SUPREME

NEWSLETTER

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Foreword by Coordinator

Since the previous Newsletter published on SUPREME website in early September 2019, the consortium has made good progress. The T0+24 Review meeting was held on September 24-25th at ASL in Sheffield and our latest Executive Board meeting was organized on December 13th. We are now actively preparing the T0+30 review meeting which will be held at TECNALIA in San Sebastian at mid-March 2020.

In the last six months, among the results obtained, we can mention: (i) the Hot Isostatic Process developed at TWI for a marine application, using Inconel 625 powder, allowed to compare the mechanical properties and microstructures of samples produced from four powders atomized under different conditions; as-HIPped samples produced with Plasma-atomized powder gave properties similar to wrought products and showed negligible amounts of Prior Particle Boundaries. (ii) the MIM process developed at CEA for water-atomized 17-4PH stainless steel powder allowed to recycle MIM scraps and L-PBF used powder in the feedstocks without any significant impact on the tensile properties; moreover, the newly developed feedstock led to a 5-7% yield process improvement compared to a reference commercial feedstock. (iii) the L-PBF process developed at IPC, using L40 steel gas-atomized powder, gave hardness, tensile strength and impact toughness higher than Maraging steel, which confirms its potential for tooling applications. (iv) GKN and IRIS have installed one monitoring system including a powermeter and gas flowmeter on an L-PBF machine; test runs were performed by GKN successfully. GKN staff has been trained to use the system in order to record production trials and send data to CEA through a server. Printing of original engine brackets while monitoring the gas and energy consumptions started running at mid-December 2019. (v) The SUPREME results were disseminated at PM Summer School (July 2019, Trento, Italy) and at AM PM Life training module (Aug.2019, Dresden, Germany). Oral presentations were given at EuroPM2019 conference (Oct.2019, Maastricht, The Netherlands) and four papers have been published in the Proceedings.

In this fifth edition of the SUPREME newsletter, OUTOTEC, leader of Work package 1 dedicated to Mineral processing, CEA, leader Work package 3 dedicated to Additive Manufacturing Processes, and TECNALIA, leader of Work package 4 dedicated to Near Net Shape processes, inform you about the latest progress and results on their respective work packages. MBN, powder supplier and partner of Work package 2 presents the results obtained on Ball milling activity. WeAre Additive and GKN, developing respectively the aeronautical and automotive use-cases will introduce the work accomplished up to now. CEA in charge of Data Collection and Life Cycle Analysis on SUPREME processes shows the Key Process Indicators (KPIs) calculation and first results. IRIS, leader of Work package 6 dedicated to processes monitoring, gives an update about sensors and process monitoring system installation at Demonstrators sites. EPMA, in charge of dissemination activity, gives some updates about the promotion of SUPREME results. Finally, the detailed presentation of the consortium continues with four more partners: DELLAS, MBN, IDONIAL and TECNALIA.

Enjoy your reading!

Dr Thierry Baffie
SUPREME project coordinator

Introduction

SUPREME aims at optimising powder metallurgy processes throughout the supply chain. It is focussed on a combination of fast growing industrial production routes and advanced ferrous and non-ferrous metals. By offering more integrated, flexible and sustainable processes for powders manufacturing and metallic parts fabrication, SUPREME enables the reduction of the raw material resources (minerals, metal powder, gas and water) losses while improving energy efficiency and thus carbon dioxide emissions, into sustainable processes and towards a circular economy. To achieve this goal an ambitious cross sectorial integration and optimisation has been designed between several powder metallurgy processes; gas and water atomisation as well as ball milling for metal powder production, laser based additive manufacturing and near-net shape technologies for end-parts fabrication. A consortium of 16 partners has been gathered on this purpose under the coordination of the Commissariat à L'Energie Atomique et aux Energies Alternatives (CEA), France. The Supreme Project kicked off on 21 September 2017 and will end in August 2020.

