FAGOR

FAGOR ARRASATE

In collaboration with:

MONDRAGON UNIBERTSITATEA

COMPOSITES

COST EFECTIVE BONNET MANUFACTURING BY COMPRESION RESIN TRANSFER MOLDING

spe AUTOMOTIVE

Unai Argarate Belategi

4/6-9-2019

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SHARINGYOURCHALLENGES

Overview of FAGOR ARRASATE

HUMANITY AT WORK | MONDRAGON

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FAGOR ARRASATE

Overview of Fagor Arrasate

SHARINGYOURCHALLENGES

COMPOSITES

- Cooperative founded in 1957
- Member of Mondragon Corporation
- Headquarters: Arrasate (Basque Country)
- Three divisions:
  - Steel division
  - Home appliances division
  - Automotive division

- Staff: 850 people
- Turnover: 290M€

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Overview of Fagor Arrasate

Production lines for lightweight design:

- AHSS & UHSS material stamping
- Steel & Aluminum hot stamping lines
- Composites forming lines

Overview of Fagor Arrasate

Production lines for lightweight design:

AHSS & UHSS material stamping

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Overview of Fagor Arrasate

SHARINGYOURCHALLENGES

COMPOSITES

Production lines for lightweight design:

Steel & aluminum HF instalation with Mechanical ServoPress **

Steel and aluminum hot stamping lines

** Patented solution

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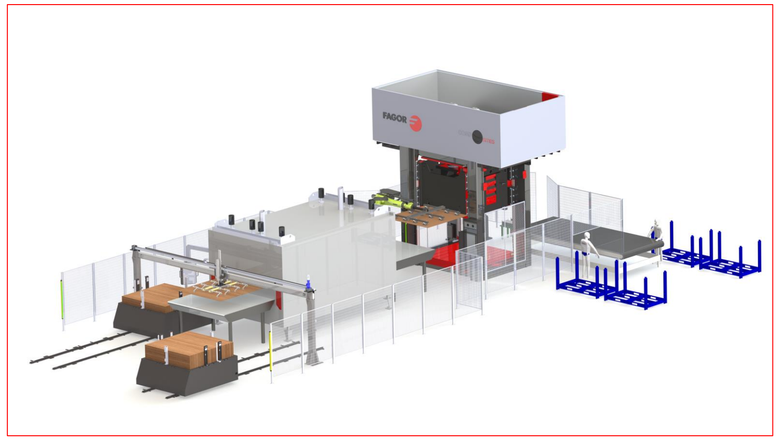
Overview of Fagor Arrasate

Production lines for lightweight design:



Composites forming lines

- **SMC**
- **GMT-LWRT**
- **D-LFT**
- **X-RTM**
- **…**

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RTM Variants Cost Analysis comparison

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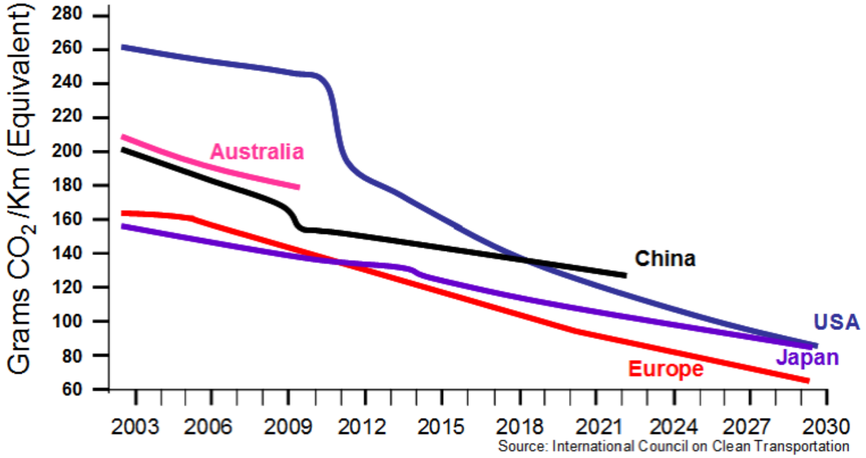
PROJECT DRIVERS

* CO_2 emission restrictions. The weight of vehicles affects directly in CO_2 emissions.

* The use of composites (CFRP) has the highest potential in.

- ✓ High weight reduction.
- ✓ High impact energy dissipation.
- ✓ High Specific stiffness and Strength.
- ✓ Excellent fatigue resistance.



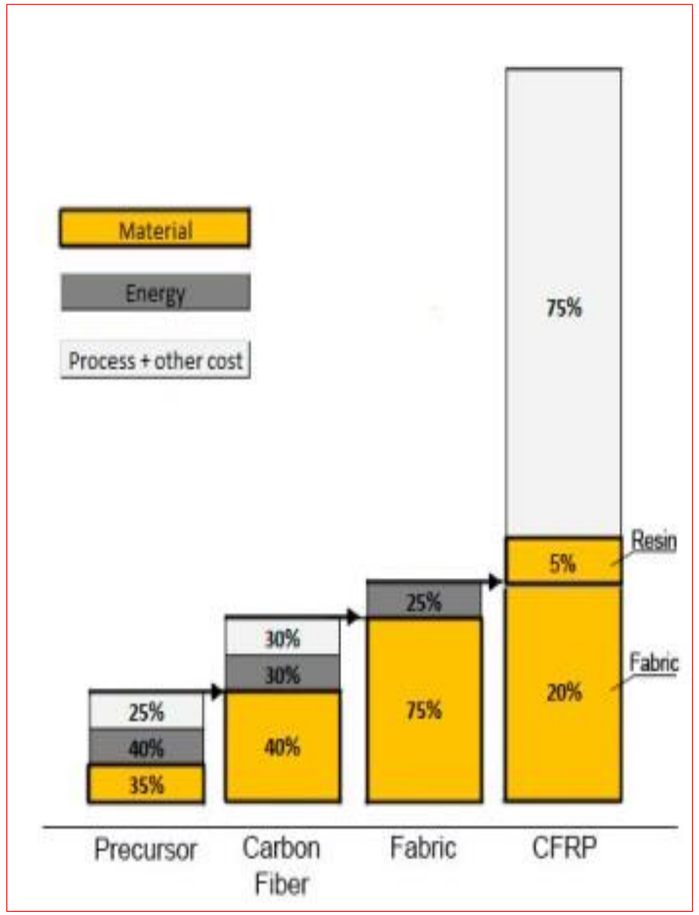
RTM Variants
Cost Analysis comparison

PROJECT CHALLENGES

* Fast and robust manufacturing process.

