Material Characterisation:
From R&D to production
A case study

Dr Nikos Pantelelis
Managing Director

Synthesites SNC
Avenue Lycée Français 5,
1180, Uccle, Belgium
Tel: +**32 (0) 472 201 382**
e-mail: be@synthesites.com
website: www.synthesites.com

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Major achievements

- 10 years in operation and 3 sites in Greece, Belgium and UK. Small company with large customers.
- Leading the technology in process monitoring for advancing composites manufacturing
- Working with top-class customers worldwide and have a very good reputation/ customer satisfaction rate.
- Currently working with 3 large wind turbine and one aerospace manufacturer to apply our technology in production

Working closely with manufacturers

AIRBUS HELICOPTERS, BOMBARDIER, GKN, AERnnova, HUTCHINSON, GE Aviation, SUZLON POWERING A GREENER TOMORROW, faurecia, Audi, schunk, TOYOTA Let's Go Places, SIEMENS, NORDEX, acciona Windpower, Vestas

R&D Centres and Universities

DLR, TUM Technische Universität München, FIDAMC, RWTH AACHEN UNIVERSITY, MONTAN UNIVERSITÄT, NATIONAL COMPOSITES CENTRE, University of BRISTOL, NPL, nlr Dedicated to innovation in aerospace, n|w University of Applied Sciences and Arts Northwestern Switzerland, eurecat Centre Tecnològic de Catalunya, tecnalia Corporación Tecnológica, AIMPLAS INSTITUTO TECNOLÓGICO DEL PLÁSTICO, MONDRAGON UNIBERTSITATEA, aimen CENTRO TECNOLÓGICO, CEMCAT, LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY LIST

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EC Funded R&D projects

Completed

iREMO: intelligent Reactive Moulding (2009-2012)
RTM, Light RTM and Infusion, Glass and carbon fibre, epoxy and polyester

MAC-RTM: Microwave curing (2011-2013), Fraunhofer ICT and Aimplas

Ecomise: First-time right composites manufacturing (2013-2016)
Partners: DLR (CO), FIB, Bombardier, Hutchinson, Airborne, Loop, Dassault Systemes, NLR
RTM and RTI, Glass and carbon fibre, epoxy

Coaline: Injection pultrusion with microwave curing and injection of coatings (2013-2017)
Fraunhofer ICT, Aimplas, Resoltech, Rescoll, Acciona

On-going

Recotrans: Multimaterial recyclable manufacturing for the transportation industry (2017-2021)
Partners: Aimplas (CO), Fraunhofer, Daimler, Far UK, Stadler, INEA, Gestamp, Arkema
RTM and pultrusion, Glass and Carbon fibre, reactive thermoplastic for automotive and rail applications

SuCoHS: High temperature aerospace applications (2018-2021)
Partners: DLR (CO), Bombardier, Aernnova, NLR, ONERA, Apodius, Collins Aerospace, L-up
Autoclave, Carbon fibre, High temp aerospace resins

SuCoHS in a nutshell

- Sustainable and Cost Efficient High Performance Composite Structures demanding Temperature and Fire Resistance
- Coordinator: German Aerospace Centre (DLR)
- SuCoHS looks into expanding the use of composite materials and providing high performance against **thermal, mechanical and fire loadings** for:
  - high performance primary structures within aircraft wing and fuselage components
  - and for aircraft interior shells in compliance with FST regulations
- SuCoHS investigates new:
  - Materials
  - Manufacturing technologies
  - Analysis methods and tools
  - Structural concepts
  - Sensor systems
- To cater for the lifecycle of a product
  - from design
  - through manufacturing
  - to operation

