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OASIS

Open Access Single entry point for scale-up of Innovative Smart lightweight composite materials and components

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Catalogue of Up-graded performances for PLs for nano-enabled products

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DISCLAIMER

Executive Summary

This deliverable (DEL D1.7) describes the upgrade/upscale of the four pilot line related to the production of nano-enabled products:

- **PL9: METcast** (Nano-enabled lightweight injected cast parts. Functionalities: Mechanical and wear resistance properties), owned by Tecnalia
- **PL10: RTM** (Nano-enabled functional polymer based composites parts), owned by IPC
- **PL11: HCIM** (Nano-enabled functional hybrid Al/composite/plastic parts products), owned by IPC
- **PL12: NanoPUL** (Nano-enabled Al/composites hybrid products), owned by Fraunhofer IGCV

This deliverable describes:

- The purpose of each pilot line and the needs for the upgrade/upscale
- An overview of the upgrade/upscale for each pilot line. Some insights on what the pilot lines are capable to offer in terms of product and process.

The delay in this deliverable was due to the COVID-19 crisis, which had stopped all activities in some of the PLs for few months.

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1. Content of the Deliverable

This deliverable DEL D1.7 is focusing on the upgrade of the following Pilot Lines (PLs), related to the production or nano-enabled products (METcast byTEC, RTM by IPC, HybridIM by IPC and NanoPUL by Fraunhofer IGCV).

Each one is described by an overview of the upgrade/upscale and the capability of the facilities within the OASIS OITB.

2. Objectives of the upgrade/upscale for the PLs for the product manufacturing

The vision of OASIS is an ecosystem of 12 nanotechnology manufacturing pilot lines (PLs), operating under a common and demanding umbrella of Sustainable Production (OASIS framework). It aims at ensuring a competitive, quality, safe and environmental friendly production, of nano-enabled products in compliance with the applicable regulation.

One major task of WP1 aims at upgrading the 12 PLs integrated in OASIS OITB to meet industrial needs:

- Upgrade of the 3 pilot lines for *nanoscale structures* (nanomaterials) in unprocessed form with intrinsic functionalities.
- Upgrade of the 5 pilot lines for *intermediate products* with nanoscale features
- Upgrade of the 4 PLs for *nano-enabled products*

This deliverable DEL D1.7 is focusing on the upgrade of the four PLs for products manufacturing:

- **PL9: METcast** (Nano-enabled lightweight injected cast parts. Functionalities: Mechanical and wear resistance properties), owned by Tecnalia
- **PL10: RTM** (Nano-enabled functional polymer based composites parts), owned by IPC
- **PL11: HCIM** (Nano-enabled functional hybrid Al/composite/plastic parts products), owned by IPC
- **PL12: NanoPUL** (Nano-enabled Al/composites hybrid products), owned by Fraunhofer IGCV

The KPIs for the upgrade/upscale of the nano-enabled products are presented on Table 1.

The upgrade of the pilot lines related to the nanoscale and for intermediate products with nanoscale features are presented in DEL D1.5 and D1.6.

Nano-enabled products	**PL#9 METcast** Nano-enabled lightweight injected cast parts. Functionalities: Mechanical and wear resistance properties	
	Current production rate Flat samples (tensile test mould)	In-line dispersion unit Real-time chemical composition of elements, accuracy <1%
	OASIS target Complex geometries 3-5 kg/batch of pre-industrial prototypes	
	PL#10 RTM Polymer based composites parts (liquid thermoset matrices : EP, UP / dry reinforcement : glass, carbon …) Functionalities: Lighter / smart (thermal and electrical properties, sensor integration)	
	No upscale needed: 24 parts (up to 2.5*2 m^2)/day	In-situ cure monitoring adapted to conductive materials In-line viscosity measurement
	PL#11 HybridIM Nano-enabled functional hybrid Al/composite/plastic parts products (Al inserts / thermoplastic matrices : PP, PA, PEI, PPS, PEEK … / Reinforcement : glass, carbon …). Functionalities: Lighter / smart (thermal and electrical properties, sensor integration).	
	No upscale needed: 450 parts (up to 1.5*1.5 m^2) /day	Thermal imaging&in-situ material-state monitoring for indirect dispersion control. NDT&functional test within cycle time
	PL#12 NanoPUL Nano-enabled Al/composites hybrid products. Functionalities: Lighter and smart structures.	
	Current production rate Approx.1m/min for rebars	In-Line Temperature Control via IR-Camera System for induction curing device, accuracy <5% or 5K; Additional sensors for temperature and pressure monitoring, accuracy <5%
	OASIS target. Approx.3m/min rebars	

