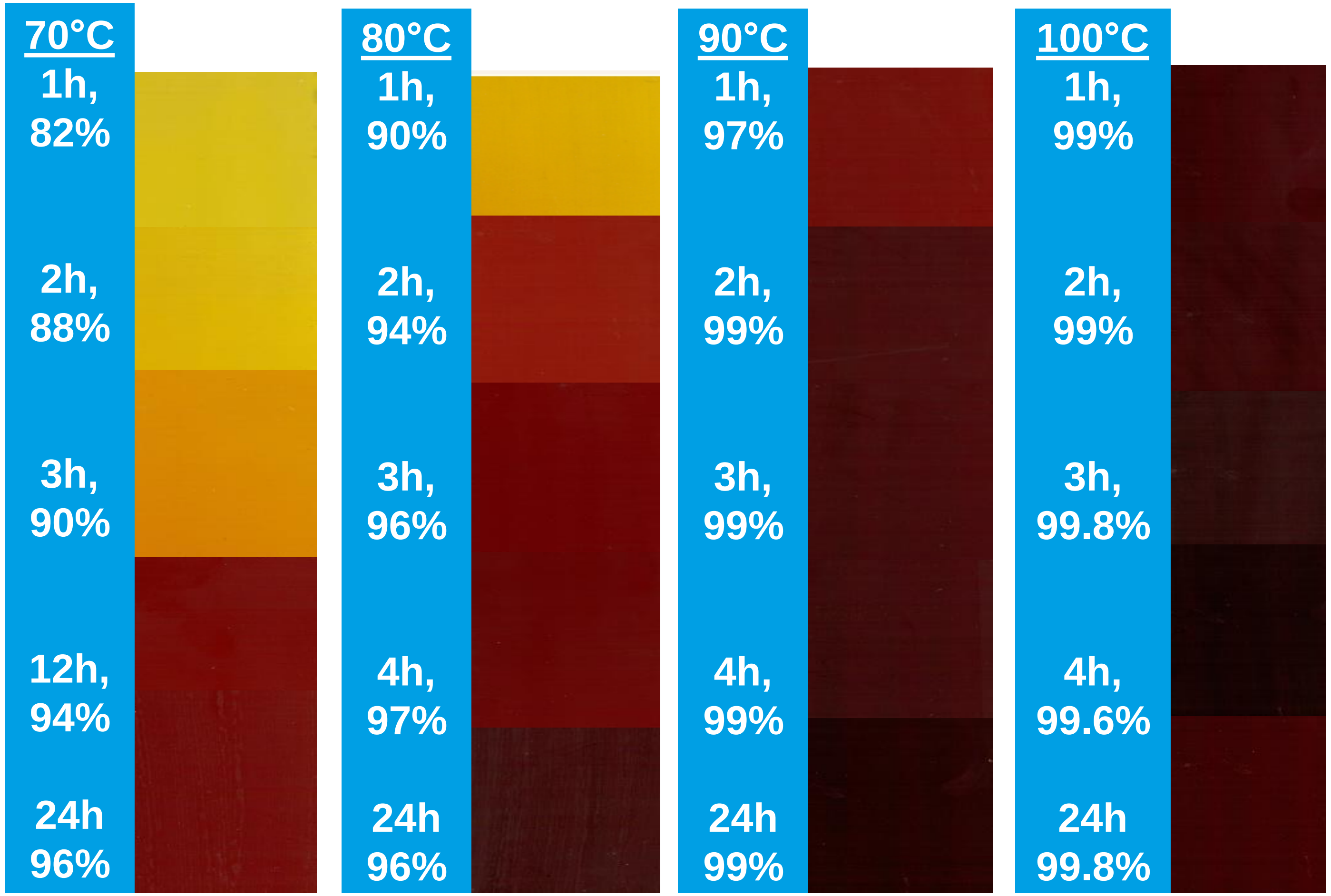


Curing time necessary to reach min. 95% conversion rate

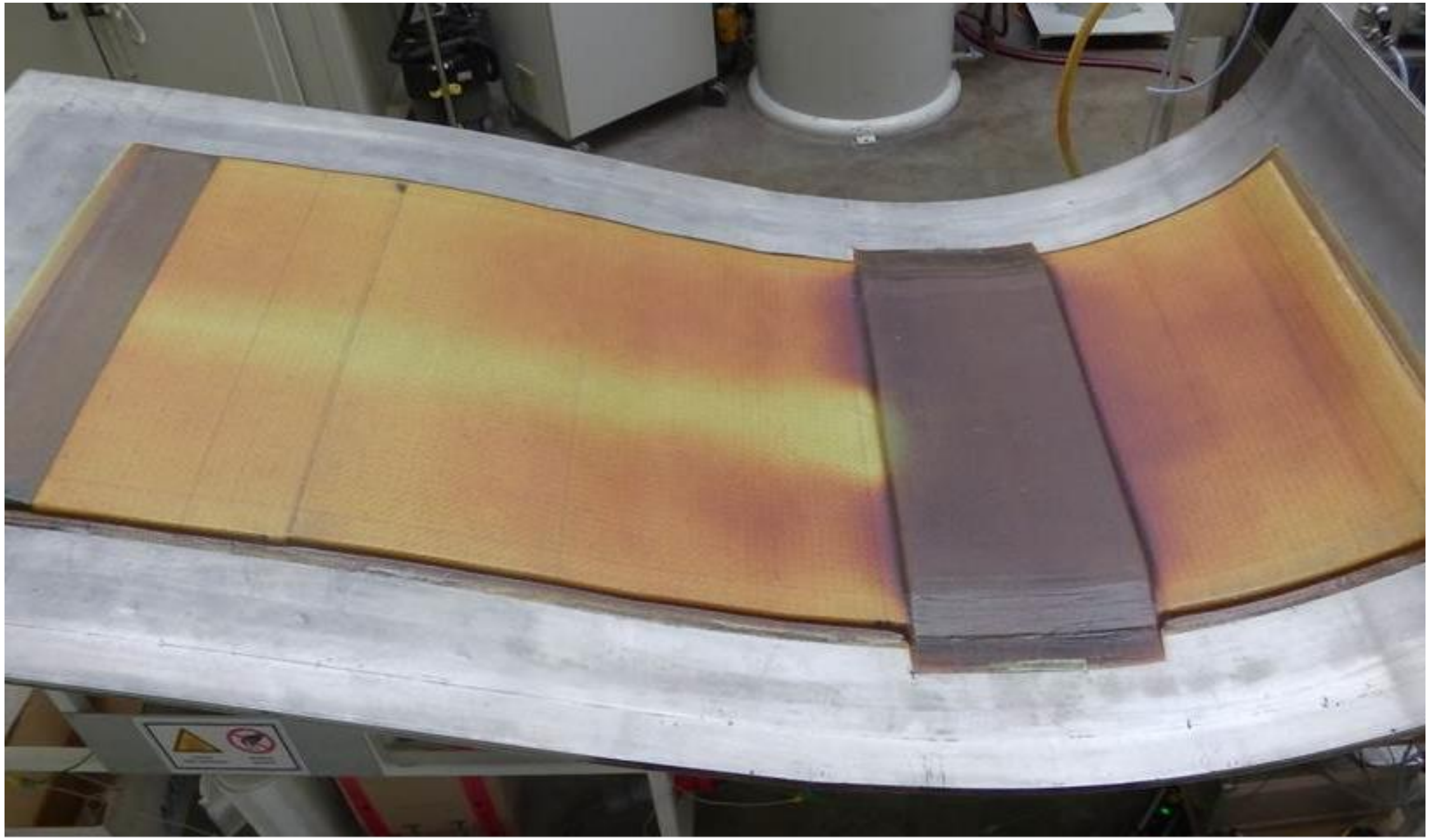