- ✓ Short cycle time.
- ✓ Good quality.
- ✓ Repeatability.
- ✓ High automation level.

SGL GROUP
THE CARBON COMPANY



Cost structure of CFRP parts. SGL.

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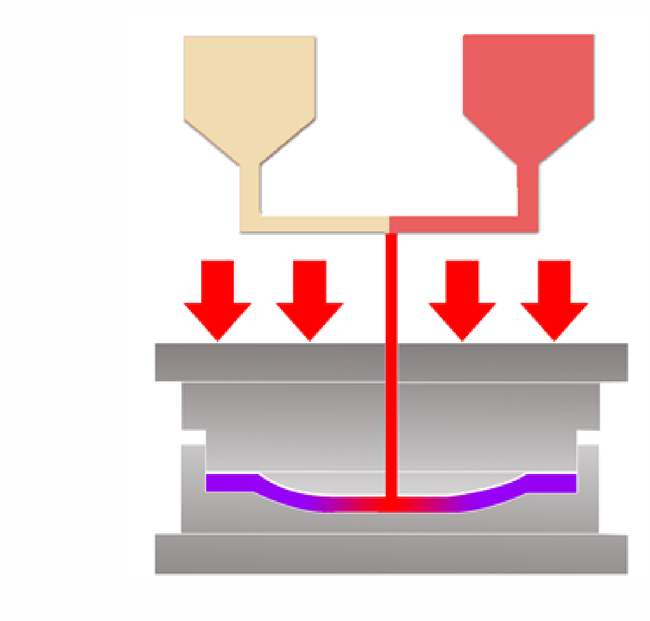
RTM Variants
Cost Analysis comparison

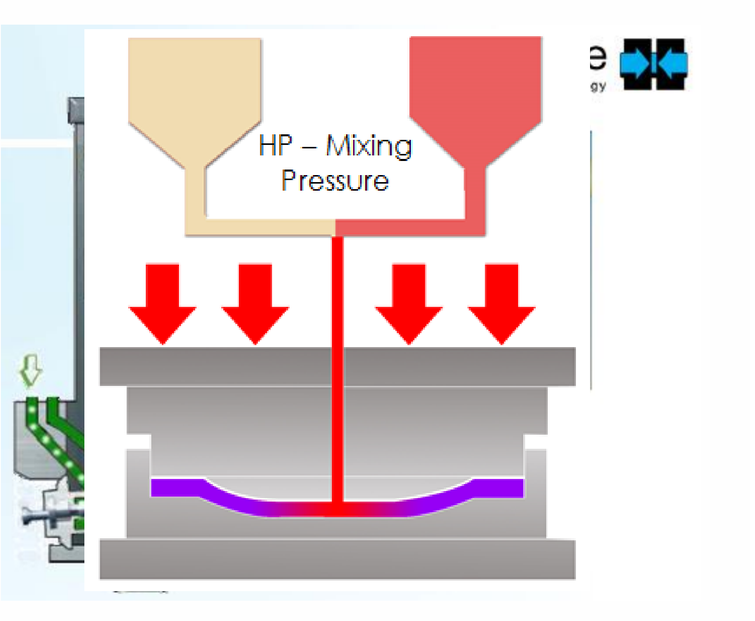
SHARINGYOURCHALLENGES

COMPOSITES

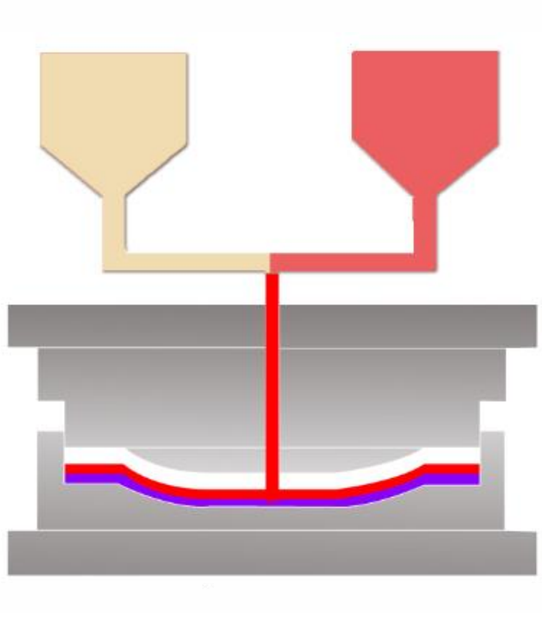
RTM



HP-RTM



CRTM



Impregnation Through	Plain	Plain	Thickness
Mixing Pressure	Low	Hi	Low
Impregnation Pressure	Low	Hi	Medium
Filling + Impregnation Time	Long	Short	Short
Curing Time	Long	Short	Short

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RTM Variants
Cost Analysis comparison

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COMPOSITES

Case Study
- Type of Part
- Nº of parts/year
- Analyze part characteristics.

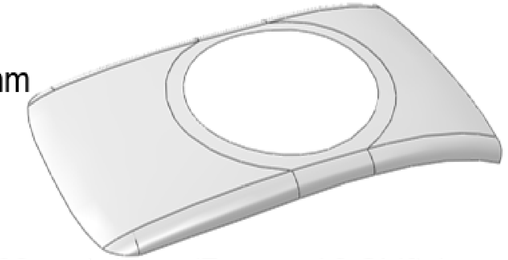
Process Simulation
- Timing
- Resin
- Inlets
- Pressure

Cost Calculation
- Tooling + Equipment
- Energy
- Plant Cost

Cost Calculation steps

Automotive Roof

- Part: Urban Electric car roof (1500 x 2000)
- Projected Area: 1,72m^2
- Thickness in Steel: 0,7 mm
- CFRP Thickness: 2 mm
- Vf = %60
- Production Volume: 90.000 parts/year (7 years / 3 Shifts)
- Same Preform
- Material Cost not considered



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RTM Variants
Cost Analysis comparison

SHARINGYOURCHALLENGES

COMPOSITES

Case Study → **Process Simulation** → **Cost Calculation**

- Type of Part
- Nº of parts/year
- Analyze part characteristics.

