Quality Monitoring and Process Control in CFRP Production

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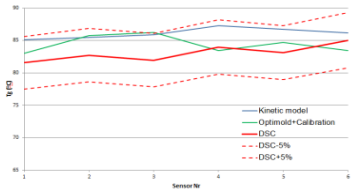
Products and Services

OptiMold system for monitoring resin cure, resin viscosity, mixing ratio quality and resin quality

OptiFlow system for optimising mould filling, process automation and simple process control

OptiSensors (durable/ disposable, flexible, outlet, custom)



Real-time calculation of Tg/ degree of cure/ viscosity/ resin quality

Automation, design and prototyping solutions

Customers and Collaborators

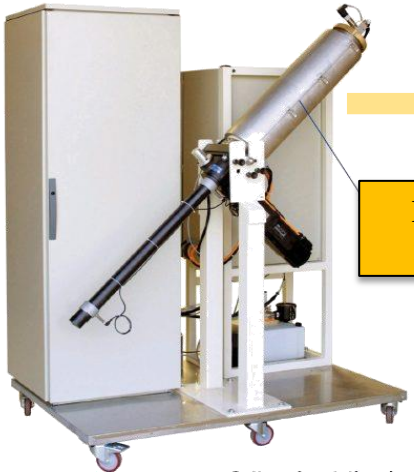
Indicative customers

AIRBUS HELICOPTERS
BOMBARDIER
Aircelle Groupe SAFRAN
AERnnova
AIRBUS GROUP
faurecia
schunk
Audi
SIEMENS

Collaborators

DLR
Technische Universität München
FASERINSTITUT FIBRE BREMEN
Fraunhofer
MONTAN UNIVERSITÄT
AIMPLAS INSTITUTO TECNOLÓGICO DEL PLÁSTICO
NATIONAL COMPOSITES CENTRE
University of BRISTOL
accis

Intelligent automation in composites moulding



Injection machine

Inline Sensors

Mould

Composite part

In-mould Sensors

Control Actions

Temperature controller(s)

DAQ + Control

Monitoring Systems

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Process Monitoring in composites manufacturing

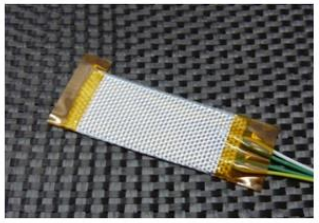
- Check resin quality and adjust process accordingly
- Detect accurately resin arrival at critical locations
  - Open/close valves based on sensors' feedback
- Monitor viscosity changes and decide when start heating
- Identify minimum viscosity and decide about pressure
- Detect unexpected events and follow alternative routes
- Improve simulation accuracy and design intelligent strategies
- Real-time decision of the cure cycle based on Tg and degree of cure (depends on the resin) rather than time

Optimold: Cure, viscosity, resin quality check

Real-time measuring of

- Resin's electrical resistance (from 0.1 MOhm up to 50 TOhm)
- temperature (0.1°C accuracy)

process monitoring sensor = electrical resistance + RTD sensors

Durable sensor	Flexible sensor	Inline sensor	Pot sensor
			
High Temp RTM • Resin arrival • Viscosity rise • Gelation • End-of-cure	VI and RT cure • Resin arrival • Viscosity rise • Gelation • End-of-cure	• Avoid pipe cleaning • Adjust cycle • Mixing ratio check	• Mixing ratio • Resin Quality • Resin aging • Adjust cycle

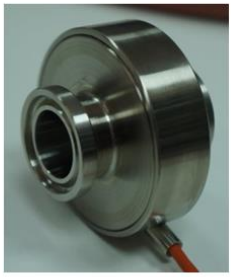
OptiFlow: Resin arrival, temperature

- 4 temperature and resin arrival sensors
- Resistance-based measurements and RTD temperature
- Continuous connection checking
- One relay output for process automation

In-mould Durable

- flat areas
- possible mark

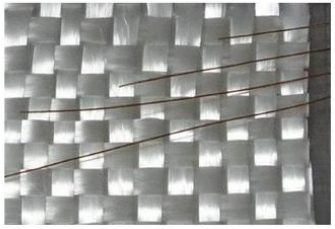
Gate sensor



- ideal for vacuum infusion in oven/ autoclave (gates, pipelines, pots etc.)

Flexible disposable

FloWire sensors



- Curved surfaces
- In the laminate for development
- Over the peel-ply
- Suitable for very long parts
- no extra protection for Carbon Fibre Preforms