Table 1: KPIs for the upgrade of PLs for nano-enabled products

3. Upgrade of the Pilot lines for the production of nano-enabled products

OASIS	Datasheet for pilot lines – METcast
OITB Member	Tecnalia
Name of Pilot line	METCAST. Nano-enabled lightweight injected cast parts
Number of the Pilot Line	PL 9
TRL of pilot line	TRL6

Description of the pilot line

PL9 is a High Pressure Die Casting (HPDC) aluminium injection unit upgraded to produce high quality nanoreinforced aluminium components. The main equipment of the pilot line is a semiautomatic 150 Tn injection unit (see Fig. 1). The pilot line can produce components with complex shapes with up to 3 Kgs. of nanoreinforced aluminium and counts with the conventional control and recording features of industrial injection machines.

Furthermore, the HPDC unit has been upgraded with the following features: i) New electrical furnace with a capacity of holding up to 400 Kgs. of nanoreinforced aluminium alloy. The tilting furnace ha substituted the original one that could not be tilted and had lower capacity. The new furnace has been provided with a rail system so that it can be translated to the degassing and ultrasound application zone (see Fig. 2). This upgrading makes it possible to increase the quality of the melt, dispersion of nanoreinforcements and to increase the safety of the cleaning and composition adjustment operations, if so needed. ii) Furthermore, a new more powerful motor has been installed to the fume extraction system previously available. iii) The ultrasound module that is used both in PL#8 and PL#9 to improve the dispersion of the nanoparticulates into the melt and that has been upgraded to make it possible its use with the new furnace. In the upgraded unit the ultrasound probe has been protected with a metallic structure that makes it possible to introduce the probe into the melt preventing the heating of the sonicator. (See Fig. 3). iv) the control unit of the HPDC unit has been upgraded in order to increase the traceability of the components in terms of production parameters and chemical composition. v) A new vacuum system has been installed and tested successfully with nanoreinforced alloys.

Pictures

Fig. 1: HPDC unit. 150 Tn


Fig. 2: Tilting Electrical furnace of the HPDC unit


Fig. 3: Ultrasound unit

Features of the Pilot Line	
Input material	Nanoreinforced aluminium alloy ingots (0.1-0.2 wt.% of nanoreinforcements)
Output/Yield material	Nanoreinforced aluminium injected components (0.1-0.2 wt.% of nanoreinforcements)
Production time	~ 6 hours per batch of 50 injected components.
Energy consumption	15 KW/h
Name of the Process	Injection of nanoreinforced aluminium alloys
Keywords of the process (max.5)	Dispersion, ultrasonic, furnace, HPDC (High Pressure Diecasting)
Keywords of the product (max.5)	Nanoparticulates, aluminium, alloys, ingots
Technological offer	Production of nanoreinforced aluminium alloy components of up to 2 Kgs. Optimization of dispersion of nanoparticulates within the aluminium melt. Safe handling of nanoparticulates
Operating mode	Manual or semiautomatic
Language	English, Spanish.

Upgraded Technology	
Parameters of the process	1. Possibility of applying ultrasonic waves and conventional degassing unit to the melt. 2. New tilting furnace with capacity of melting of 400-500 Kgs. per batch. 3. Traceability of injection cycle parameters-alloy composition and nanoreinforced ingot production parameters integrated in the HPDC control unit. 4. New fume extraction system 5.- New vacuum system for the production of high-quality injected components
KPI achievement	1.- Production unit for the fabrication of nanoreinforced aluminium injected components in **batches of up to 50-100 components /8 hours.** 2.- Production of nanoreinforced components with up to **0.1-0.2 wt.%** of nanoparticulates with good dispersion and metal quality. 3.- Possibility of applying ultrasound waves to the melt to guarantee dispersion of nanoreinforcements and subsequently the quality and performance of the nanoreinforced material.

OASIS	Datasheet for pilot lines – RTM
OITB Member	Centre Technique Industriel de la Plasturgie et des composite (IPC)
Name of Pilot line	RTM Polymer based composites parts
Number of the Pilot Line	PL10
TRL of pilot line	TRL6

Description of the pilot line:

The pilot line consists in a 300T vertical press (Fig. 4), with a platen size of 3,0 m x 2,5 m. A bi-component injection machine matching industrial standards and allowing for the manufacturing composite parts with complex shapes and surfaces up to 3 m^2 with an output of 24 parts/day. Most of the thermoset resins can be processed on this pilot line. This pilot line has been equipped with a set of sensors so as to be able to in-line monitor the current status of the process, for regular and nano-enabled composite materials.