Degree of Cure and Colour Change

Colour of test plates 4mm cured 2h@60°C, then

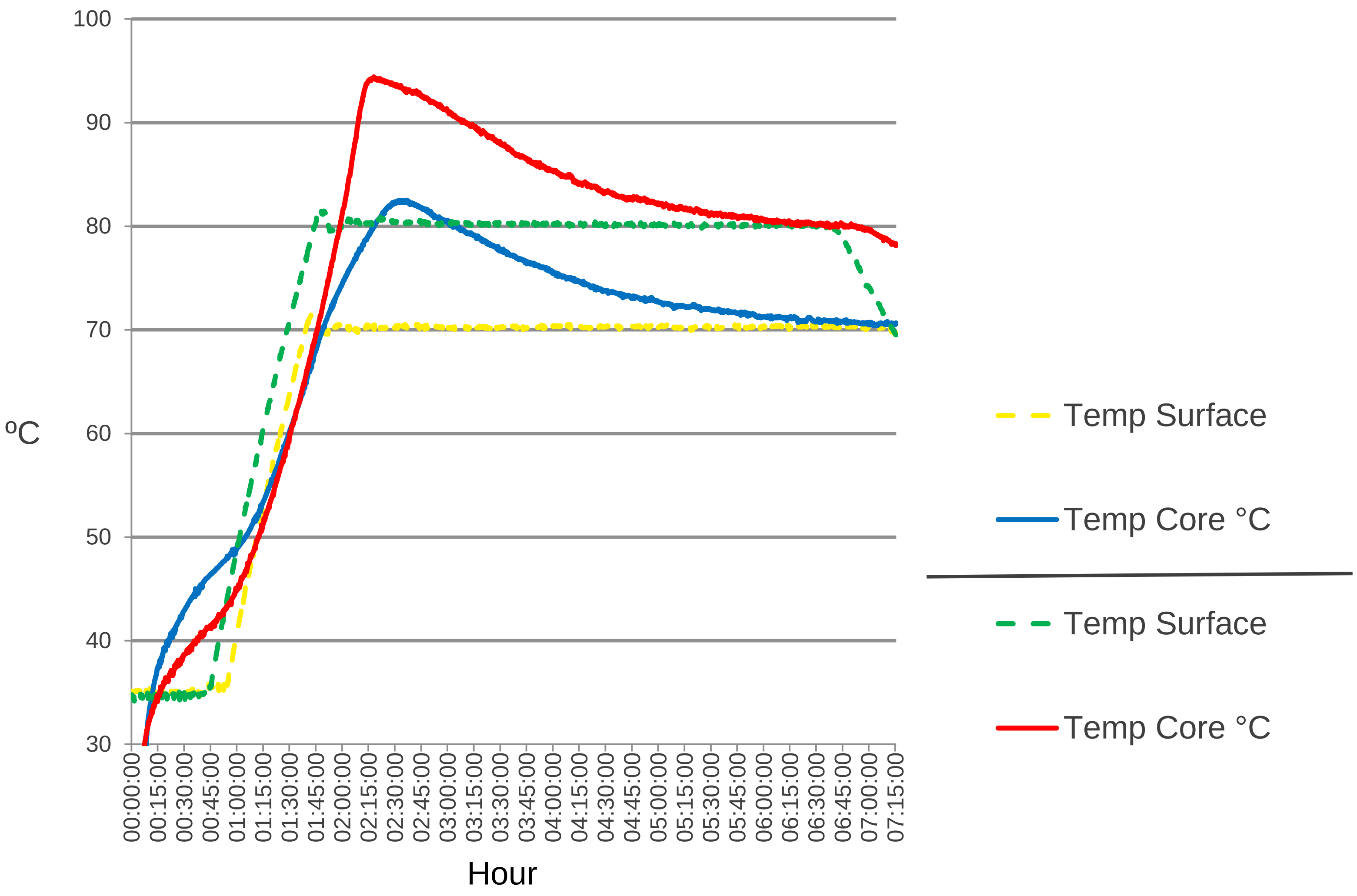