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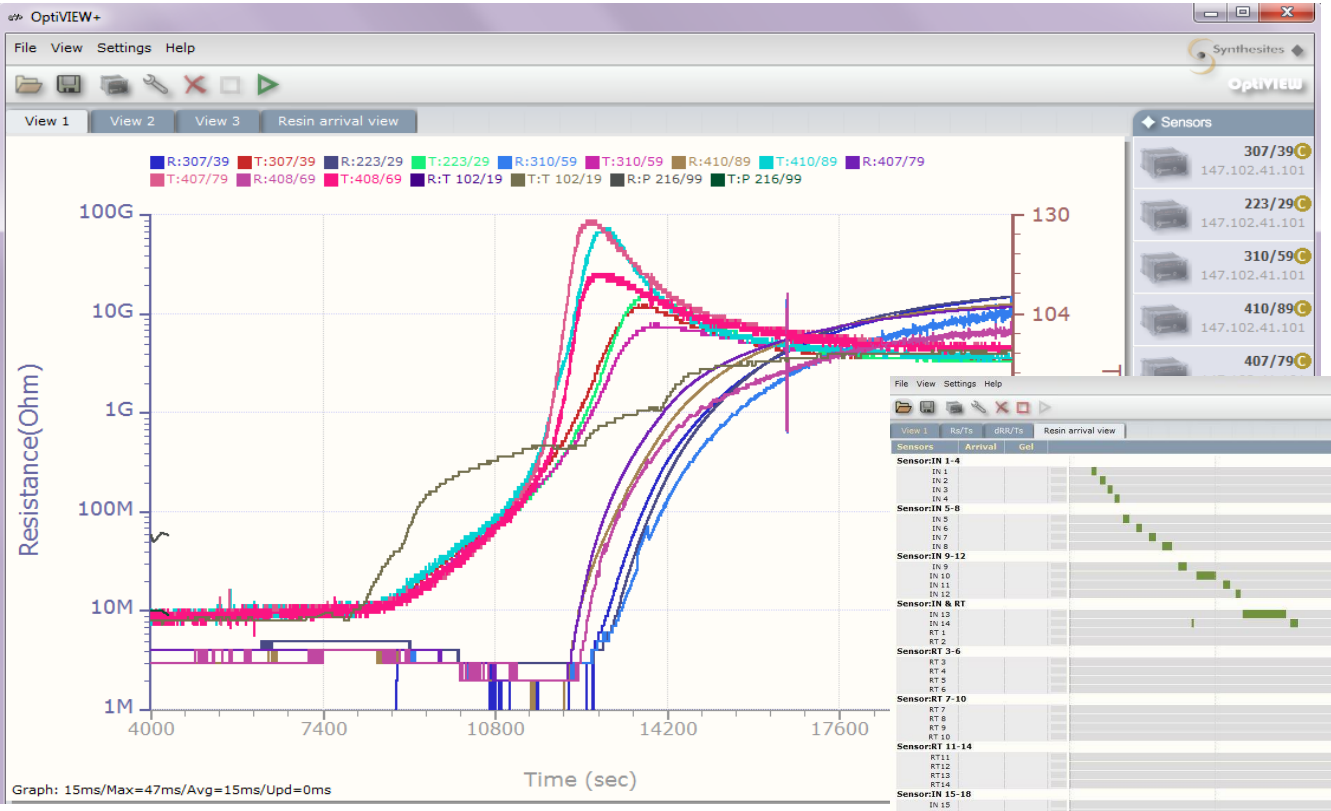
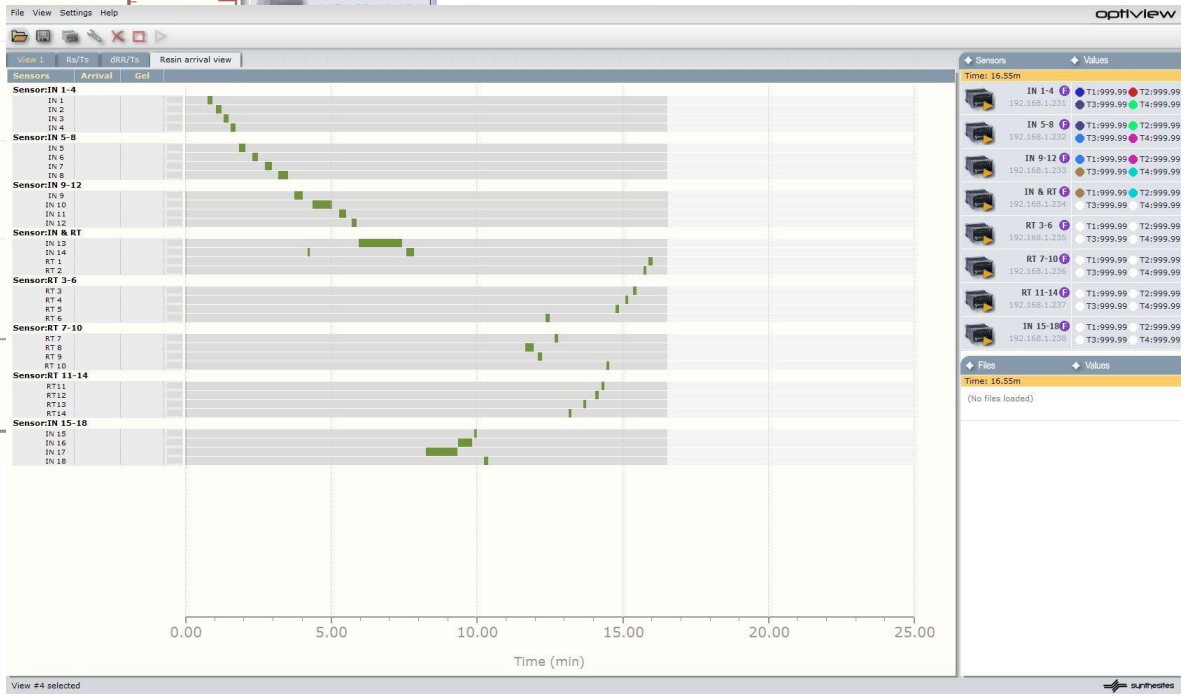
Optiview: DAQ software





OptiView software for both Optimold and OptiFlow systems

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Co-Funded R&D projects

On-going

Ecomise: Composites manufacturing (9/2013-8/2016)
Partners: DLR (CO), Faser I., Bombardier Aero, Hutchinson, Airborne, Polyworx, Loop, Samtech, Dassault System, NLR
RTM and RTI, Glass and carbon fibre, epoxy
Aerospace, automotive and marine applications

Coaline: Injection pultrusion with mw and coatings (9/2013-2/2017)
ICT and Aimplas involved

Completed

iREMO: intelligent Reactive Moulding (9/2009-8/2012)
RTM, Light RTM and Infusion
Glass and carbon fibre, epoxy and polyester
Automotive and infrastructure applications

MAC-RTM: Microwave curing (11/2011-10/2013)
ICT and Aimplas involved

iREMO Project (2009-2012)

intelligent REactive polymer composites MOulding

In iReMo for the first time the following technologies were applied to the liquid moulding of composite materials:

-Robust neural network modeling through bootstrap aggregated neural networks which will be used in optimisation and control.