Even if this pilot line fully complies with industrial standards, the uniqueness of this line consists in its ability to (Fig. 5):

- Fully monitor the process parameters: temperatures, flow rate, pressure at different locations, mixing ratio
- Fully monitor the resin flow during the impregnation step, using a viscosity sensor and pressure measurements located in-mold
- Fully monitor the resin cure stage thanks to a network of sensors placed in the tool.

This monitoring is of prime importance for deeply understand the process behavior and also gives evidences for the quality of the produced part.

In addition, a unique know-how has been developed so as to (i.) design, (ii.) manufacture and (iii.) check "smart" structural composite parts made by the RTM process. Examples of new functionalities that have already been integrated into a structural part are stain gauges, thermal sensors, heaters, and capacitive touch sensors (non-exhaustive list). This integration into composite parts aims at light weighting and reducing the overall production time (cost reduction).

Moreover, the RTM pilot line has been upgraded so as to be able to manufacture products (Fig. 6), following the recommendation of IRNS regarding the manufacturing of nano-enabled materials (standard ED 6181).

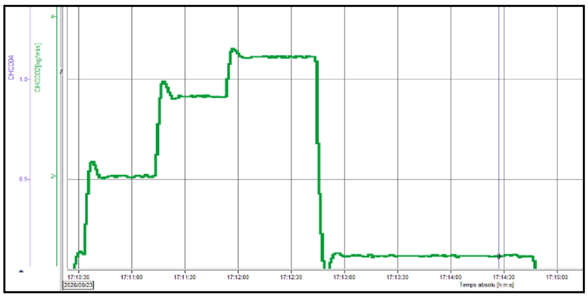
Pictures

Fig. 4: Overview of the PL#10 – RTM

Fig. 5: New ancillary equipment for controlling/monitoring the pilot line

Fig. 6: Ventilated cabinet for manufacturing preparing nano-enabled productions

Features of the Pilot Line	
Input material	Liquid thermoset matrices: most of the thermoset resin, including EP, UP Dry reinforcement: glass, carbon, basalt or natural fibers. Other materials can be considered upon request
Output/Yield material	Nano-enabled functional Polymer based composites parts including lighter / smart functions (thermal and electrical properties, sensor integration).
Production time	24 parts / day. Size up to 2.5 x 2 m^2
Energy consumption	The energy consumption of the epoxy dosing machine is monitored
Name of the Process	Resin Transfer Molding / High Resin Transfer Molding
Keywords of the process (max.5)	RTM process, in-line monitoring
Keywords of the product (max.5)	Smart composite, thermoset composite
Technological offer	Production of nano-enabled composites demonstrator manufactured using the RTM process, including in-line and in-mold measurements.
Operating mode	Manual and automated
Language	French, English

Upgraded Technology	
Parameters of the process	Typical process parameters for the RTM process are: - Resin injection with a flow rate ranging from **0.05 to 1 kg/min**, at a pressure of **50 bars.** - Mixing ratio of 100:20 - The resin can be injected at a **temperature of 80°C** in a preheated tool (**max temperature > 200°C)** - A **cycle time of 20 min** can be obtained (high-dependency on the resin curing kinetics) Some deviations from this typical values can be performed (upon requests)
KPI achievement	A new setup has been defined so as to perform: - In-line measurements of the process parameters such as flow rate, temperatures and pressures (Fig. 7) - In-mould characterization of the pressure and curing stage of nano-enabled composites (Fig. 8 left and right) - In-line measurement of the viscosity of the resin after mixing of the two components  **Fig. 7:** Measurement of the resin flow rate