Colour change indicating degree of cure



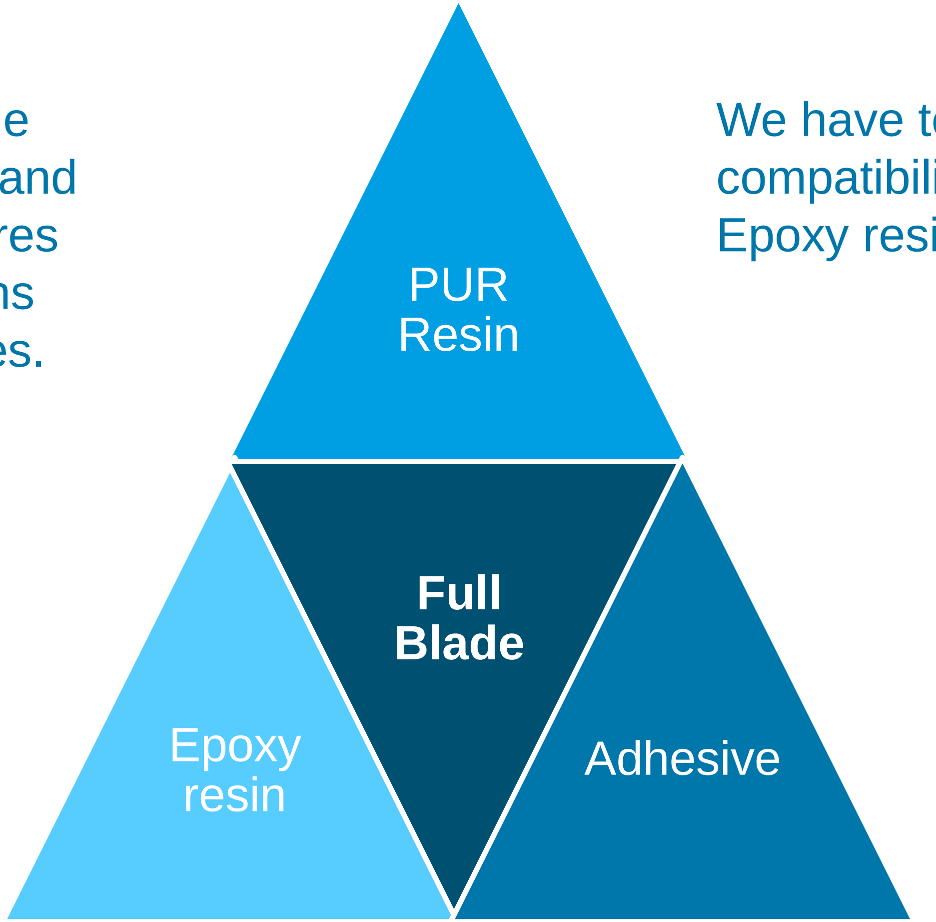
Exothermic peaks of thick layer composite