40 Researchers and engineers

14 Partners

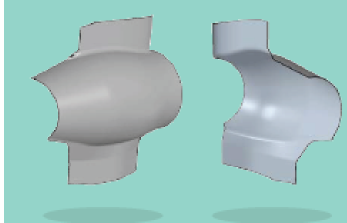
36 Months

7 European Countries

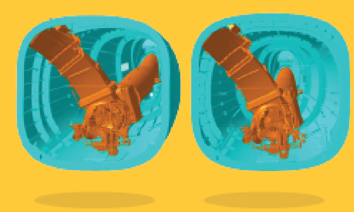
571.5 person-months

EU contribution 6 638 939 €

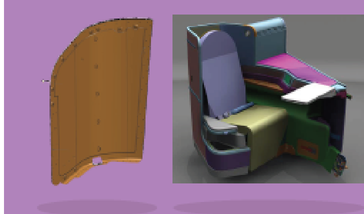
High temperature nacelle component
(Bombardier)



Tail cone panel substructure
(Aernnova Engineering)



Composite aircraft interior shell
(Collins Aerospace)



These developments will **reduce weight, costs and energy consumption** while **increasing performance and reliability**

Recotrans in a nutshell

RECOTRANS Project aims at implementing technologies and design solutions to deliver vehicle weight savings without raising prices.

Production time reduction from **10 to 50%** by means of the reduction in polymerization time.

Energy saving by at least **10%** because of the reduction in the temperature losses and the reduction of cycle time.

Cost reduction up to **35%** due to weight reductions which involve a reduction in operational costs, reduction in raw materials needed for joining metal structures and reduction in maintenance cost.

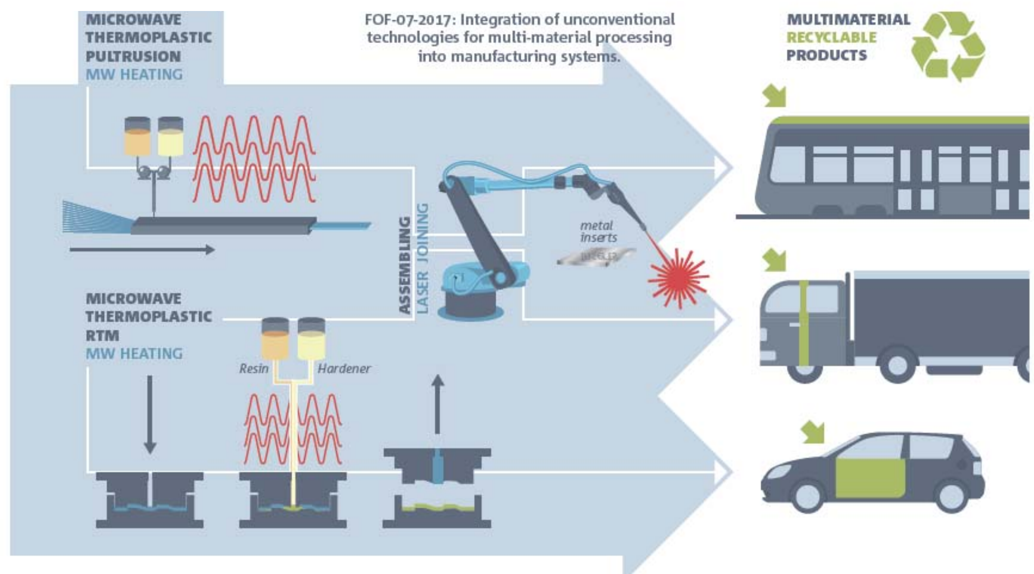
AIMPLAS PLASTICS TECHNOLOGY CENTRE
STADLER
Gestamp
Mercedes-Benz
ARKEMA
INEA
TECNOCLAD
synthesites
Far COMPOSITES
CTAG
ITU
Fraunhofer ICT
POLYMEC