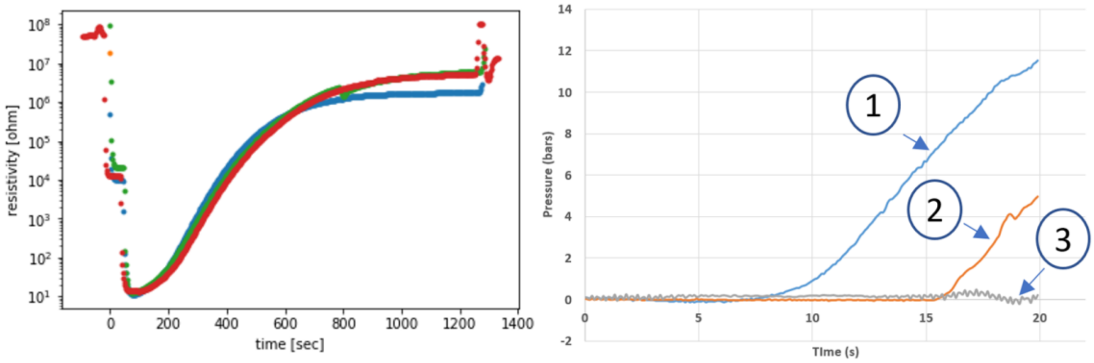


Fig. 8 : In-mold measurement of the curing stage of an epoxy resin (left) ; In-mold measurement of the pressure at different locations (right)

In the scope of the showcase VDL, all the nano-enabled intermediate products have been successfully integrated into the RTM pilot line:

- Aerogels Material for enhanced thermal insulation (pilot line PL#1 Functionalised nanoparticles, UCLM)
- Heating elements, made of buckypapers (Pilot line #4 Buckypapers, TECNALIA)
- Impact resistance & surface finishing (pilot line #5 CNT-doped veils, TMBK)
- Dry plies with nanopowder for improved fire resistance (pilot line #6 FXply, ADAMANT)
- Printed sensors / Actuators (pilot line #7 PICTIC, CEA)

OASIS	**Datasheet for pilot lines – HybridIM**
OITB Member	Centre Technique Industriel de la Plasturgie et des composite (IPC)
Name of Pilot line	HybridIM Nano-enabled functional hybrid Al/composite/plastic parts products
Number of the Pilot Line	PL 11
TRL of pilot line	TRL5

Description of the pilot line:

The pilot line HCIM (Horizontal Composite Injection Molding, Fig. 9) enables producing composites parts, with size up to 1,5 m, based on overmoulding technology in a cycle time around 1 minute (Fig. 10). The HCIM process involves the heating and the forming of thermoplastic prepregs, followed by an injection moulding step in order to overmould some areas of the prepreg. The insertion of electronic components like printed sensors, as well as the use of functional materials, enable the manufacturing of smart composite parts (Fig. 11).
In-line control of this process is enabled by temperature and pressure measurements in the mould during the process. In addition, non-destructive testing (NDT) technologies are available to provide information about inserts localization and defects (porosity, delamination, impurity, fiber orientation, void, welding line). Infra-Red (IR) Thermography associate to therahertz technology enables to detect defects and inserts in parts. IR Thermography has a higher resolution with carbon fibre, contrary to Terahertz which is outperform with glass fibre.

IR thermography analyses material's temperature during cooling of few degrees. Defects and heterogeneities generate hot or cold points. This technology is limited to thin thicknesses. Two different modules can be applied to composite materials. First is the pulse method (Fig. 12, left): this is a flash heating of several milliseconds generated by xenon light which is applied to the product, inducing temperature increase of 5 to 10 °C.
Second is a lock-in module (Fig. 12, right): the heat's intensity and frequency are modulated as sinusoid signal. This is generated by a halogen light. Input and output signals are compared.
A cooled camera captures results of both modules. The sensor of this camera is cooled by cryogenics enabling to reduce the background noise, improve sharpness and receive short wavelengths.

Pictures

Fig. 9: HCIM pilot line

Fig. 10: Composites parts from pilot line HCIM: thermoplastic matrix reinforced by glass fibre

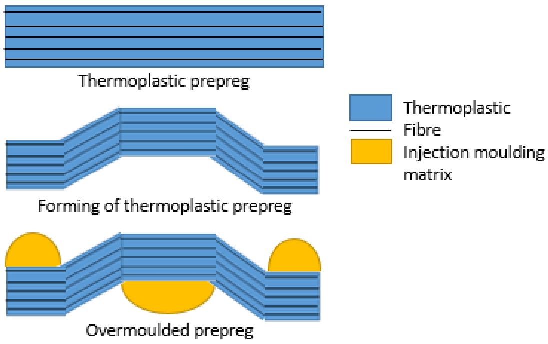


Fig. 11: Illustration of product from pilot line HCIM

Fig. 12 Pulse system of Infra-Red Thermography (left) and Lock-in system of Infra-Red Thermography equipment (Right).