60 layer UD composite



Compatibility with other resins and adhesives

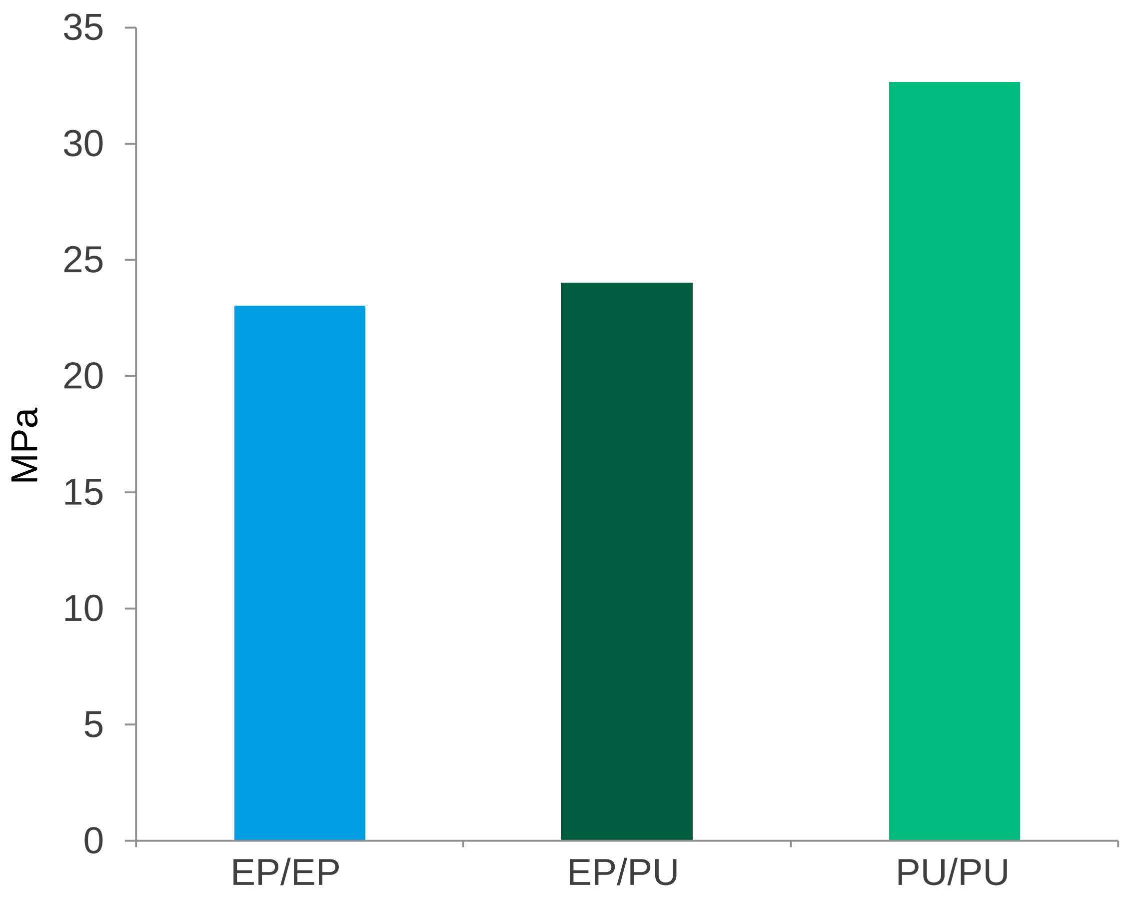
It is obvious to start using the PUR resin for the Root ring and the Spar Cap, but this requires compatibility with other resins and common used adhesives.



We have tested the compatibility with selected Epoxy resins and adhesives.

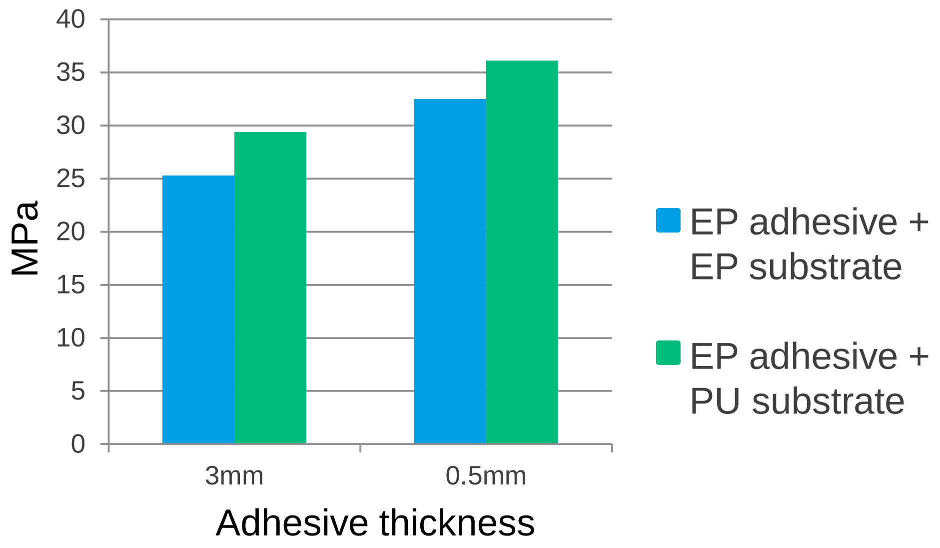
Lap shear strength between PUR and Epoxy resin