7 Countries

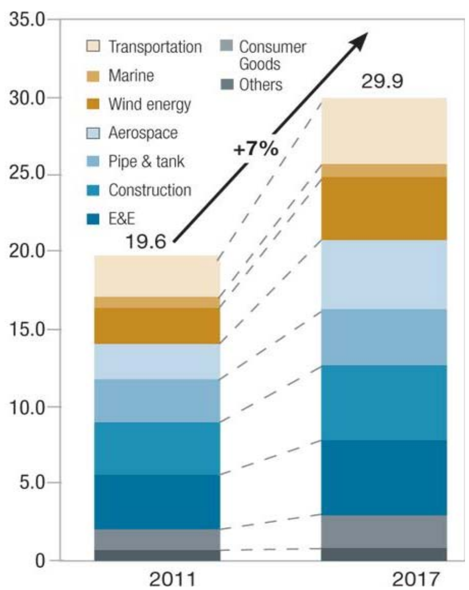
13 Partners

42 Months

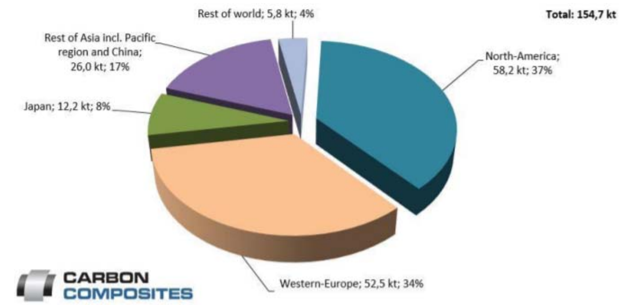
4.5 Million Euros

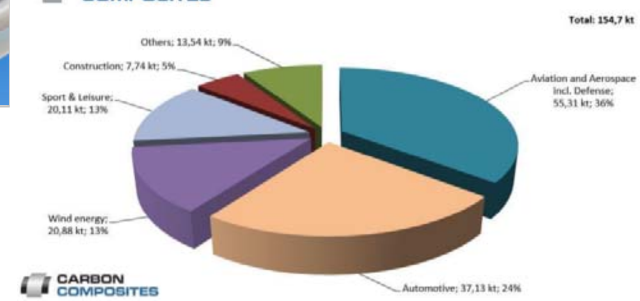


Composites' Fast Growing markets



Wind Energy	Automotive	Aerospace
		





Facts

- Composites are complex living materials that are transformed onsite.
- No manufacturer monitors what is happening into their production.
- Mass production is still a challenge for many manufacturers.