-Reliable optimisation control by incorporating model prediction confidence bounds in the optimisation objective function

-Iterative learning control based on neural network models

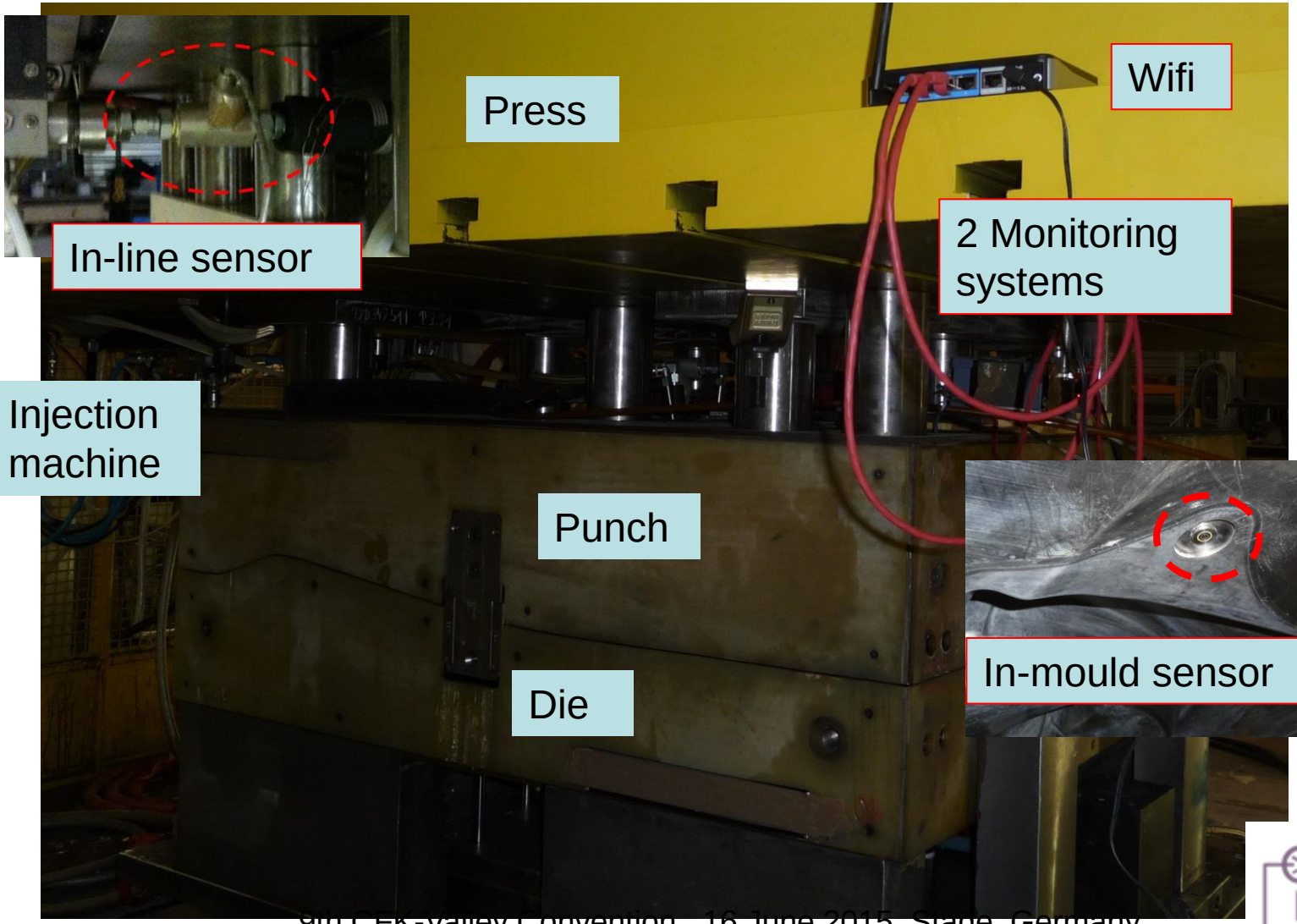
-Self-learning material models

-Self-calibrating process monitoring tools

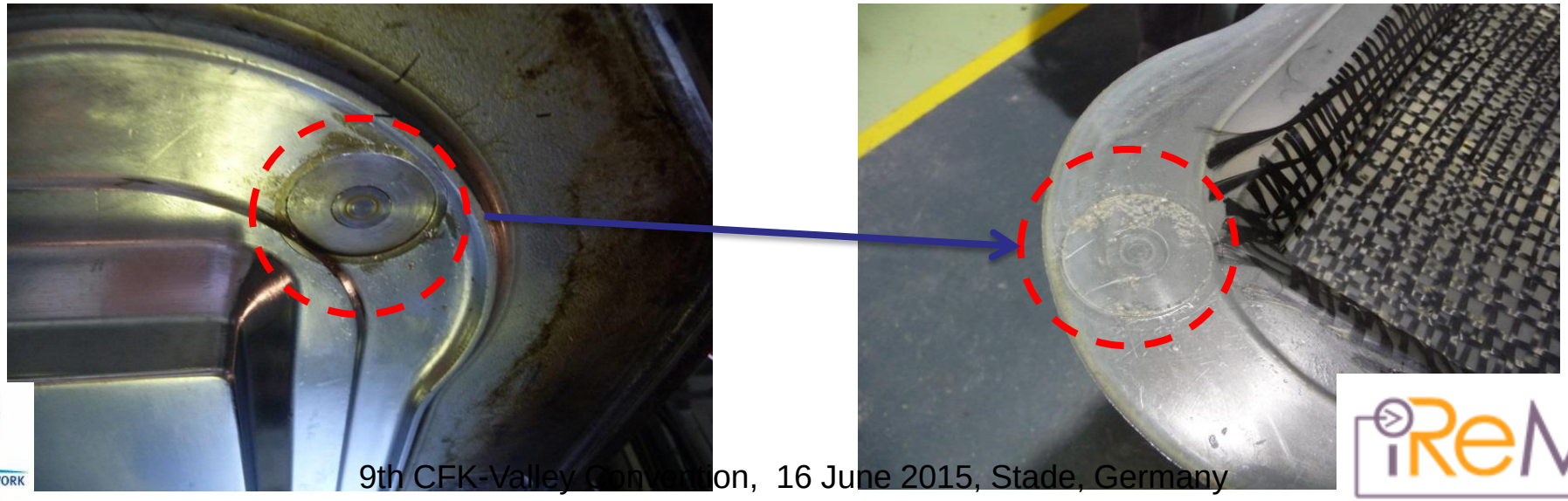
Industrial Demonstrators

- Automotive (Sotira)
- Constructions (Acciona)
- Marine (KarnicBoats)