- Timing
- Resin
- Inlets
- Pressure

- Tooling + Equipment
- Energy
- Plant Cost

Cost Calculation steps

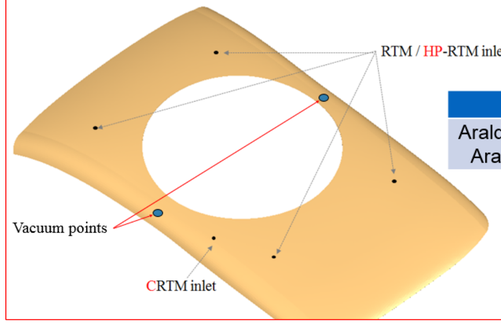
***Resin and inlets.**

***Filling and impregnation time.**

***Clamping force.**

***Pressure distribution.**

Resin & Inlets

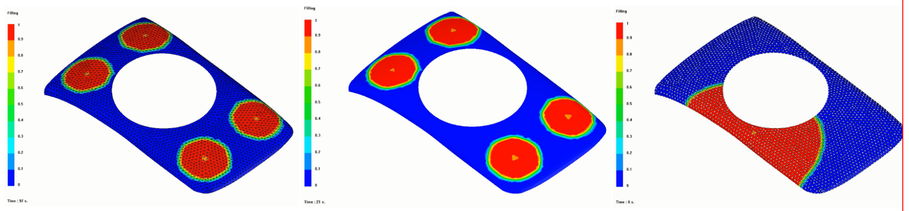


HUNTSMAN

RTM	HP-RTM	CRTM
Araldite LY 564 Aradur 2954	XB 3585 Aradur 3475	XB 3585 Aradur 3475

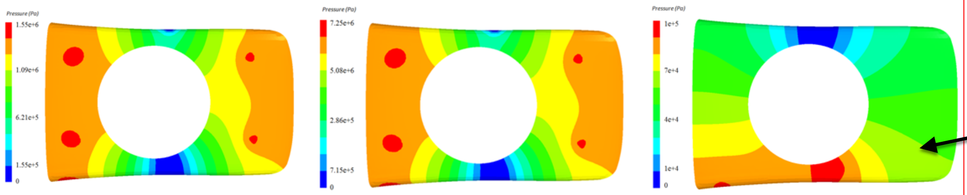
Process	Injection pressure (bar)
RTM	15
HP-RTM	70
CRTM	1

Filling + Impregnating



RTM HP-RTM CRTM

Pressure Distribution at the end of Filling Stage



RTM HP-RTM CRTM

Parallelism control needed

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RTM Variants
Cost Analysis comparison

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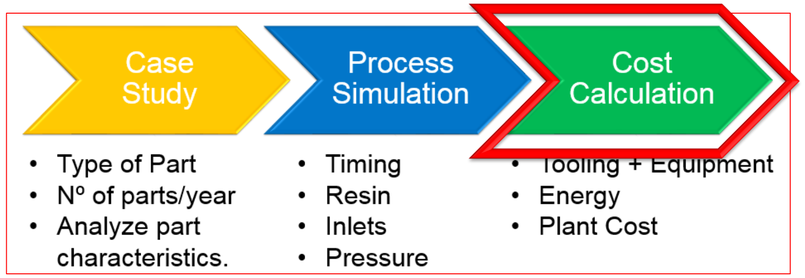
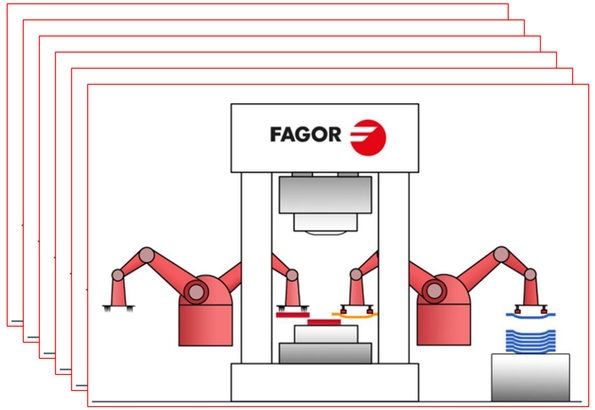
COMPOSITES



Cost Calculation steps

RTM
HP-RTM
CRTM
} Cell



*Cell cost in each scenario considering:

*Number of cells needed (Press, injection system, mold and robots).

*Energy cost.

Process	RELATIVE TOTAL COST (per part)
RTM	4,7
HP-RTM	2,2
CRTM	1,0

*Relative numbers.

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RTM Variants
Cost Analysis comparison

SHARINGYOURCHALLENGES

COMPOSITES

ADVANTAGE

1. CRTM is the fastest process.
2. Investment level is the lowest.
3. Bigger Plant area for RTM and HP-RTM than for CRTM.
4. Part cost considering investment payback and energy consumption in CRTM is much lower.

TO CONSIDER

1. CRTM has limitations for complex geometrical parts

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CRTM process characterization

CRTM process characterization

Raw materials


Epoxy (XB 3585 / Aradur 3475, HUNSTMAN)

Biaxial fabric (HPT 610 C090, 50k, SGL)

Binder (Araldite LT 3366 BD)