The SUPREME Consortium

The SUPREME Consortium sees a mixture of organisations covering the full value chain from mineral to end parts applications: Atomising Systems Ltd (United Kingdom), CEA (France), Centro Ricerche Fiat (Italy), Dellas Srl (Italy), European Powder Metallurgy Association (Belgium), Fundación IDONIAL (Spain), GKN Sinter metals (Germany), Innovation Plasturgie Composites (France), IRIS (Spain), MBA Incorporado SL (Spain), MBNnanomaterialia (Italy), Outotec (Finland), We Are Additive Defense (France), RHP Technology GmbH (Austria), Tecnalia Research and Innovation (Spain) and TWI Ltd (United Kingdom).

Promotion

The promotion of the project is continuously carried out, mainly by EPMA participating in external conferences and exhibitions, where material concerning the project is shown, and explained to interested conveners.

Exhibitions:

SInce the previous issue of this newsletter EPMA attended several exhibitions

- TCT Show, Birmingham, UK (09/2019)
- Advanced Engineering, Birmingham, UK (10/2019)
- EuroPM 2019, Maastricht, The Netherlands (10/2019)
- Formnext, Frankfurt, Germany (11/2019)
- 38. Hagener Symposium PM, Hagen, Germany (11/2019)
- Transmission Expo, Berlin, Germany (12/2019)

Of these, Formnext was by far the most attended, with about 35000 visitors, but also the TCT (8000) and AE events (15000) were rather large and represented a good occasion to show SUPREME banners and distribute leaflets. The Hagener Symposium is the German Fachverband Pulvermetallurgie annual conference, and despite the small attendance it has a very high scientific relevance.

Figure 1: B. Vicenzi (EPMA) with the advanced SUPREME roller banner at the 38. Hagener Symposium Pulvermetallurgie, Hagen, Germany, November 2019

Fig 2: The SUPREME booth at the EPMA EuroPM 2019 Congress & Exhibition, Maastricht, The Netherlands, October 2019

Promotion (continued)

Especially the EPMA EuroPM 2019 Congress & Exhibition, the EPMA annual conference (about 1100 participants) saw many activities for SUPREME. There was a dedicated SUPREME booth, that received many visits, where some exhibits from the member companies' activities within the projects were on show: powders produced by ASL, diamond cutting tools from Dellas, plastic parts produced from AM-made cavities by IPC, an aeronautical engine part made by WeAre Additive Defense through L-PBF, and a poster about HIP of Inconel 625,and new promotional material (roller banner, leaflets) were made available. Also, results from SUPREME have been the subject of 3 oral presentations (see below) in the technical sessions.

Training and scientific dissemination

In August, Dr Thierry Baffie of CEA took part as a lecturer in the EPMA-run PM Life Additive Manufacturing Week Lifelong Training course, held on 26th-30th of August at Fraunhofer IFAM in Dresden, Germany. PM Life is a project co-funded by EIT Raw Materials within Horizon 2020, that delivers training to professionals, academic young researchers, and even unemployed interested engineers, in the field of Powder Metallurgy, in the form of several different modules, each one on one specific PM topic or PM technology. In Dresden, the topic was Additive Manufacturing. The lecture given was titled "The SUPREME project: material and energy efficiency optimization from mineral ore extraction to AM processes".

Fig 3: Thierry Baffie presenting his lecture on SUPREME at the PM Life AM Module in Dresden, August 2019

Also, results from SUPREME have been the subject of 3 oral presentations (from CEA, GKN, and IPC) and a poster (from RHP).

- 14/10/2019 17:00-18:30 - Session 9 - Properties of AM Materials – Steels

  Oral: "Study on the influence of various 316L atomized powders on the microstructures and mechanical properties of parts obtained by Laser Powder Bed Fusion process", T. Baffie, S. Cayre, S. Chomette, P. Faucherand, G. Gaillard, L. Aixala (CEA-LITEN, Grenoble, France)

  Oral: "Performance and Quality parameter and their effect on LPBF manufactured high carbon steel structures using water atomized powders", S. Blümer, S. Höges, M. Schneider, D. Zhu, L. Möller (GKN, Germany)

- 15/10/2019 14:30-16:00 - Session 26 - Beam Based Technologies 1

  Oral: "Development of a new tooling steel (L40) for Laser Powder Bed Fusion: influence of exposure parameters and powder atomization", T. Joffre, N. Maillol, J. Bajolet (CT-IPC, Oyonnax, France)