iREMO
SOTIRA Test case
RTM press



iREMO
SOTIRA Test case
RTM press



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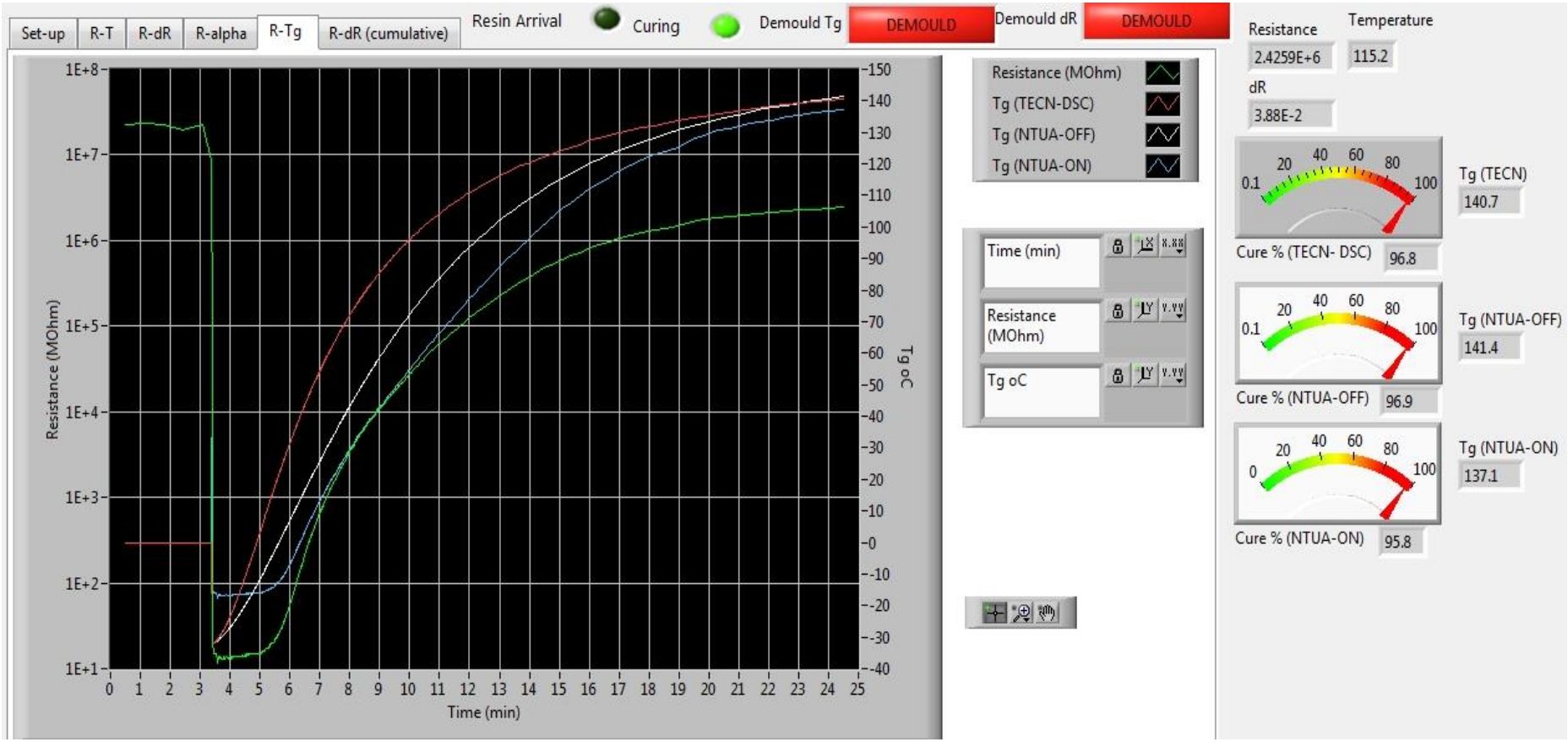
iREMO
SOTIRA Test case
RTM Control based on Tg



Online control of RTM press based on real-time Tg

SEVENTH FRAMEWORK PROGRAMME

iREMO

COALINE Project (2013-2017)

Development of an innovative manufacturing process for the Inline coating of pultruded composites

www.coaline.eu

COALINE will develop an in-line clean one-stage pultrusion process, which is free of VOCs and small particles emissions, able to produce properly coated composite pultruded profiles by means of the development of the sensing technology, advanced mould design and microwave aided curing needed to foster an improved composite – coating adhesion with a reduced labour and processing cost.