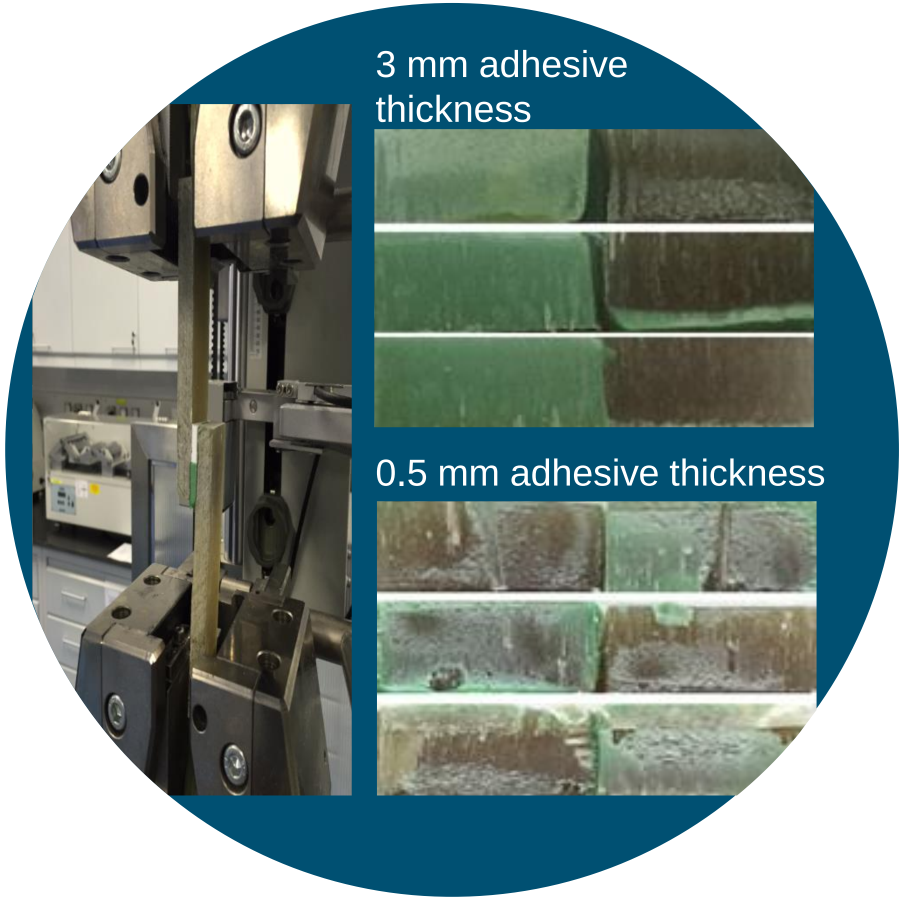
Lap shear strength between two layers of resin



Lab shear strength between substrate and Epoxy adhesive

Lap shear strength with epoxy (EP) adhesive





Properties of polyurethane resin FRP

Uniaxial glass fiber TM+ glass (EKU1200 (0) PU (TM+))

Property	Test method	Item	Unit	Data range	FWF%
0° Tensile property	DIN EN ISO 527-5 Type A	Tensile strength	MPa	1200-1400	76-78
		Tensile modulus	GPa	49-52	
		Dependent variables	%	2.0-3.0	
0° Compressive property	DIN EN ISO 14126 Form B	Compressive strength	MPa	1100-1200	76-78
		Compressive modulus	GPa	50-52	
		Dependent variables	%	2.0-3.0	
90° Tensile property	DIN EN ISO 527-5 Type B	Tensile strength	MPa	60-70	76-78
		Tensile modulus	GPa	16-20	
		Dependent variables	%	0.4-0.5	
90°Compressive property	DIN EN ISO 14126 Form B	Tensile strength	MPa	200-250	76-78
		Tensile modulus	GPa	18-22	
		Dependent variables	%	2.0-3.0	
Inter-laminar shear	ASTM 7078	Shear strength	MPa	70-80	76-78
		Shear modulus	GPa	5.0-6.0	

| **Data source: CPIC Test Report QC2017/009**

Properties of polyurethane resin FRP

Biaxial glass fiber E- glass (EKB800 (+45/-45) PU)

Property	Test method	Item	Unit	Data range	FWF%
0°Tensile property	DIN EN ISO 527-5 Type A	Tensile strength	MPa	180-200	76-78
		Tensile modulus	GPa	16-78	
		Dependent variables	%	12-15	
0°Compressive property	DIN EN ISO 14126 Form B	Compressive strength	MPa	200-240	76-78
		Compressive modulus	GPa	16-18	
		Dependent variables	%	5.0-6.0	
±45° Shear	ASTM 7078	Shear strength	MPa	60-80	76-78
		Shear modulus	GPa	5.0-6.0	

| **Data source: CPIC Test Report QC2017/009**

Properties of polyurethane resin FRP

Triaxial glass fiber E-glass EKT1250(0,+/-45) PU

Property	Test method	Item	Unit	Data range	FWF%
0°Tensile property	DIN EN ISO 527-5 Type A	Tensile strength	MPa	700-800	74-76
		Tensile modulus	GPa	30-31	
		Strain	%	3.0-4.0	
0°Compressive property	DIN EN ISO 14126 Form B	Compressive strength	MPa	700-800	74-76
		Compressive modulus	GPa	35-37	
		Strain	%	2.5-3.5	

| **Data source: CPIC Test Report QC2017/009**

We have much more data.