Terahertz (Fig. 13) is a non-destructive control system using non-ionizing rays based on Terahertz electromagnetic waves (between IR and microwaves). The wavelengths are comprised between 75 GHz and 10 THz. These waves can penetrate dielectric materials and probe them for internal properties analysis through a non-destructive method.
Terahertz can be used in transmission (Fig. 14, sensor and detector either side of parts) and in reflection (Fig. 14, sensor and detector on the same side). Each method is in accordance with different types of defects. Reflection is adapted to porosities, inserts position, impurities and delamination. Transmission method is in accordance to fibre density and plies orientation.

Main advantages of these technologies are non-destructive and non-contact testing, repeatability results and speed of the scan; furthermore, this equipment doesn't require any specific safety measurement.

Fig. 13: Terahertz technology

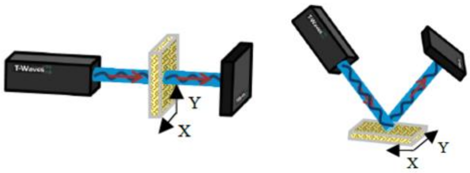


Fig. 14: Transmission (left) and reflection (right) mode

Features of the Pilot Line	
Input material	Composite thermoplastic matrices : PP, PA, PEI, PPS, PEEK… / Reinforcement : glass, carbon, basalt, natural fibres
Output/Yield material	Nano-enabled functional hybrid Al/composite/plastic products including Lighter / smart functions (thermal and electrical properties, sensor integration).
Production time	450 parts (up to 1.5x1.5 m2) /day
Energy consumption	-
Name of the Process	Manufacturing: Horizontal Composite Injection Molding Nondestructive evaluation: IR thermography & terahertz
Keywords of the process (max.5)	Stamping/overmolding process, nondestructive evaluation, reduced cycle time for high volume production
Keywords of the product (max.5)	Smart composite, thermoplastic composite, net shape
Technological offer	Production of nano-enabled Al/composites hybrid demonstrator manufactured using the stamping/overmolding process, including in-line nondestructive assessment.
Operating mode	Manual or automated
Language	French, English

Upgraded Technology - Nondestructive evaluation (IR Thermography & Terahertz)	
Parameters of the process	• Temperature prepreg: maximum setpoint 500 °C • Clamping force: maximum 1000 KN • Size of mould: maximum 1200 x 1400 mm • Flow rate of injection: maximum 2160 cm^3/s
KPI achievement	Both terahertz and IR-thermography are implemented so as to be able to perform an in-line control of the produced nano-enabled composite products. They follow the same approach as represented on the picture below

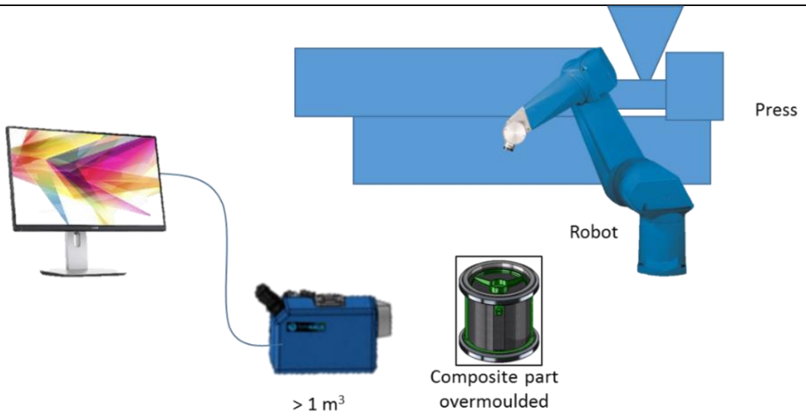


Fig. 15: In-line control strategy for performing an non-destructive evaluation of nano-enabled composite products

Both Infrared thermography and terahertz technologies were characterized.
An example of pulse thermography result can be seen on Fig. 16 at different frequencies.

Fig. 16: A picture of sample (left), (A) Pulse thermography result at 2,22 Hz and (B) Pulse thermography results at 11,11 Hz

This sample has three identical inserts localized at different levels in the part thickness. Depending on the frequency, it is possible to see these inserts. Porosities can be seen at the middle of each insert (blue circles). An electronic device is observed like a black point (orange square).
Another nano-enabled sample has been analysed with pulse thermography and with lock-in thermography (Fig. 17). Two position pins can be seen with pulse thermography and also with lock-in thermography (blue circles). LEDs are visible on both methods in orange circles.