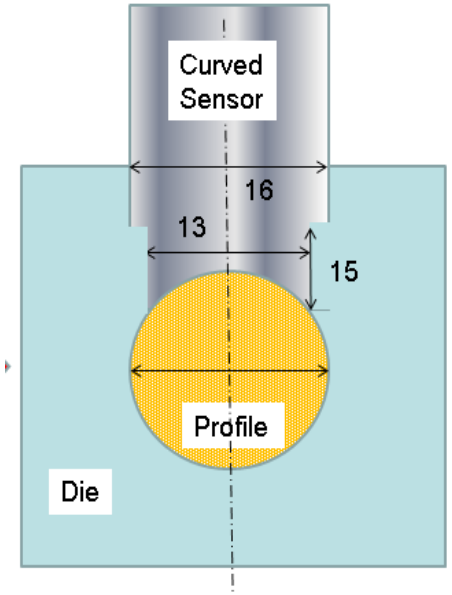
Industrial Demonstrators

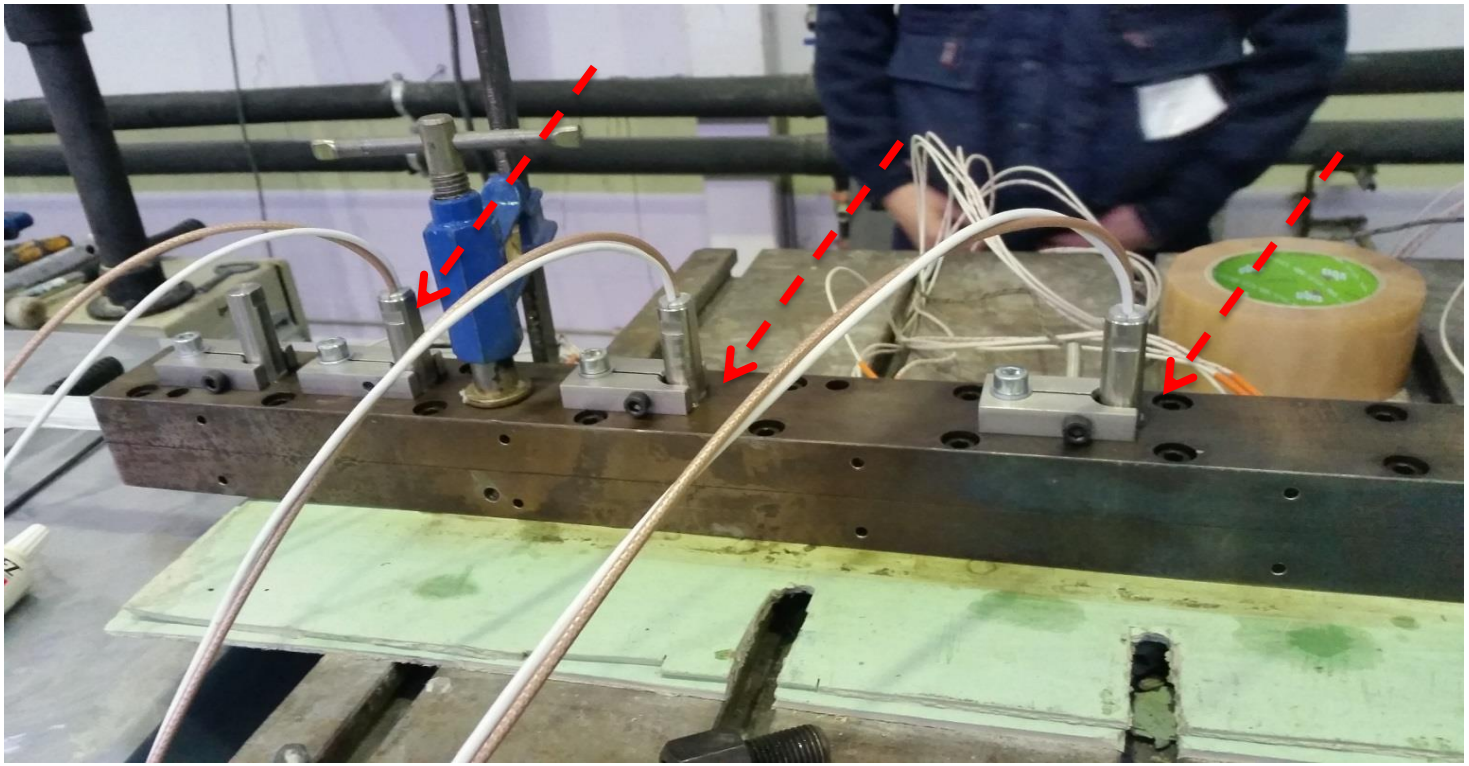
- Automotive (Alke)
- Constructions (Acciona)

Partners

AIMPLAS, MUEGGE, FRAUNHOFER, COMPOSITES ARAGÓN, SYNTHESITES, POLYMEC, RTU, RESOLTECH, RESCOLL, ECOINNOVA, ACCIONA, ALKÈ

COALINE
AIMPLAS Test case
3 curved cure sensors





ECOMISE Project (2013-2016)

Enabling Next Generation COmposite Manufacturing by In-Situ Structural Evaluation and Process Adjustment

www.ecomise.eu

Objective

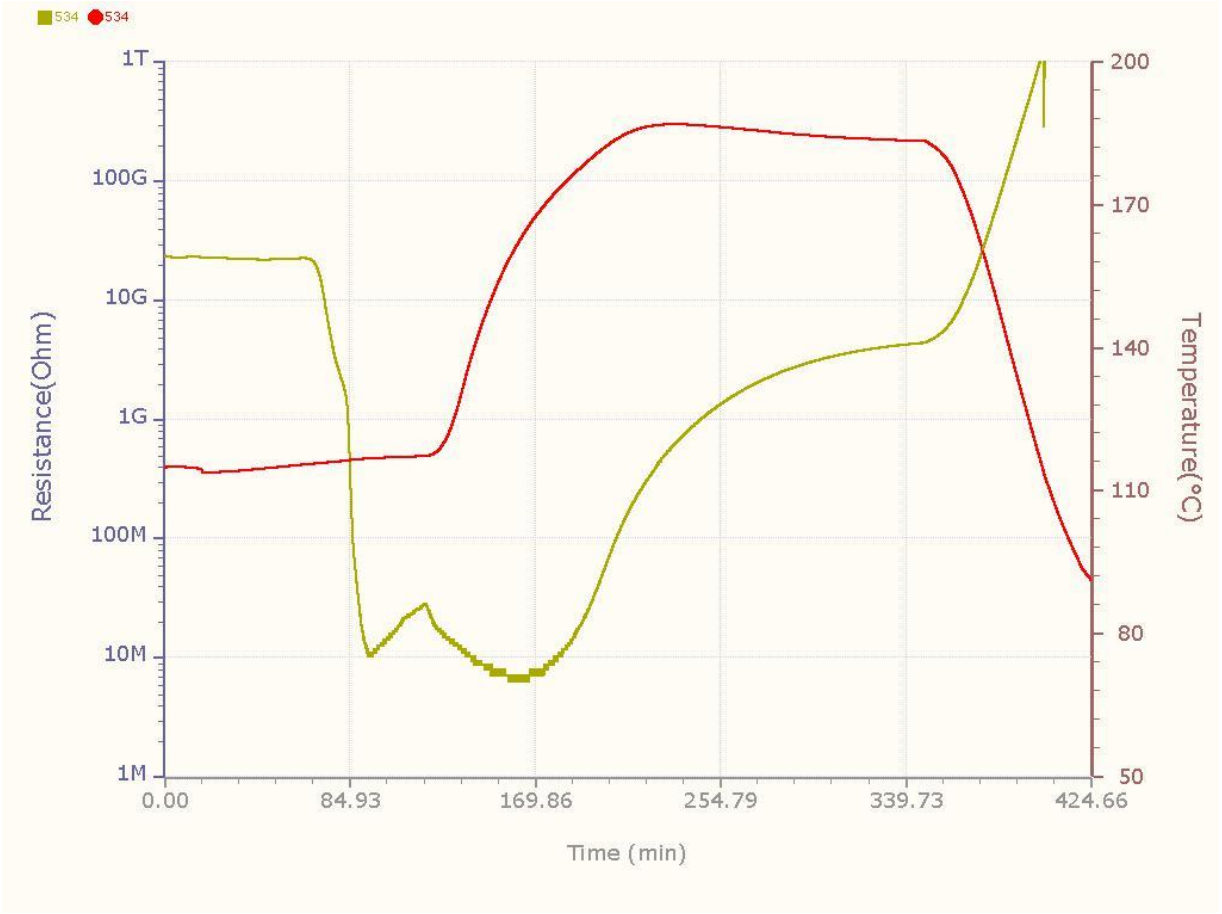
A breakthrough composite manufacturing system is being developed comprising probabilistic process prediction, online process monitoring, in-situ structural evaluation and in-situ process adjustment. By means of industrial applications the focus is laid upon preforming processes such as pick & place and dry fibre placement, as well as subsequent infusion and curing processes such as Resin Transfer Infusion (RTI) and Resin Transfer Moulding (RTM).