Some examples:

- **Ageing test**
  - 70 °C 95 % Rel. Humidity
  - 80 °C natural humidity
  - In water at 23 °C
    - Tensile module
    - Tensile strength
    - Mass change

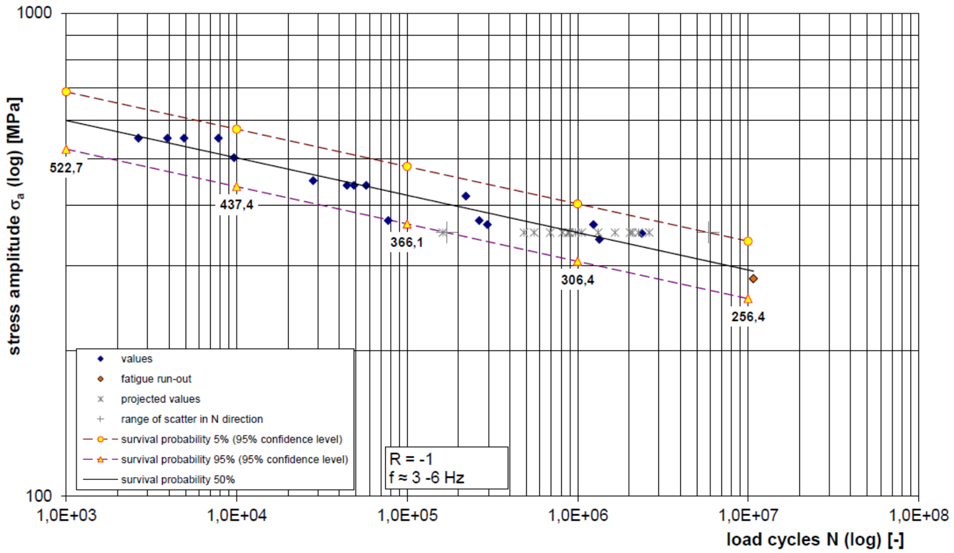
- **Test of composite**
  - Fatigue R = -1, R = 0,1
  - Tensile
  - Compression
  - Interlinear shear

- **Impact strength**
- **Tg. by DMA, TMA, DSC**
- **Conversion rate by DSC**
- **Strength. vs. temperature**
- **Water absorption**
- **Shrinkage**
- **Tensile strength**
- **Compression strength**
- **Creep**
- **Shear strength**
- **Elongation**

Test results

Fiber reinforced composite – fatigue test R= -1 tension – compression

Polyurethane

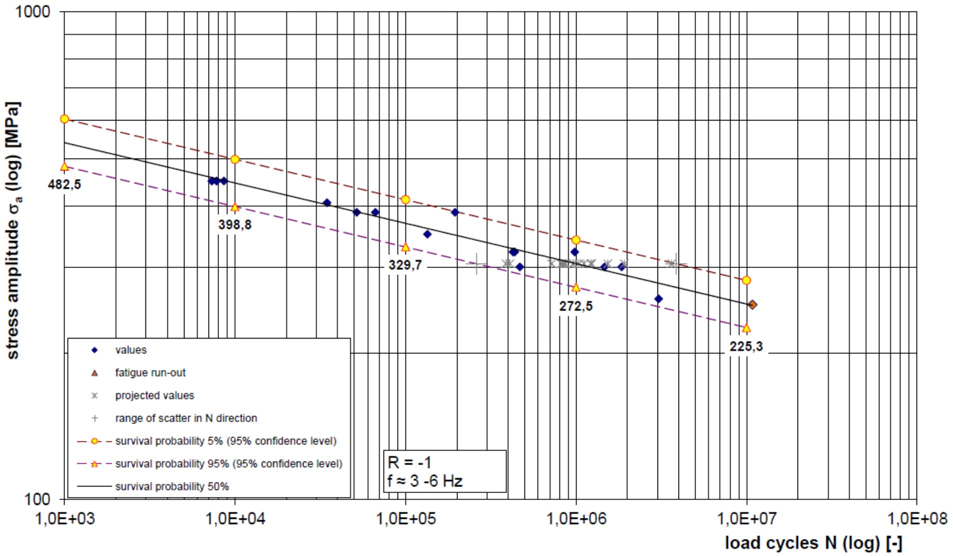


Statistical evaluation of the S-N curve, R = -1, test series B027/16-PUR04-SNC

Slope exponent of the S-N-curve:	12,9
σ_a at 10^6 load cycles (50 % S-N-curve) [MPa]:	351,3
Regression equation (50 % S-N-curve):	$y = 1022{,}5 \cdot x^{-0{,}0773}$
Coefficient of correlation:	r = -0,951
Quantile factor k_s (scatter of σ unknown) for n = 16:	2,52