These results are obtained in collaboration with our supplieurs (Edevis and Thermoconcept).

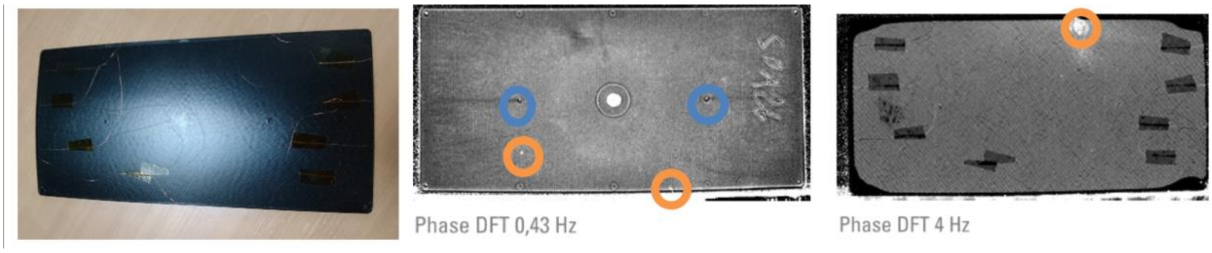


Fig. 17: A picture of sample (left), (A) Pulse thermography result at 0,43 Hz frontside and (B) Pulse thermography results at 4 Hz backside

Datasheet for pilot lines - NanoPUL

OITB Member	Fraunhofer IGCV
Name of Pilot line	NanoPUL
Number of the Pilot Line	PL12
TRL of pilot line	TRL6

Description of the pilot line:

The modular pilot line 12 is an open access infrastructure for companies, which was implemented for the production of high performance nano-enabled composites in industrial scale. The pultrusion line has a modular setup and can run from 0.05 m/min up to 3 m/min. Utilizing this modular setup, it is possible to investigate different fiber reinforcements, such as UD-fiber-rovings, mat and woven fabrics. Further reinforcement can be implemented in line with a braider and/or a winder. All state of the art impregnation systems are applicable and a variety of resin systems and fillers can be processed. The modular setup is also consisting of three different heating device setups, which can be combined in all variations. This includes IR-heating, an inductive heating unit and electrically heated dies. Furthermore there is the possibility to measure, control and monitor all important process parameters. Examples include an online pressure monitoring for the impregnation chamber as well as a temperature control system, consisting of various thermocouples supplemented by a fully integrated IR-Camera system. In total this results in an optimal environment for research, material- and process development on the basis of innovative approaches in the field of nano-enabled pultrusion.

Picture

Fig. 18: Modular Injection chamber - Showcase-Example: Rebar product

Fig. 19. Setup example - Inductive heating unit

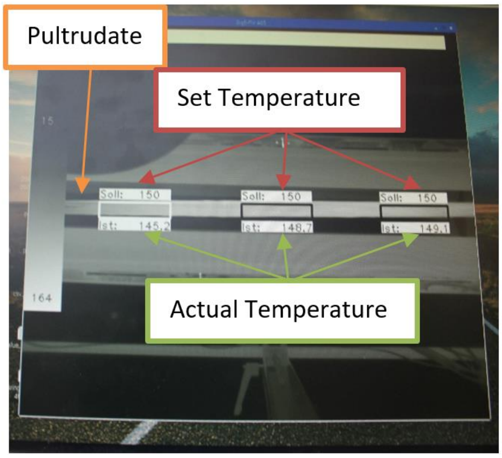


Fig. 20. Setup example - IR control and online monitoring system for the IR-heating field and inductor

Features of the Pilot Line	
Input material	Nano-enabled resin, Fiber reinforcement, Fillers
Output/Yield material	Nano-enabled composite
Production time	1-5 days
Energy consumption	0,15 – 1 kWh per meter profile
Name of the Process	Pultrusion
Keywords of the process (max.5)	Continuous process, sustainable, energy efficient, cost effective, High output
Keywords of the product (max.5)	Composite material, high end mechanical performance, functional properties, added value products, light weight
Technological offer	The pilot line is suited to investigate all important material- and process-parameters for pultrusion products. Different fiber reinforcements (UD-Fibers, Mats, Woven fabrics…), impregnation methods (open-bath, closed injection), resin systems (Polyurethan, Vinylester, Polyester, Epoxy (amine, anhydride)…), functional additives (Flame retardancy, electromagnetic properties, …) and fillers (nanoparticles, clay….) can be processed on the line. For each setup the perfect process window can be found regarding the fiber guiding, process speed, curing temperature and curing method. For this task, a big variety of different tools is in stock.
Operating mode	Semi-automatic to automatic
Language	English and German