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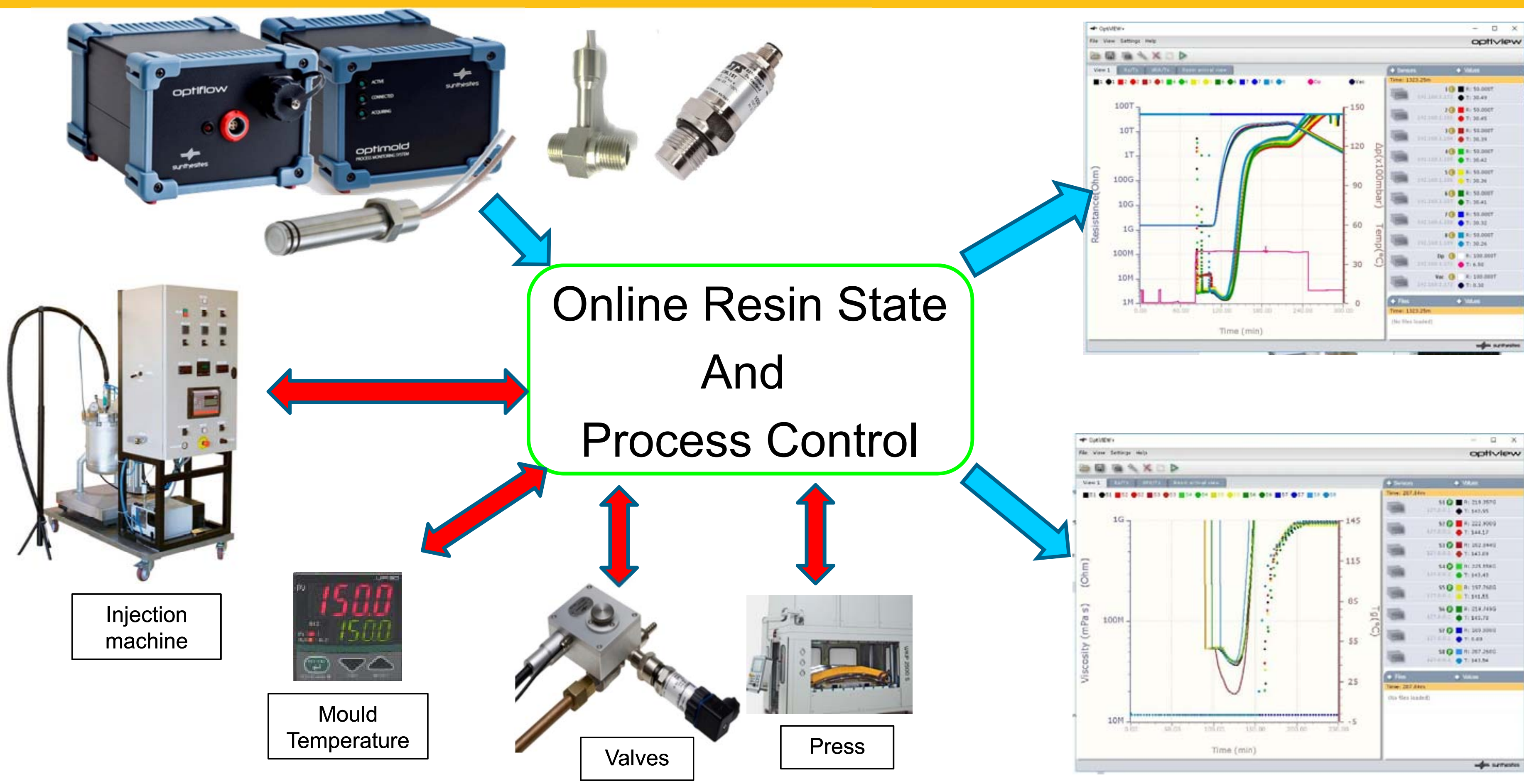
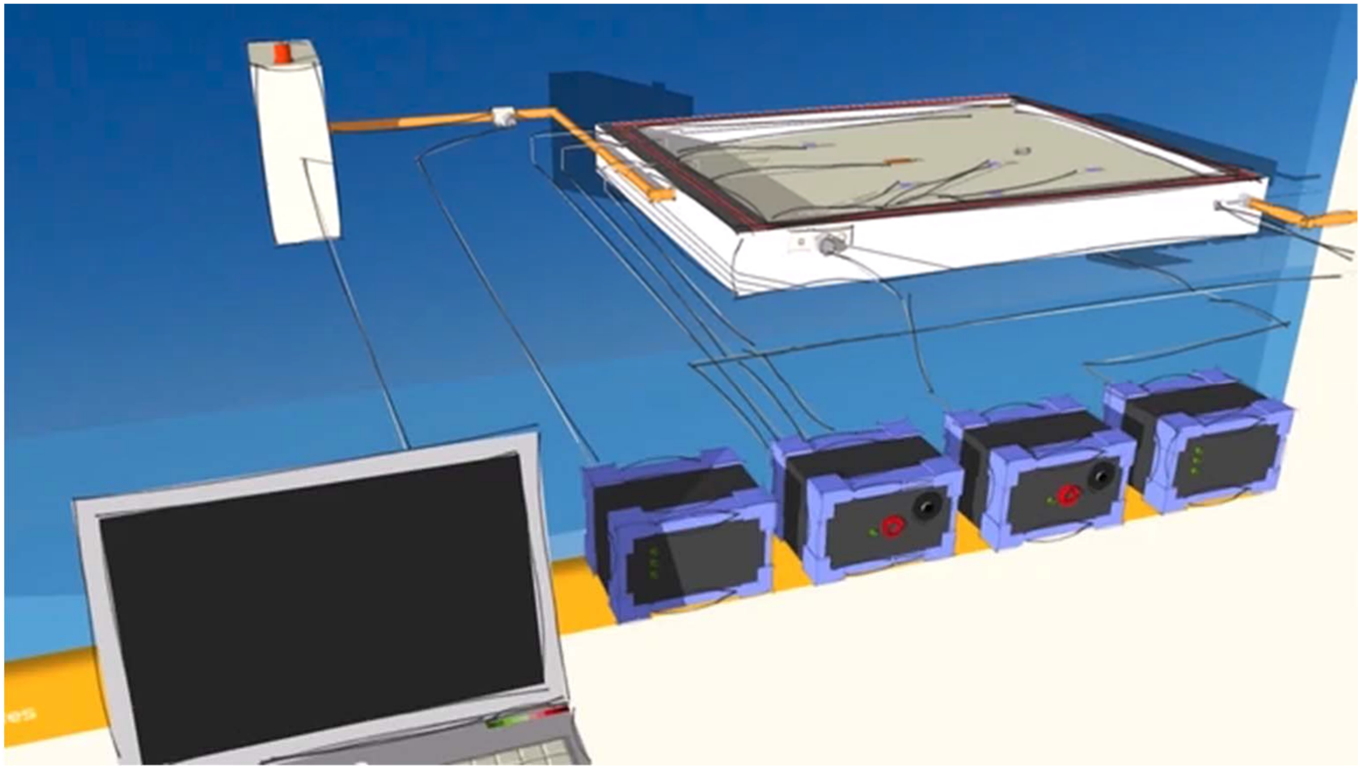
Our Approach