Characterization

Curing kinetics

Rheology

Permeability

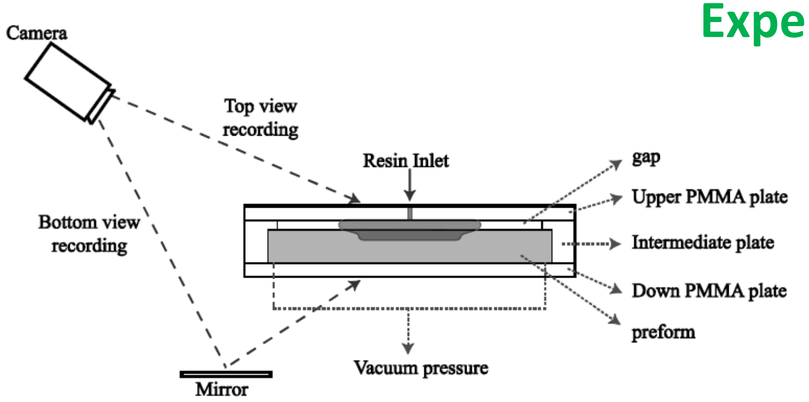
Compressibility

$$v = -\frac{1}{\mu} K \cdot \nabla P$$

CRTM process characterization

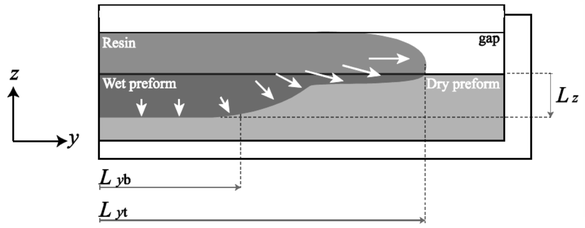
Simulation
+
Experimental analysis

Injection stage



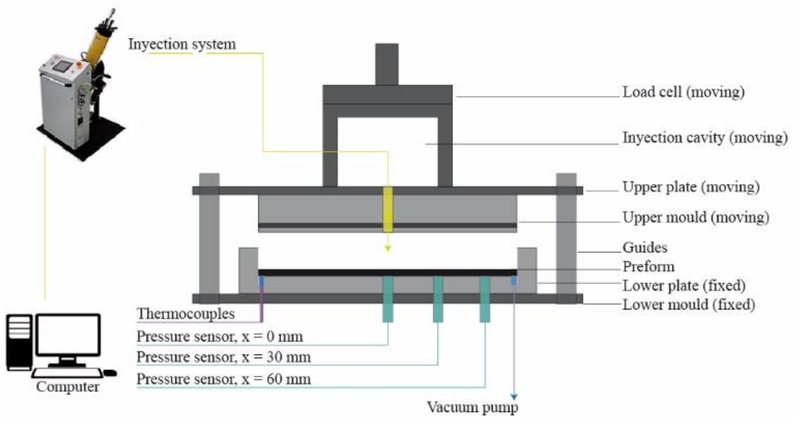
Studied parameters:

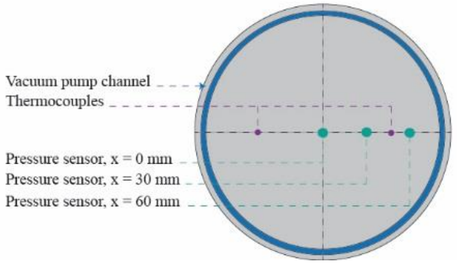
- Resin viscosity
- Preform permeability
- Gap thickness
- Injection pressure
- Injection flow-rate
- Injected resin volume



Resin distribution

Compression stage



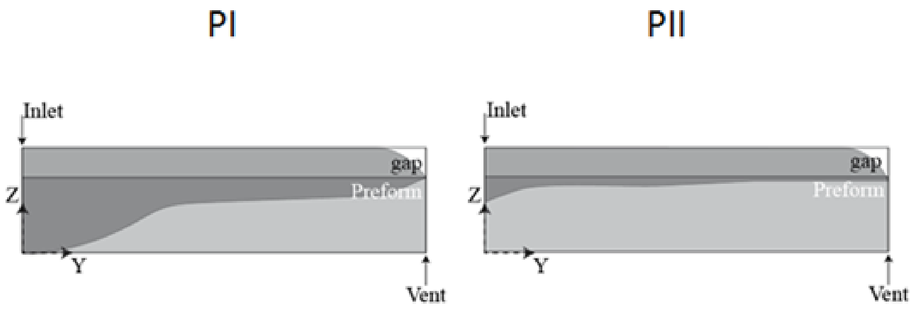


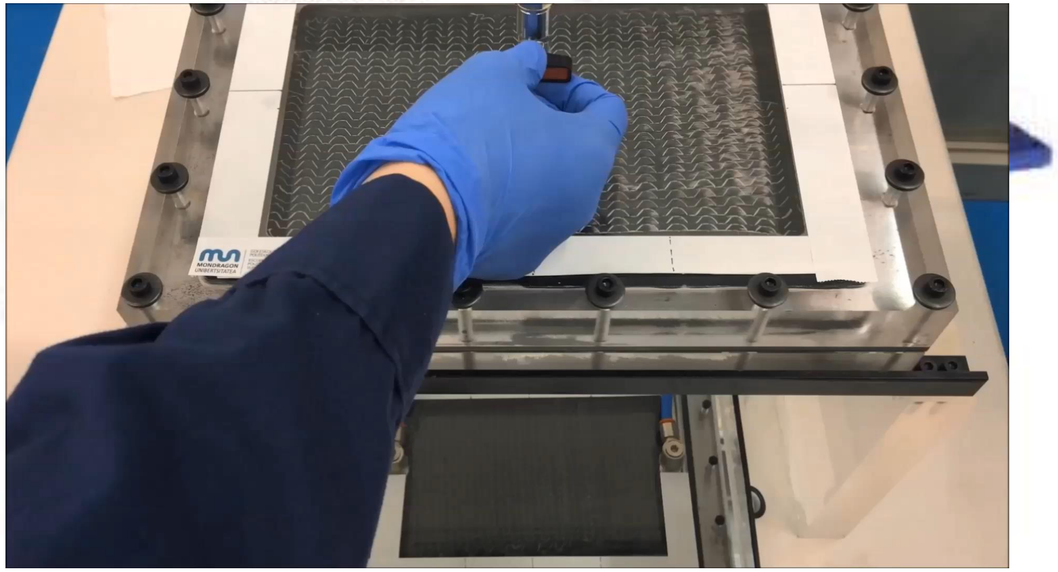
Studied parameters:

- Initial resin distribution
- Compression speed
- Compression pressure

CRTM process characterization

Injection stage





Resin distribution depends mainly on:

-Gap thickness. →

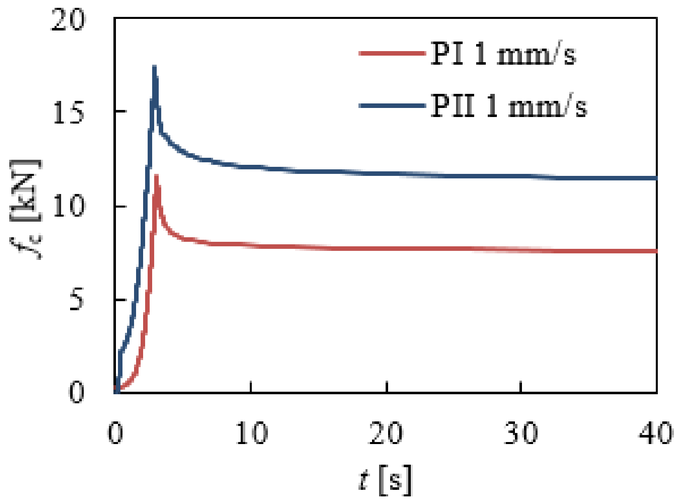
-Permeability of the preform through thickness.