Industrial Demonstrators

- Aerospace (Bombardier)
- Automotive (Hutchinson)
- Marine (Airborne)

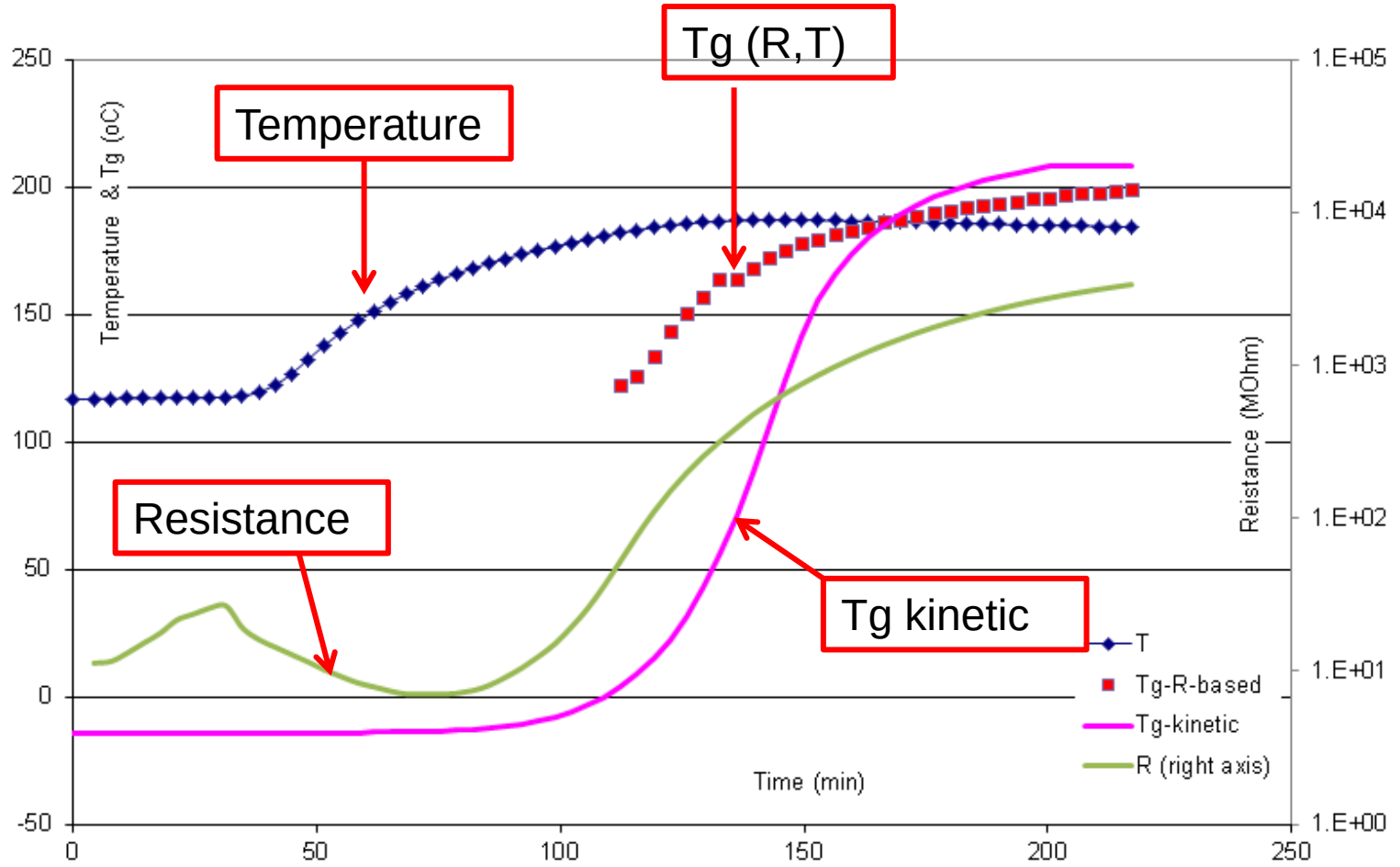
Partners

ECOMISE
Bombardier Test case
2nd trial



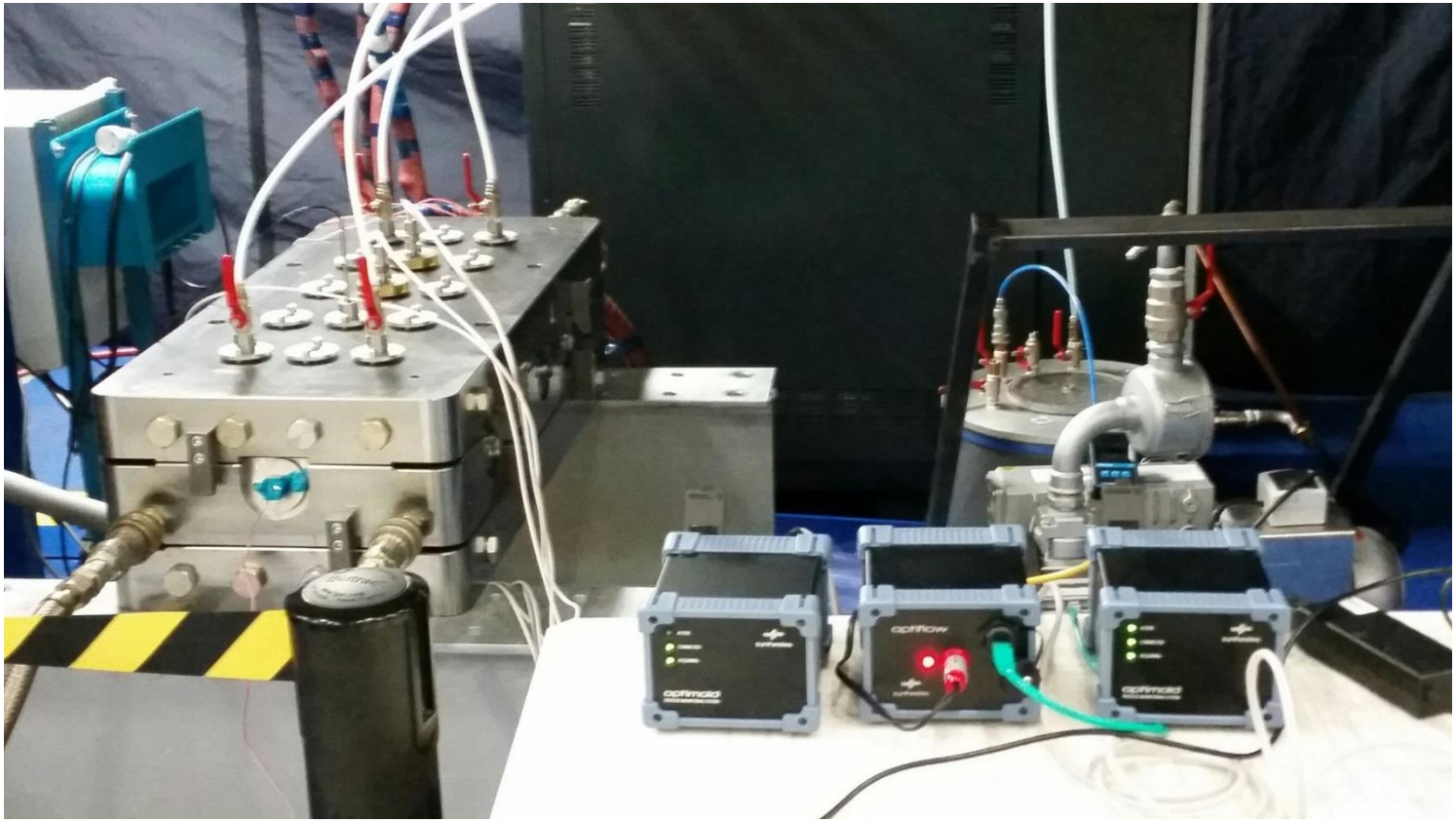
Infusion in an autoclave

ECOMISE
Bombardier Test case
Resistance and real-time Tg



Cycom 890: Correlation between resistance and Tg real-time prediction

ECOMISE
Airborne Test case
Mould Set-up



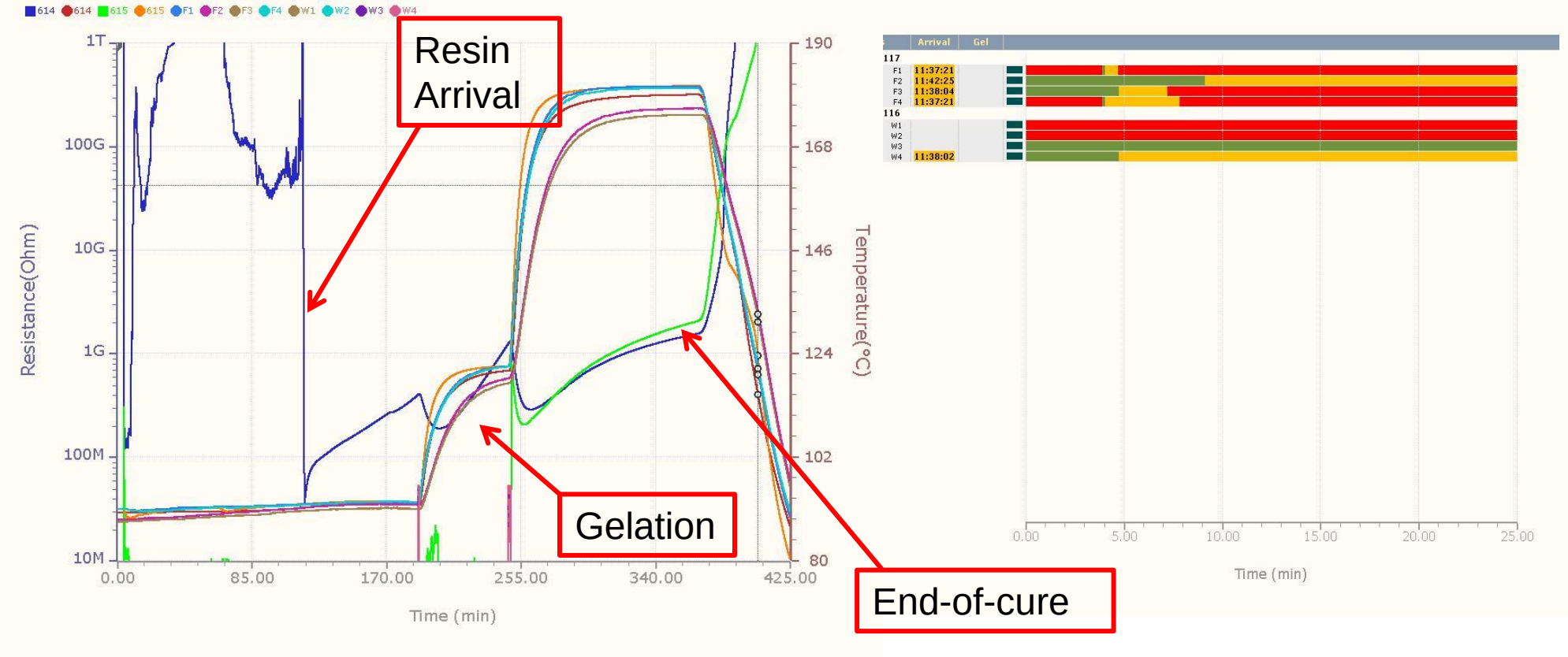
Mould Cavity

- 700 x 200 x 100 mm
- Draft angle: 15°
- Total volume: 16 lt

Process Monitoring (sensors)

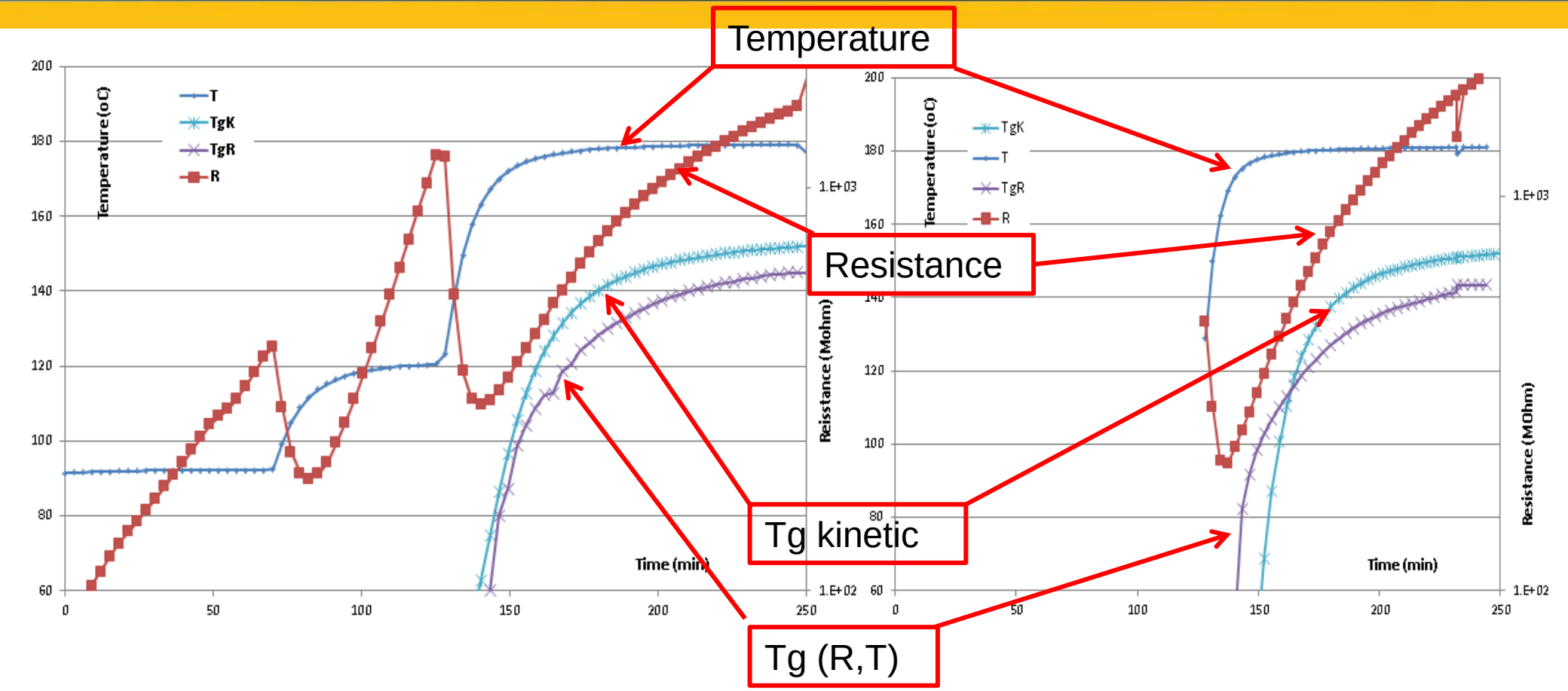
- 8 Resin Arrival
- 2 cure durable
- 2 pressure
- 12 temperatures

ECOMISE
Airborne Test case #2
Flow and cure monitoring



6 temperature and 2 resistance curves (left figure) and 8 resin arrival sensors (right figure).

ECOMISE
Airborne Test case #2
Tg prediction for two sensors



Simultaneous Tg prediction based on kinetic model and resistivity for cure sensor #1 (left figure) and cure sensor #2 (right figure).

Conclusions

- Real-time process monitoring has matured towards industrial applications
- Within Ecomise project considerable advancements have been made to complete our sensors' series with flow sensors that can help significantly in the identification of the resin's flow paths
- Process monitoring can also provide reliable and quantified information about the Tg evolution so demoulding can be optimised.
- Furthermore, the reliable and intelligent process monitoring combined with appropriate modelling and simulation tools can provide a unique platform for optimal control of the process ensuring product quality.

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Acknowledgements

Some developments and results presented here were partially supported by the European Commission FP7 programme under Grants:

- Ecomise: NMP2-SL-2013-608667 (Enabling Next Generation Composite Manufacturing by In-Situ Structural Evaluation and Process Adjustment).
- Coaline: NMP2-SL-2013-609149 (*Development of an innovative manufacturing process for the in **LINE COA**ting of pultruded composites)*
- *iREMO: NMP2-SL-2009-228662 (intelligent REactive polymer composites Moulding)*

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Thank you