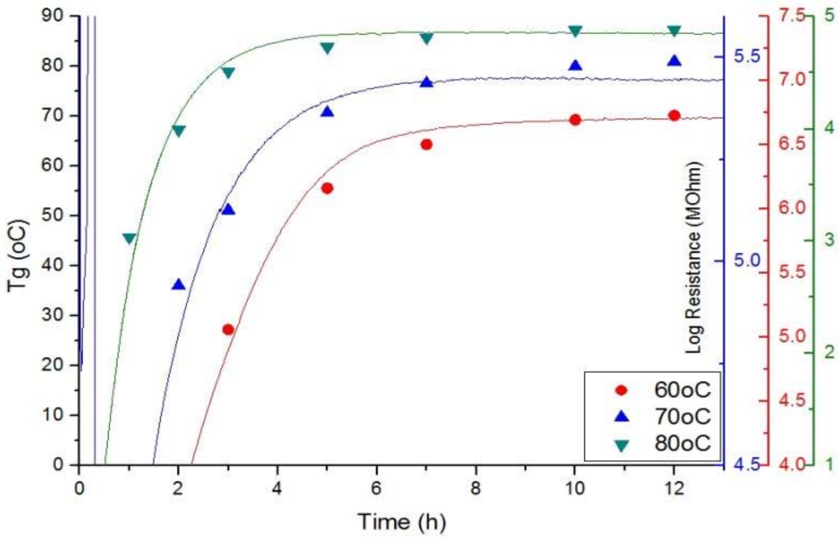
How it works



Benefits

Synthesites technology can help composites manufacturers to:

- Reduce cycle time
- Ensure quality and traceability
- Optimise resources online
- Ensure the benefits of Industry 4.0
- Shift easier to new and improved materials
- Reduce time-to-market
- Reduce trial-and-error
- Increase in-depth knowledge of production



Correlation of resistance and Tg at isothermal runs.