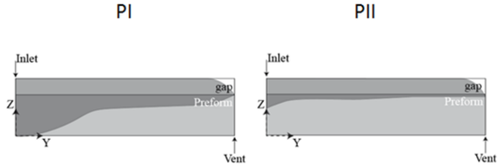
PARALLELISM CONTROL

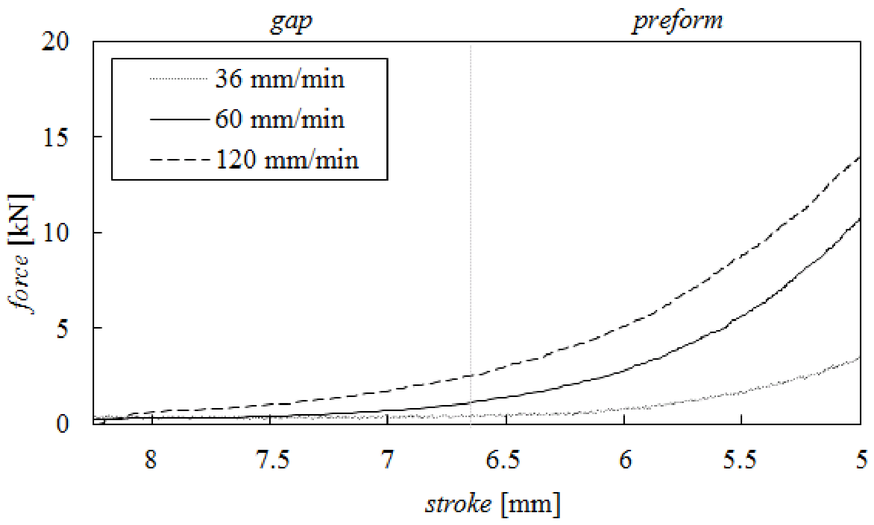
Compression stage

Compression time and loads depends mainly on:

-Resin volume.
-Speed control of the compression phase.







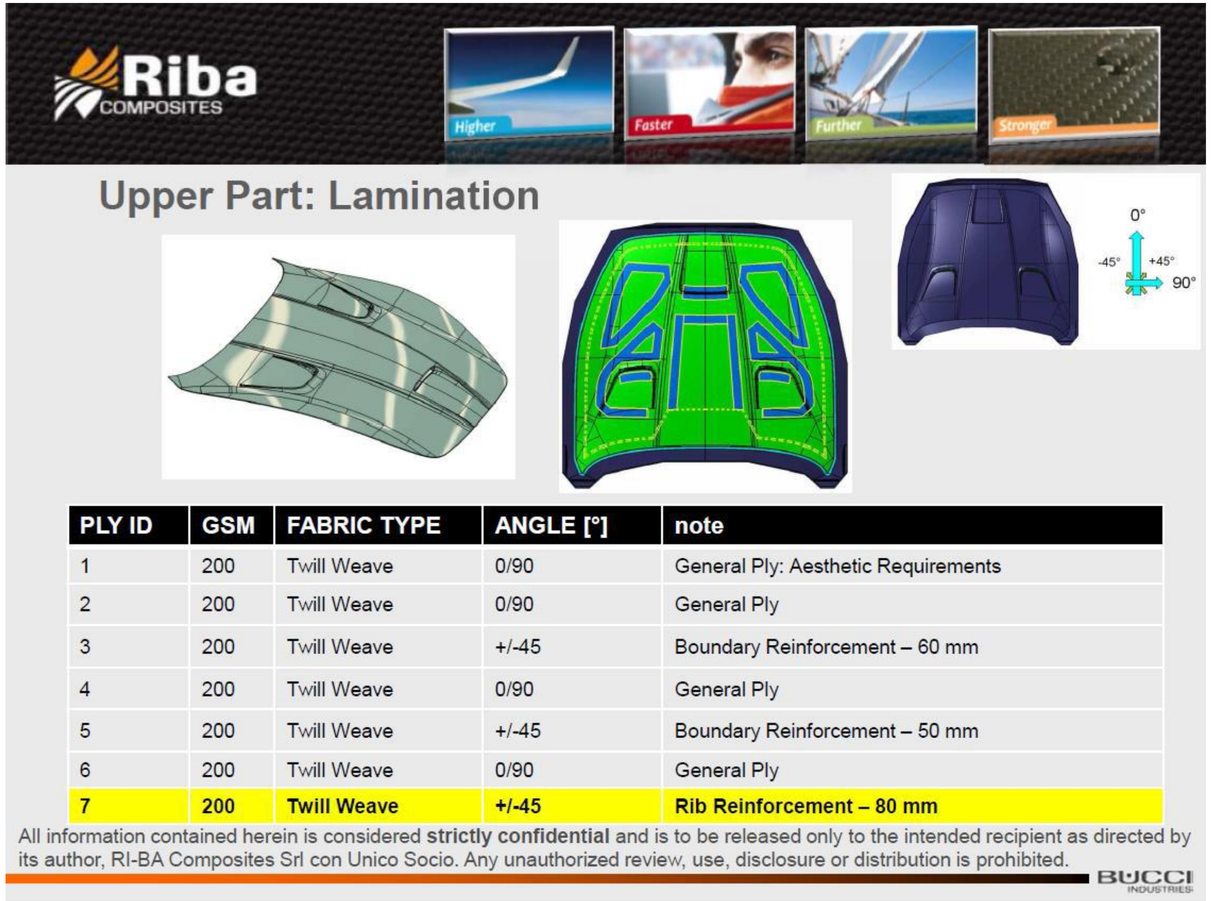
Speed control:

*Gap stroke with fast speed.
*Preform stroke with slow speed.