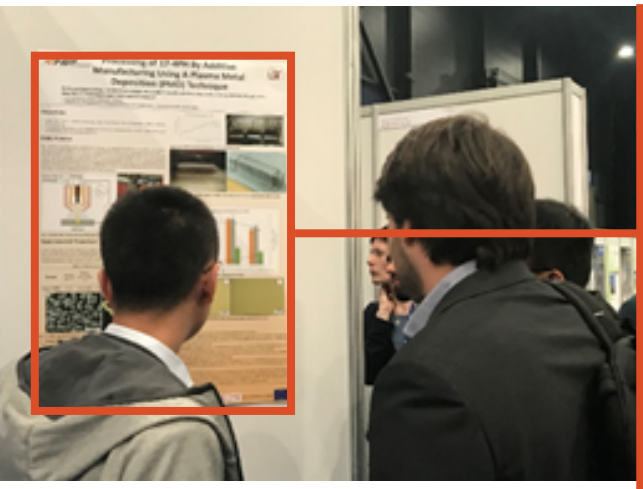
- 16/10/2019 08:00-09:30 - Session 40 - Material Deposition Technologies

  Poster: "Processing of 17-4PH by additive manufacturing using a Plasma Metal Deposition (PMD) technique", E. Ariza Galván, I. Montealegre-Meléndez, E. Pérez Soriano, C. Arévalo Mora, J. Meuthen, M. Kitzmantel, E. Neubauer (RHP Technology, Austria)

Fig 4: Dr. Ing. Thierry Baffie

Fig 5: Mr Sebastian Blümer

Fig 6: Dr Thomas Joffre



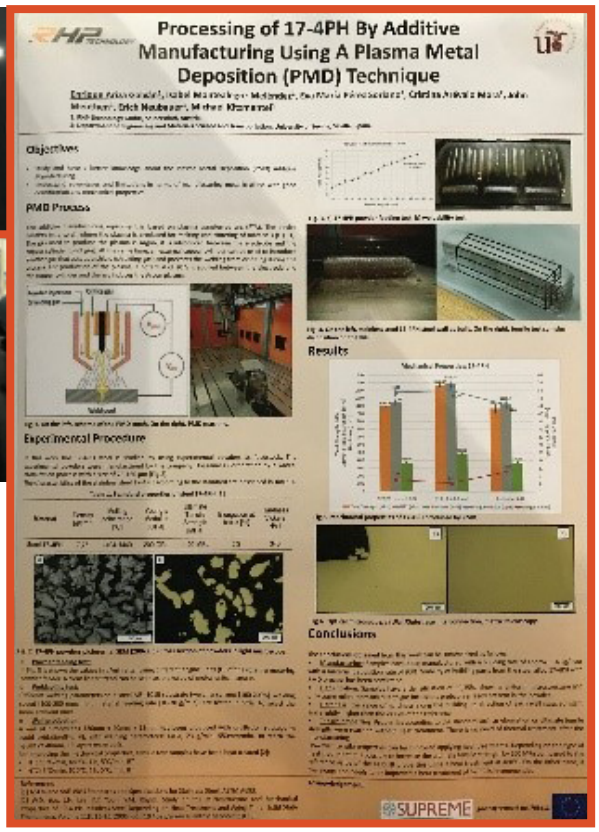


Fig 7: Poster - E. Ariza Galván

Supreme Review Meetings

On 24th-25th September 2019, the SUPREME Project T0+24 General Meeting took place in Sheffield (UK), organised by the local partner Atomising Systems Limited. The programme of the meeting included a Review Meeting on 24th September, where all the workpackages were addressed and the status of the project was discussed, and a Technical Meeting on the 25th, when four separate internal technical workshops on the various demonstrator activities ("use cases") ran in parallel. Finally, an interesting visit to the ASL premises closed the meeting. On 13th December 2019, the T0+27 Executive Board Meeting was held via a Skype conference. All WP leaders took part, and all issues concerning the project activities were addressed, including the rearrangement of the technical programme and of the budget.