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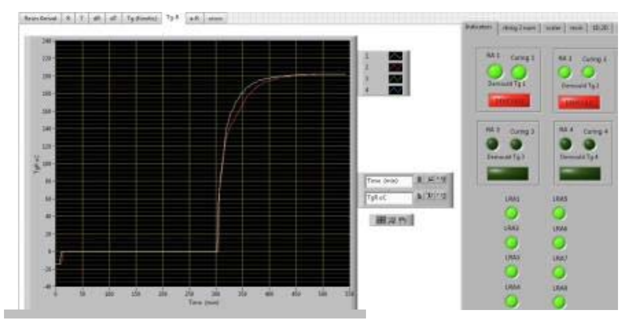
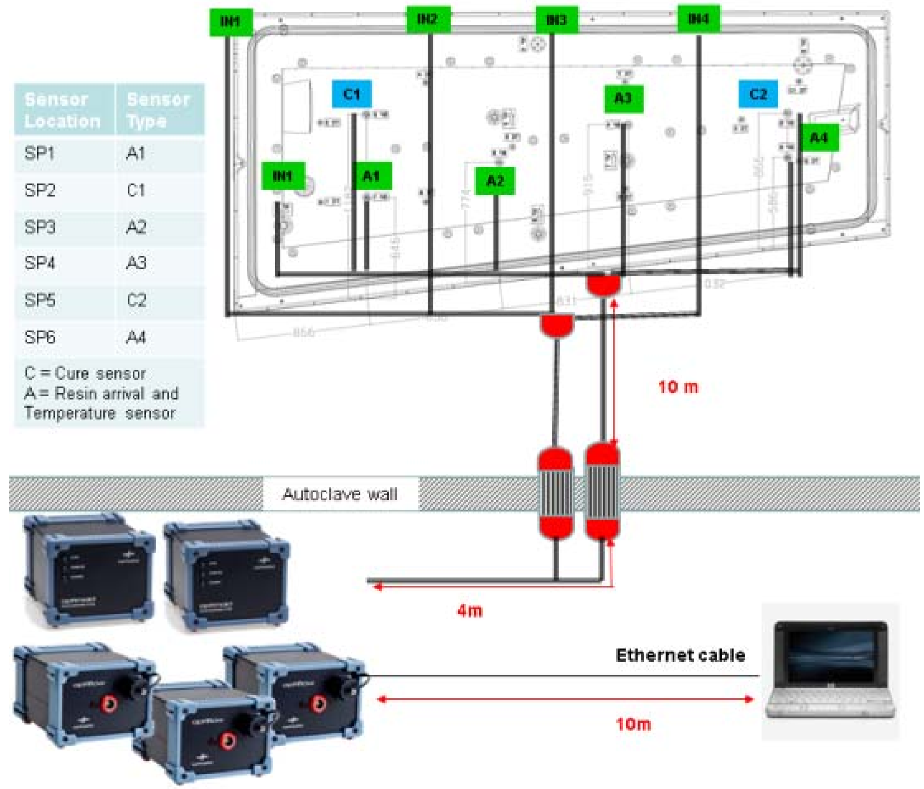
Demonstration in Aerospace @Bombardier Belfast

Wing Production Unit, Bombardier Shorts, Belfast,
ECOMISE FP7 project (2016)