Upgraded Technology	
Parameters of the process	1. Inductive and infrared heating 2. Fiber Impregnation 3. Pultrusion speed
KPI achievement	1. **Inductive heater** for magnetic particles 2. **IR-Camera control** for IR-heater and inductive heater 3. **Modular injection chamber** for nano enabled resins 4. **Winder** for surface modification of the rebar

4. Conclusions

These pilot lines are part of an ecosystem of 12 nanotechnology manufacturing pilot lines, providing nanomaterials, nano-intermediates, nano-enabled products and associated services for the development and commercialization of lightweight multifunctional products based on aluminium and polymer composites.

The up-graded performances for PLs for the production of the nano-enabled products have successfully been performed: PL9 - METcast, PL10 – RTM, PL11 – HCIM and PL12 - NanoPUL.

The pilot lines are fully operational fully and ready to start the democases' development. This document can be used as a public catalogue of technical information from the PLs for the SEP.

Additionally, this public catalogue of technical information reflects a state of the PLs from the OASIS project for dissemination purposes (WP7).

5. Degree of Progress

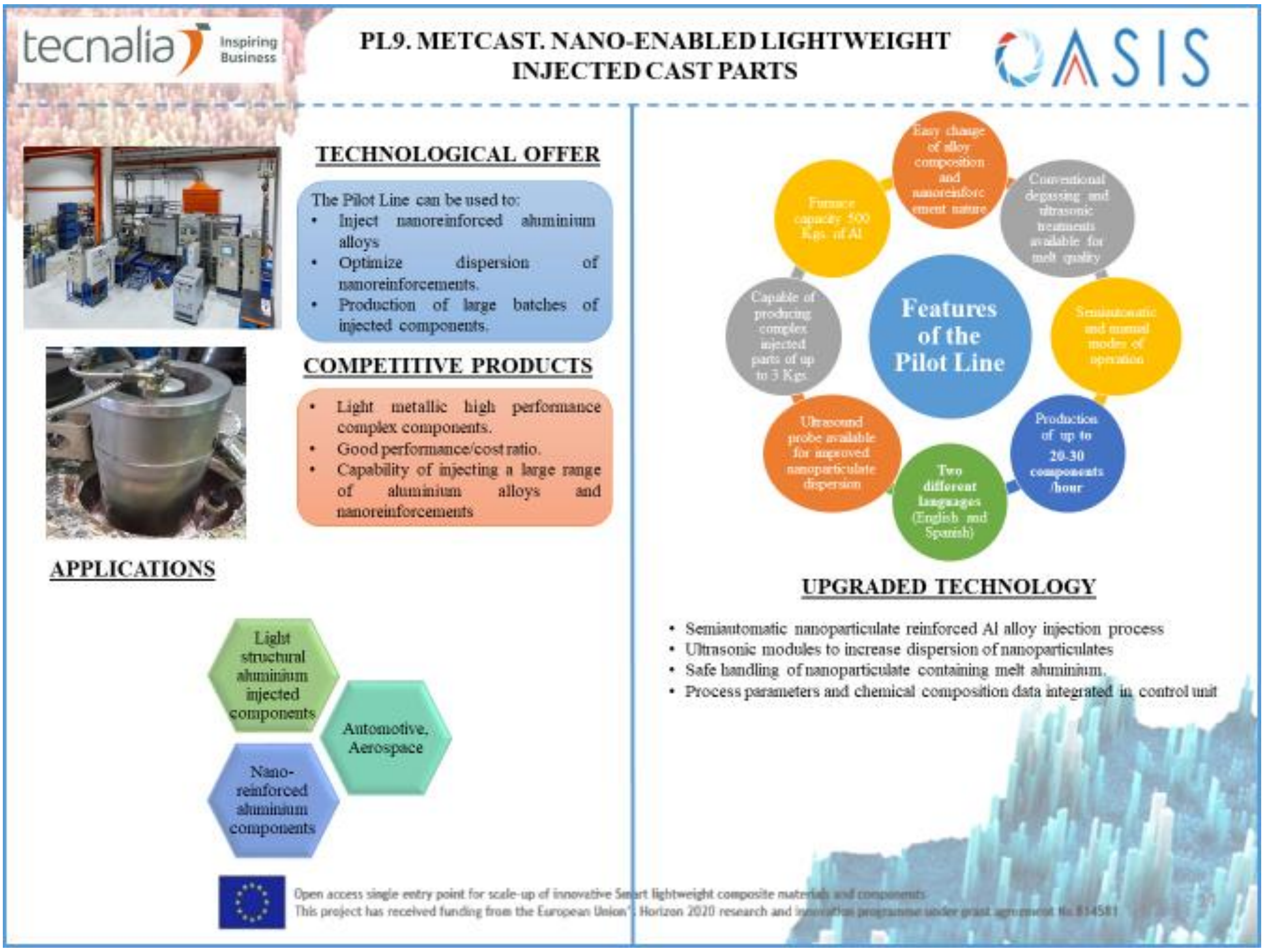
This deliverable is a 100% complete

6. Dissemination Level

This deliverable is public.

7. Appendix

The presentation of the upgrade/upscale of the PLs for the manufacturing of the nano-enabled products is attached in that section.




IPC
RTM POLYMER BASED COMPOSITES PARTS
OASIS
TECHNOLOGICAL OFFER
The Pilot Line can be used to:
• Develop smart composite parts
• Perform in-line control of the process parameters, including viscosity
• Perform in-mold control of the curing stage and pressure
COMPETITIVE PRODUCTS
• Large smart composite parts.
• Functionalised materials.
• xxx.
• High production rate
APPLICATIONS
Building and construction
Automotive industry
Aerospace
Features of the Pilot Line
Smart composite
High production rate 24 pc/day
In-line monitoring of the process
In-mold control of the pressure and curing stage
Production of parts up to 1,5 m
Adapted to thermoset composites
Process compliant with standard ED 6181 (nanosafety)
Nano-enabled composite
UPGRADED TECHNOLOGY
Implemntatation of the monitoring at different stages of the process to guarantee homogeneity of nano-filled compositions including:
• In-line monitoring of the curing stage of the thermosetting resin
• In-mould pressure has been successfully monitored