Bonnet manufacturing

Bonnet manufacturing

Part Design



PLY ID	GSM	FABRIC TYPE	ANGLE [°]	note
1	200	Twill Weave	0/90	General Ply: Aesthetic Requirements
2	200	Twill Weave	0/90	General Ply
3	200	Twill Weave	+/-45	Boundary Reinforcement – 60 mm
4	200	Twill Weave	0/90	General Ply
5	200	Twill Weave	+/-45	Boundary Reinforcement – 50 mm
6	200	Twill Weave	0/90	General Ply
7	**200**	**Twill Weave**	**+/-45**	**Rib Reinforcement – 80 mm**

Playbook definition

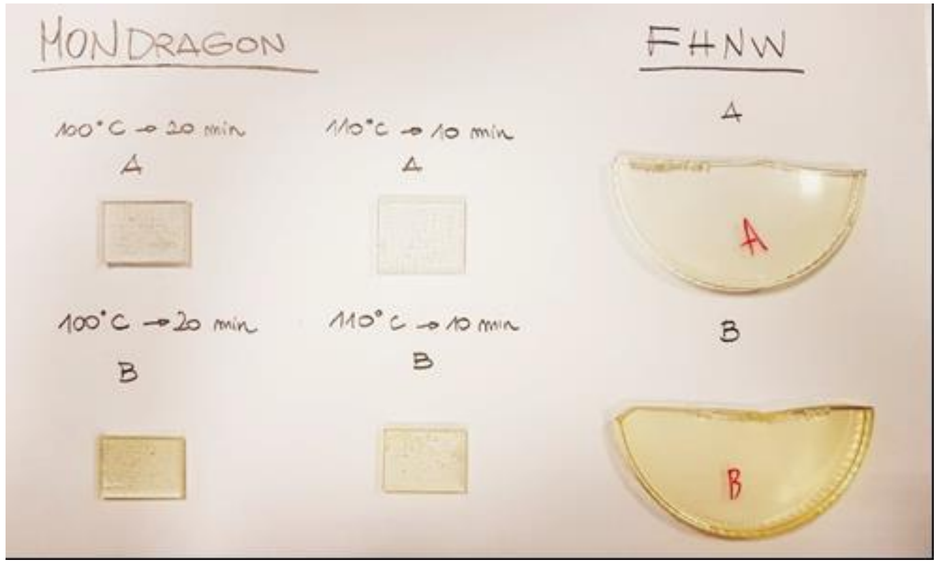
Bonnet manufacturing

Resin and hardener selection

***Tg superior to 120ºC to assure part stability.**
***Good resin transparency.**

Material	Araldite LY3585/3458	Araldite LY3585/3475	TRAC 06150	TRAC 06300
producer	Huntsman	Huntsman	Hexion	Hexion
T_g before aging	~ 120 °C	Up to 140 °C	Up to 130 °C	Up to 130 °C
T_g after aging	~ 113 °C	>135 °C	To be tested	To be tested
Yellowing	Reference	Better than LY3585/3458	Worse than LY3585/3458	Better than LY3585/3458
Processing	Reference	Less exothermal than LY3585/3458	Less exothermal than LY3585/3458	Less exothermal than LY3585/3458
Campatibility with XB3366 binder	YES	YES	To be checked	To be checked

Tests for getting Tg



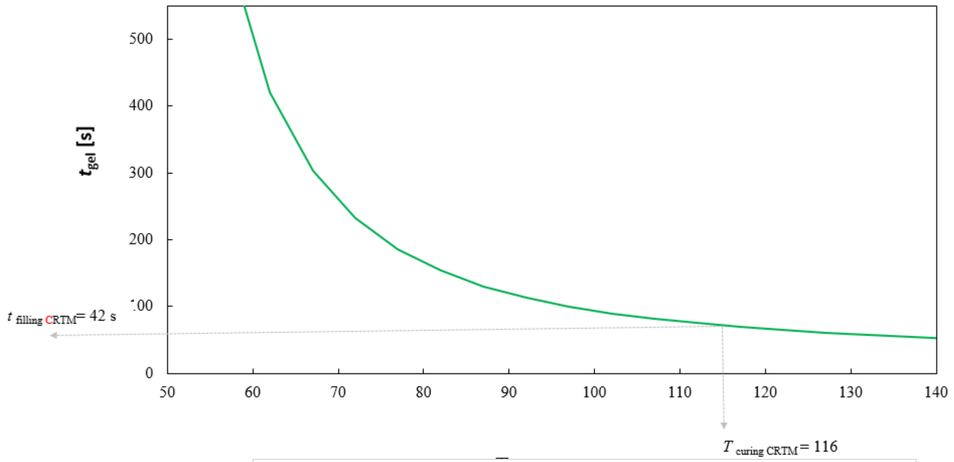
Yellowing on resins

Selected resin and hardener: XB3585- Aradur 3475

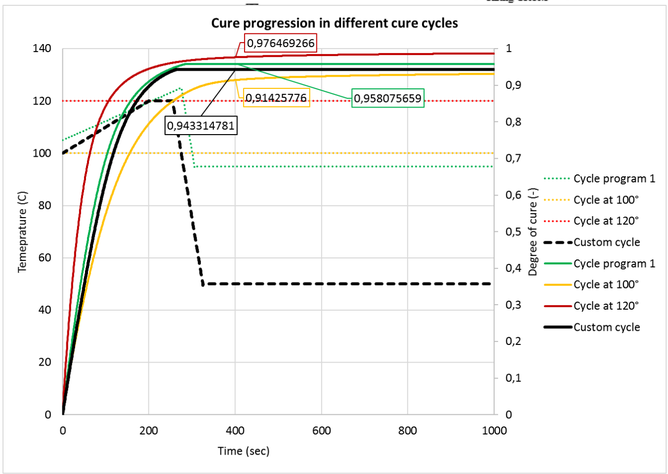
Bonnet manufacturing

Process window

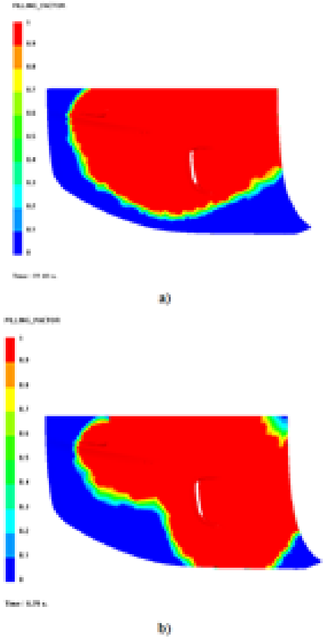
T ↑ ⇒ t_{Curing} ↓ ⇒ t_{gel} ↓ ⇒ $t_{gel} > t_{filling}$