Regression values of 95 %-survival probability S-N curve with 95 % confidence level

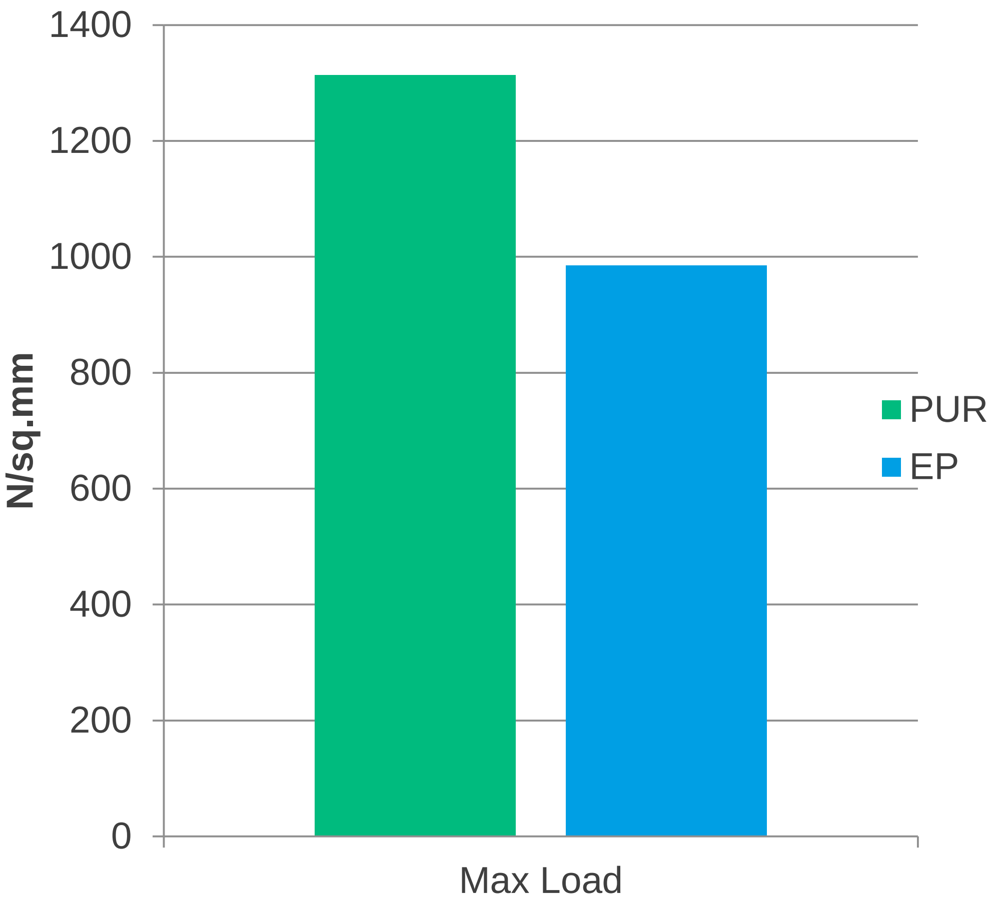
Epoxy

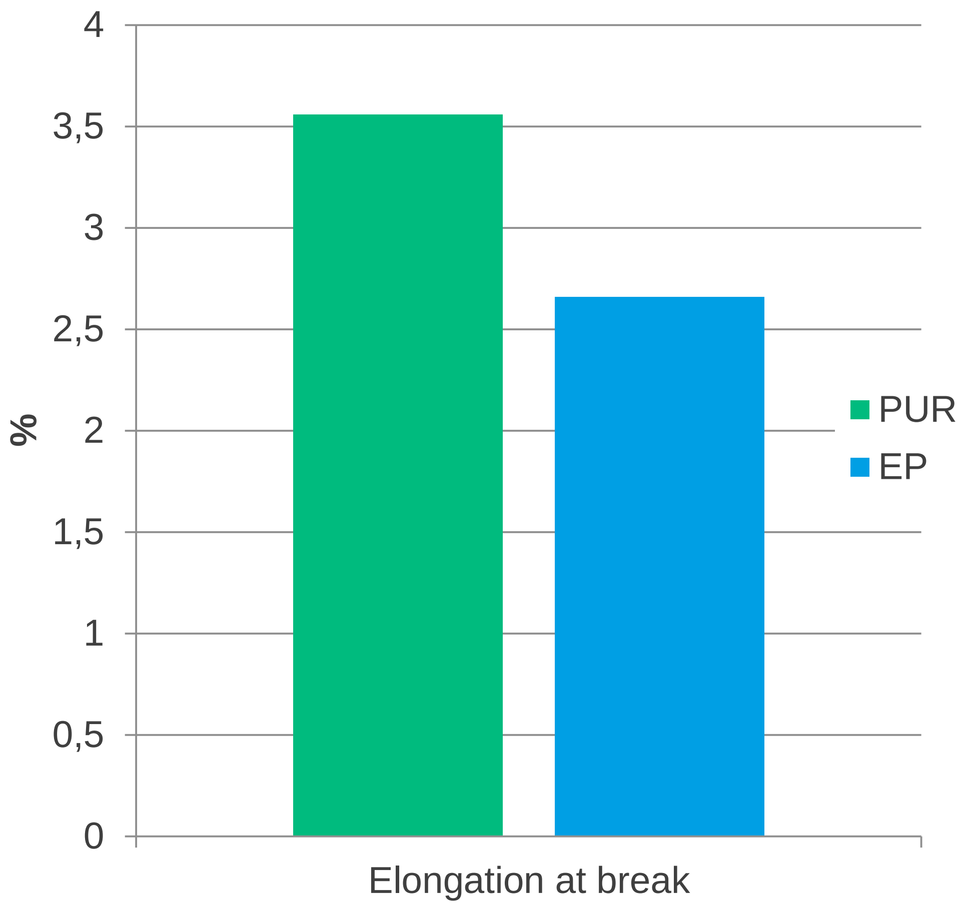


Statistical evaluation of the S-N curve, R = -1, test series B027/16-EP02-SNC

Slope exponent of the S-N-curve:	12,1
σ_a at 10^6 load cycles (50% S-N-curve) [MPa]:	304,7
Regression equation (50% S-N-curve):	$y = 954{,}9 \cdot x^{-0{,}0827}$
Coefficient of correlation:	r = -0,972
Quantile factor k_s (scatter of σ unknown) for n =16	2,52

Three point bending



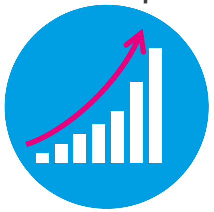


Longer and longer blades –

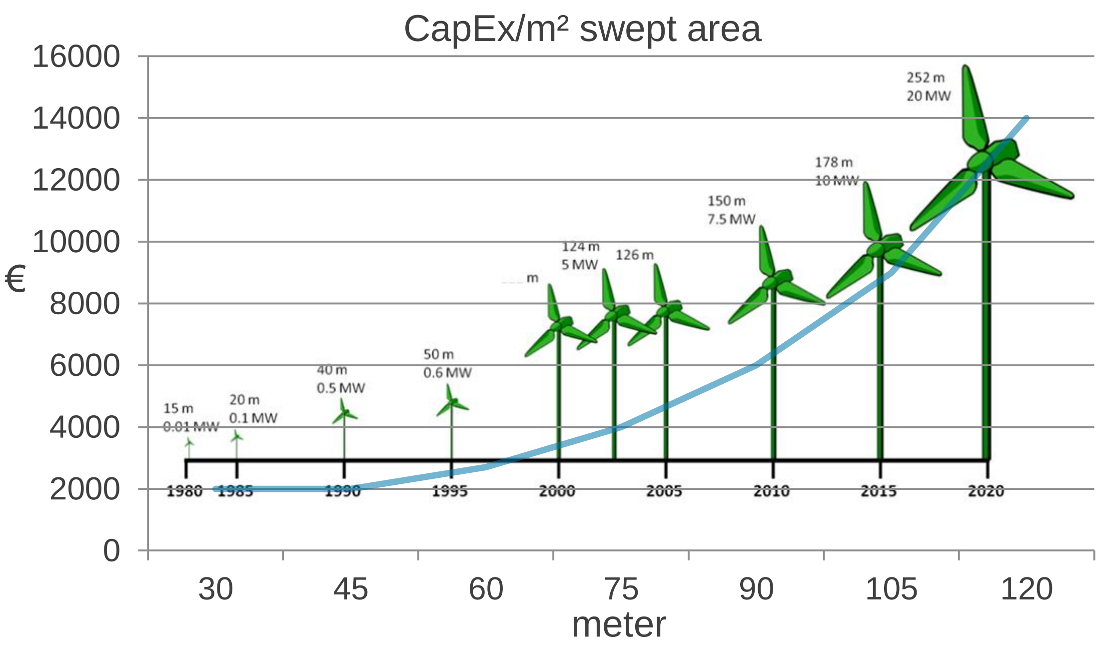
– leads to exponential increase of the cost

Blade weight

Space required



Mold cost



| **Source SGRE presentation AMI conference**

Value for our customers

Low viscosity

Fast curing

Better properties

Improved Productivity

- Low viscosity, faster infusion speed
- Faster curing, improve productivity, less investment
- Lower exothermic

Faster production leads to reduced CAPEX needs

Superior Performance

- Superior interface with glass fabric
- Excellent mechanical performance
- Superior fatigue resistance

Enables lighter blades & lower material cost

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Thank you for your attention

Kim Klausen
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