Open access single entry point for scale-up of innovative Smart lightweight composite materials and components
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814581


IPC
HYBRIDIM NANO-ENABLED FUNCTIONAL HYBRID AL/COMPOSITE/PLASTIC PARTS PRODUCTS
OASIS
TECHNOLOGICAL OFFER
The Pilot Line can be used to:
• Develop smart composite parts
• Perform in-line control of 100 % product
• Apply non-destructive testing technologies
COMPETITIVE PRODUCTS
• Large smart composite parts.
• Functionalised materials.
• 100 % quality controlled.
• Short cycle time.
APPLICATIONS
Electronics
Transport
Building and construction
Features of the Pilot Line
Smart composite
Cycle time around 1 minute
100 % quality controlled
Production of parts up to 1,5 m
Adapted to non-conductive thermoplastic matrices
In-line control and non-destructive testing
Defects located
Localisation of components
UPGRADED TECHNOLOGY
• Implementation of thermography equipment enabling pulse and lock-in thermography in cycle time.
• In-line control with terahertz technology.
Open access single entry point for scale-up of innovative Smart lightweight composite materials and components
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814581


Fraunhofer
IGCV
NANO-ENABLED FUNCTIONAL HYBRID
AL/COMPOSITE/PLASTIC PRODUCTS
OASIS
TECHNOLOGICAL OFFER
The Pilot Line can be used to:
• Pultrusion of nano-enabled resins
• Different profiles, resin systems and reinforcement materials
• Evaluate and monitor process parameters
COMPETITIVE PRODUCTS
• Different curing methods
• Functionalised resin systems
• Faster pultrusion speed
• Wide range of pultrusion profiles
APPLICATIONS
Automotive
Transport
Building and construction
Features of the Pilot Line
Dosing machines for PU and EP
Pultrusion speed up to 3 m/min
Process parameter monitoring
Production of parts up to a crosssection of 245 mm x 400 mm
All standard resin system processable
In-Line pressure measurement
Inductive heating
Infrared heater with IR-camera control
UPGRADED TECHNOLOGY
• Implementation of an IR- Heating tunnel
• Implementation of an Induction Heating unit
• Implementation of an IR - Camera control system (Online Monitoring) for IR-Heating tunnel and Induction Heating unit
• Implementation of a Modular Injection chamber
• Upgrade for modular fibre guidance system
• Implementation of pressure sensors
Open access single entry point for scale-up of innovative Smart lightweight composite materials and components
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