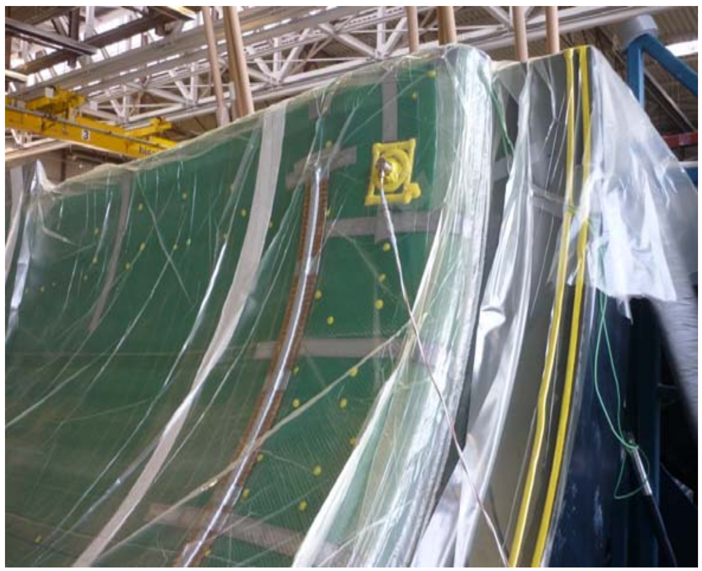


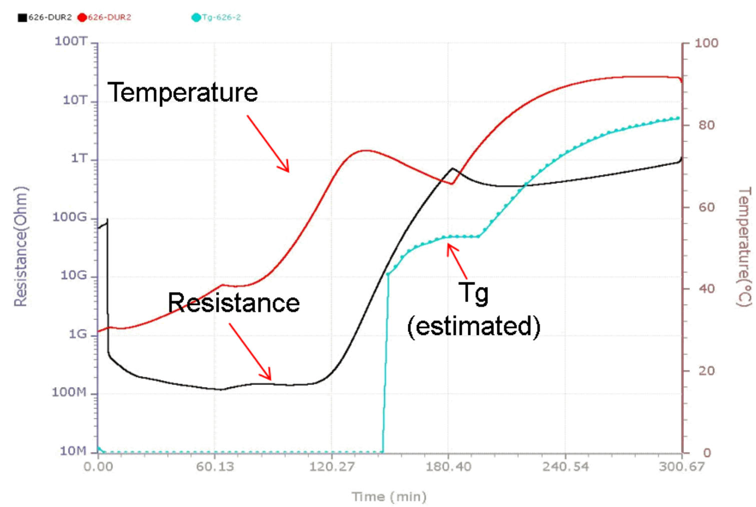


Real-time Tg prediction and demoulding decision based on targeted Tg.

Production Trials
@Wind Turbine Blade production

New vacuum-bag durable sensor attached in a half shell
@ Carbon Rotec 2017





In collaboration with CARBON ROTEC COMPOSITE TECHNOLOGY

Stop heating when Tg reaches e.g. 60^{o}C at 5 critical locations (lagging curing zones)

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Quotes from the market

Positive

- "Huge potential in using this technology in our production"
- "Why there are not many publications on this technology?"
- "Three years I am trying to promote your technology internally in the company, Finally I did it!"

Puzzled

- "This technology is in the centre of production so it brings together several departments"
- "How it works? We need to verify it ourselves."
- "Is it robust enough for production?"

Negative

- "We 've used something similar and didn't work"
- "Too expensive"
- "Who needs it?"
- "We don't want to reduce manufacturing time as the labour syndicates will not like it"

Characterisation

- for Flow (viscosity, permeability)
- for Cure (degree of cure, Tg)

(Resin suppliers provide only basic information)

Modeling

- Flow models are based on Darcy law for flow through porous media! Huge efforts from Academia to model the permeability tensor have not been paid off!
- Cure modeling is very limited and mostly for aerospace manufacturing.
- Lack of using real experimental data to improve model accuracy!

In practice

- Information drawn mainly from technical datasheets. Only in aerospace there is more in-depth knowledge and available resins are limited.
- In filling, trial-and-error is king!
- 95% of the manufacturers follow recommended recipes which may be extended in production. In general 30% curing time is added on top of the already conservative resin manufacturer recipes.
- Online quality control is very much a taboo. Only temperature is being monitored.