Gel Point



Curing Degree



Process simulation

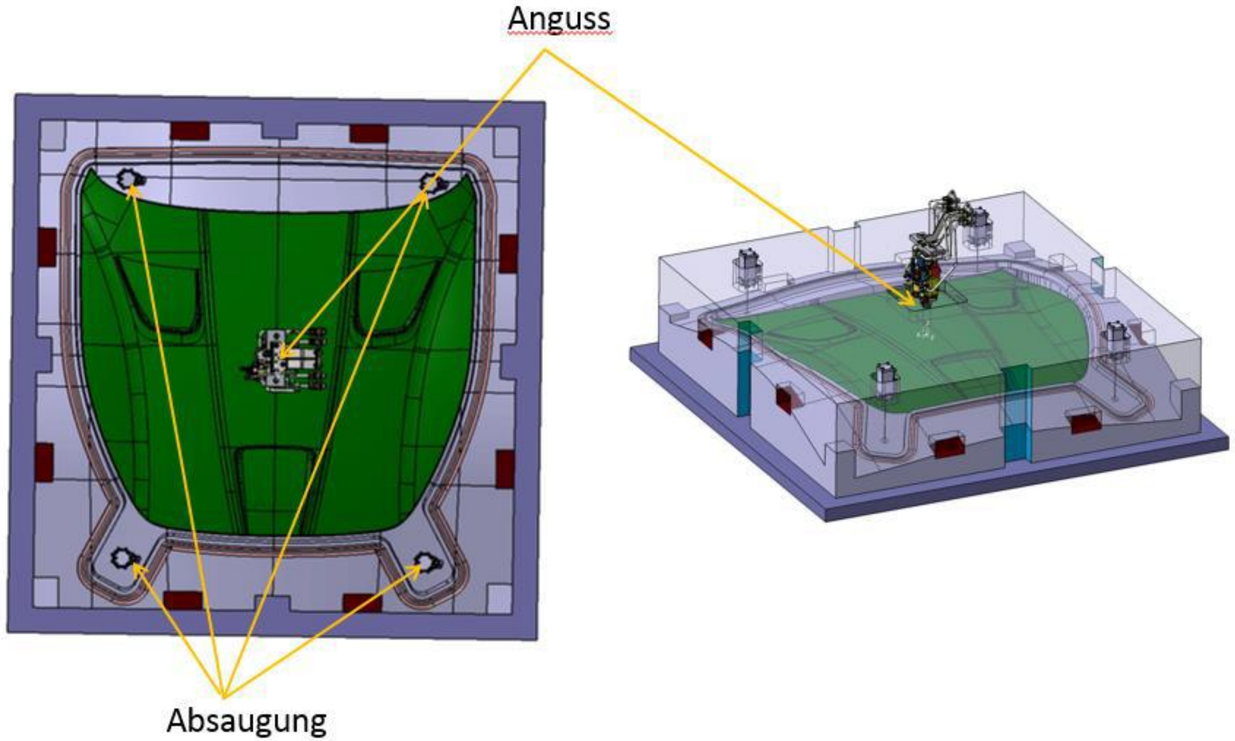
Circle time

Gap Injection time [s]	27	
Mould closing time [s]	5	
Curing time [s]	238	
CRTM circle time[s]	270	4,5min
Mold temp [°C]	116,5	
Injected resin and hardener[l]	1,9	

Bonnet manufacturing

Mold design

Resin/Vacuum:



Bonnet manufacturing

Results

Adjusting of the process

Test number	Gap (mm)	Mould temperature (ºC)	Resin temperature (ºC)	Injection strategy	Resin volume (l)	Injection pressure (bar)	Closing velocity (mm/s)	Vacuum (yes/no)	time		
									Injection (s)	Compression (s)	Curing (min)
1	3.3	82	60	Centre	1.8/1.8	5	1	-	30	5	30
2	1.3	86	60	Centre	0.6/1.8	5	1	Yes	180	5	30
3	3.3	82	60	Centre	0.5/2.2	5	1	-	180	5	30
4	3.3	83	60	Centre	2.2/2.2	5	1	Yes	30	5	30
5	3.3	80	60	Front	2.2/2.2	5	1	Yes	108	5	30
6	3.3	75	60	Front	2.2/2.2	5	1	Yes	28	5	20
7	3.3	99	60	Centre	2.2/2.2	5	1	Yes	60	5	30

PART MANUFACTURING VIDEO

New press architecture

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New press architecture

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COMPOSITES

REDUCED HEIGHT

INTEGRATED PARALLELISM CONTROL

BOLSTER DEFORMATION CONTROL

RAPID CLOSING SPEED OF THE SLIDE

SHORT PRESSURE BUILD UP TIME

REDUCED ENERGY CONSUMPTION

CUSTOMIZED CONTROL SYSTEM FOR CRTM

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New press architecture

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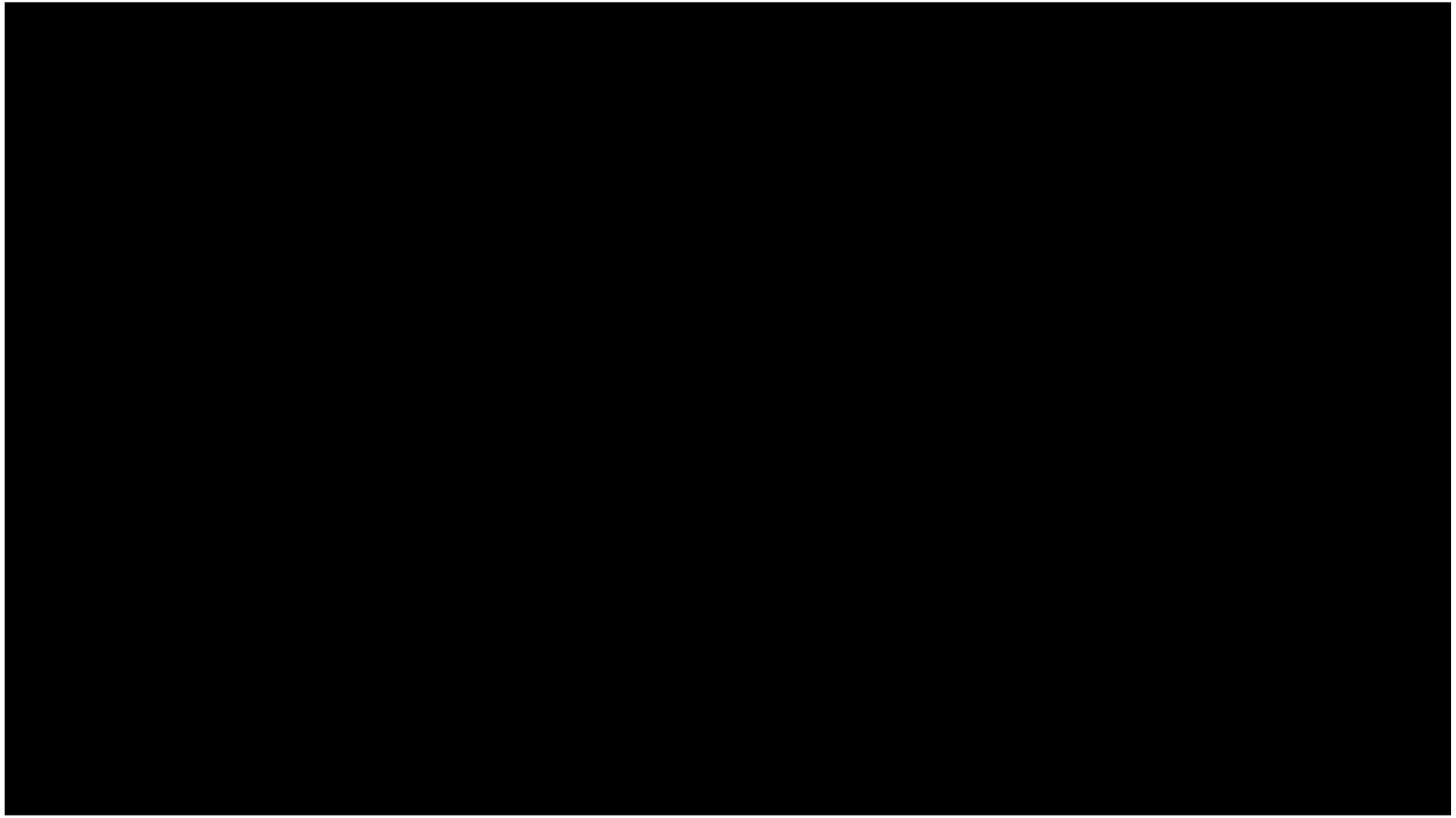
COMPOSITES



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COMPOSITES

Advanced Compression Resin Transfer Molding Line

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Advanced Compression Resin Transfer Molding Line.

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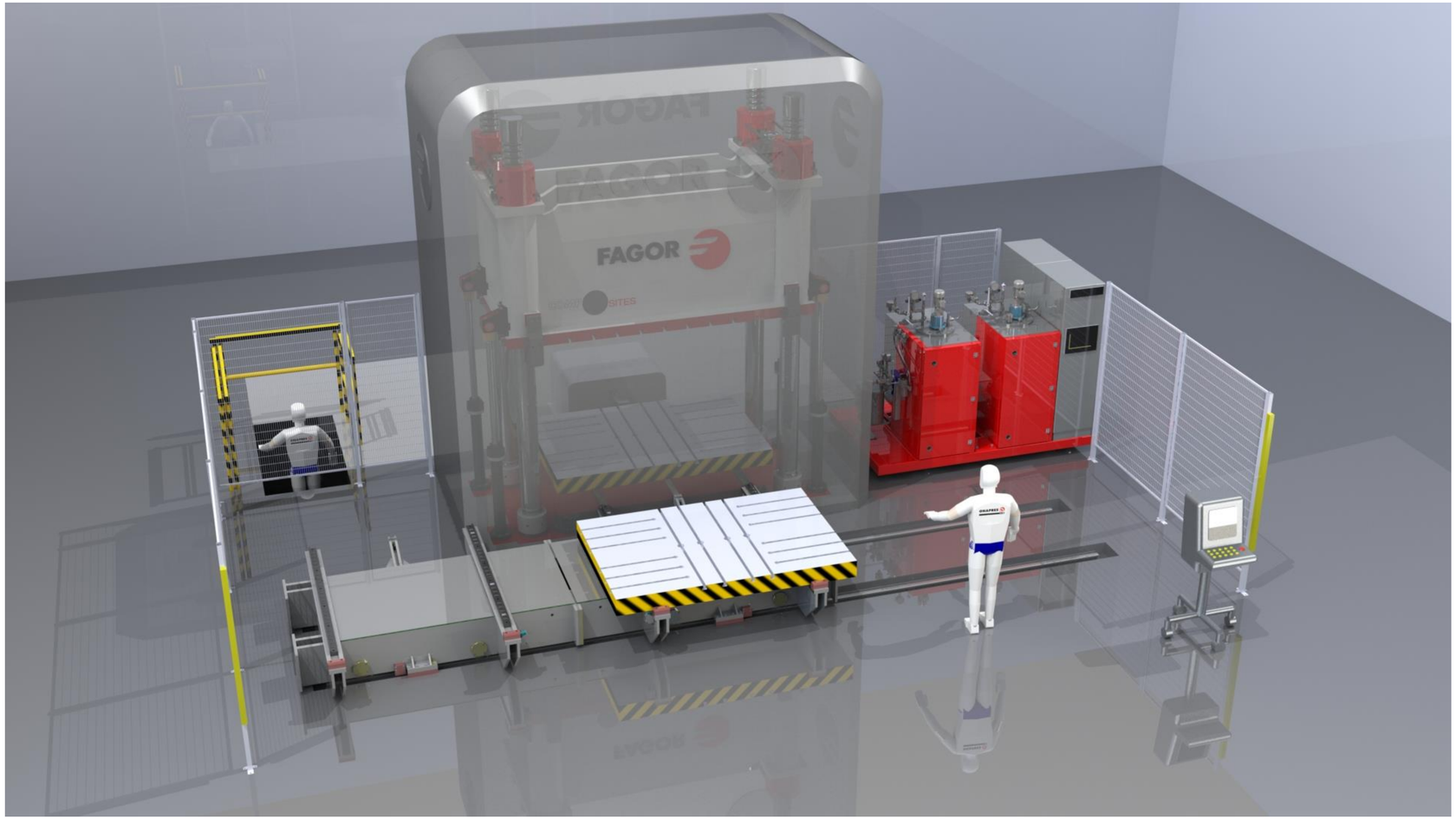
COMPOSITES



ADJUSTED TO THE REAL NECESSITIES OF THE CRTM PROCESS

INCLUDED A SPECIFIC CONTROL CONFIGURATION FOR CRTM

FLEXIBLE AND READY FOR USING FOR OTHER PROCESSES

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Summary

Summary

- ✓ CRTM is the most suitable manufacturing process from cost, energy consumption and cycle time point of view.
- ✓ Specific CRTM process knowledge has been developed and has been implemented in our press and cell control.
- ✓ A tight cell solution has been defined for CRTM.

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Thank you!

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