Challenges when using cure kinetic models online

- Kinetic models depend only on (measuring) temperature so resin or batch-to-batch deviations cannot be accounted for
- Significant resources and knowledge to develop new kinetic models
- They are well established in aerospace but hardly used in any other application.
- They are accurate enough mainly at the end of cure but :
    - Questionable accuracy in non-isothermal cases or even for well established aerospace resins
    - Additional errors in the transformation of degree of cure to Glass Transition temperature (Tg)
    - Characterisation is not focused on industrial performance

We had to invent our way to industry

Step	Description	Duration (m)	Who
1*	Receive 1kg resin sample for preliminary test and coupon manufacturing	1	SYN
2*	DSC/DMA of around 20 coupons	1	Customer
3*	Produce preliminary online Tg program	1	SYN
4*	Industrial trials on-site	1	Customer+SYN
5	Finalisation of online Tg program	1	SYN
6	Field trials and preliminary approval	2	Customer
7	Validation at production	3	Customer

Indicative duration of each step. * If resin is already characterized by SYN this step is not necessary

Resins characterised: 10 for aerospace, 6 for automotive and 10 for wind energy applications

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Online Tg estimation at DSC accuracy

Comparison of various isothermal and realistic test cases showing the difference between Tg estimated online with the ORS software and T_g measured right after demoulding by DSC by CarbonRotec GmbH

Online Tg with DSC accuracy

	Trial	Duration [h]	T_g-ORS (°C)	T_g- DSC (°C)	Difference (°C)
Isothermal	80DV1	3	73.17	73.34	-0.17
	80DV3	2.5	70.30	70.91	-0.61
	80DV4	2.5	73.45	72.49	0.96
	80-120'	1.92	66.96	66.02	0.94
	80-90'-1	1.50	62.04	61.80	0.24
	80-90'-2	1.50	65.52	65.21	0.31
	80-D2-2	1.50	61.88	60.59	1.29
	60-260'	4.33	55.02	56.51	-1.49
	70-190'	3.17	64.92	65.39	-0.47
Isothermal cases, mean difference					1.61
Isothermal cases, standard deviation					2.42
Non-isothermal	TEB1-1		61.37	59.54	1.83
	TEB1-2		69.36	70.93	-1.58
	TEB2-1		60.00	58.64	1.36
	TEB2-2		70.02	70.30	-0.28
	LESW1-1		76.97	74.35	2.62
	TESW1		71.34	69.18	2.16
	Shell1-1		80.36	78.92	1.44
	Shell1-2		75.72	77.83	-2.12
	Shell2-1		79.60	77.70	1.89
Non-isothermal cases, mean difference					2.15
Non-isothermal cases, standard deviation					1.26

In collaboration with CARBON ROTEC COMPOSITE TECHNOLOGY

Conclusions
What's next

- Composites are involved in all high-tech applications.
- Production scale-up and productivity increase are in high demand
- Composites manufacturing is quite conservative and sub-optimal.
- Currently Europe and US are leading composite manufacturing but Asia is catching-up fast
- Need for more R&D in resin characterization
- Establish a close collaboration between sensing, modelling and simulations (digital twins)
- Need to develop material databases with useful parameters for composite manufacturers
- Establishing real-time quality control methods is necessary
- Digital twins and Industry 4.0 are the next targets and scaling-up composites production should take full advantage of them.

RECOTRANS

7 COUNTRIES | 13 PARTNERS | 42 MONTHS | 4.5 MILLION EUROS

CTAG, INEA, Mercedes-Benz, POLYMEC Pultrusion Composites, ARKEMA, Gestamp, TECNOCLAD Laser Solutions, Fraunhofer ICT, STADLER, synthesites, Far COMPOSITES, ITU, AIMPLAS Plastics Technology Centre

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SuCoHS

SUSTAINABLE & COST EFFICIENT HIGH-PERFORMANCE COMPOSITE STRUCTURES DEMANDING TEMPERATURE AND FIRE RESISTANCE

DLR, AERnnova, HEXAGON Manufacturing Intelligence, apodius, BOMBARDIER, Collins Aerospace, n|w, UP, nlr, ntpt, ONERA The French Aerospace Lab, synthesites, TFC Biomass Based Chemicals, Technobis tft-fos, TUHH Technische Universität Hamburg