The next meeting will be the T0+30 General Meeting that will be held in Tecnalia, San Sebastián, Spain, on 17th-18th March 2020. With only 6 months to go to the end of the project, this will be the last physical general meeting before the Final Review Meeting, so it will be very important for a successful conclusion of the activity. (maybe we can put a picture of Tecnalia taken from their partner presentation)

Results and demonstrators Update

WP1: AIMING TO PERFORMANCE IMPROVEMENTS IN MINERAL CONCENTRATION PROCESSES (J. KAARTINEN, OUTOTEC)

Task 1.1 Grinding process improvements

In Task 1.1 the focus is on advanced instrumentation and control of the ore grinding – an essential step before the actual concentration can take place. The process that has been studied is a two-stage iron ore grinding circuit at LKAB Kiruna. The feed of the circuit consists of crushed iron ore particles of average size around 30 mm, and the output is mineral slurry which contains the ground ore particles (size reduced below 100 µm) and water. Most of the energy in the circuit is consumed by the two grinding mills.

Improved process monitoring

The work was started by adding new instrumentation to the circuit: volumetric charge measurement devices (MillSense®) for the both mills, particle size measurement device (RockSense®) for the feed ore and an additional sample line for the particle size analyzer (PSI500®) to analyze the primary mill product fineness. MillSense contains a strain sensor installed on the mill liner bolt; it detects the angle when the liner hits the charge inside the mill and can then estimate the total volumetric charge of the mill. RockSense, on the other hand, scans the 3D profile of the rock particles on the conveyor belt and calculates the particle size distribution from that information. PSI500 utilizes laser diffraction to determine the particle size distribution of the solids in the slurry.

Process improvement targets

Main improvement targets in Task 1.1 are to reduce the overall energy consumption and the time spent in over- and under-grinding (measured by the standard deviation of the product particle size), as well as to improve the stability and throughput of the grinding circuit. This will have a huge impact on the reduction of CO_2 emissions. A set of additional KPI variables is monitored as well, mainly to ensure that the operation of the circuit otherwise remains the same when the improved control is utilized.

Model predictive controller for the circuit

The control strategy for the grinding circuit optimization relies on model predictive control (MPC). MPC is based on dynamic process models that describe the main relationships between the input and output variables of the process, and the control can include a set of constraints. The models are estimated from data collected as a result of step response tests of the process. Control targets are given by determining setpoints for the controlled variables, and the controller then calculates the control moves that are needed to reach the setpoints as well as possible.

The whole grinding circuit at LKAB Kiruna is controlled with one MPC controller. The most important variables that the controller is manipulating are the fresh ore feed rate and the water/solids ratio of the feed. Correspondingly, the main controlled variables are the primary mill power and charge, and the final product particle size distribution and mill load.

Fig 9: MPC controller dashboard for the process operators in the Outotec's advanced process control system (ACT).

Performance testing in grinding

TThe MPC controller has been successfully implemented at Kiruna and the final tuning and testing is currently in progress. Once the work is ready and the operators have been trained, the obtained performance improvements will be evaluated using on/off tests. There the MPC controller is compared to manual control in a scheduled set of experiments. This procedure is needed in order to compensate the effect of unknown changes in the feed ore – otherwise the changing particle size and ore hardness of the feed can skew the obtained results.

Task 1.2 Flotation improvements

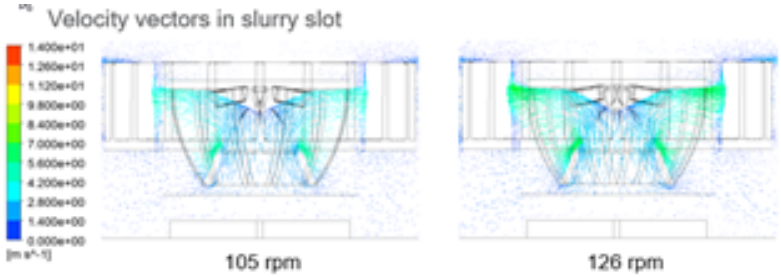
Task 2 is aiming to improve flotation performance to reduce waste (maximize mineral recovery) and reduce energy input per unit of feed. Waste reduction is focused on improvement of fine particle recovery by addition of microbubbles to a standard flotation machine. Energy reduction will be obtained by reduction of the rotor while maintaining the functionality of the flotation machine.

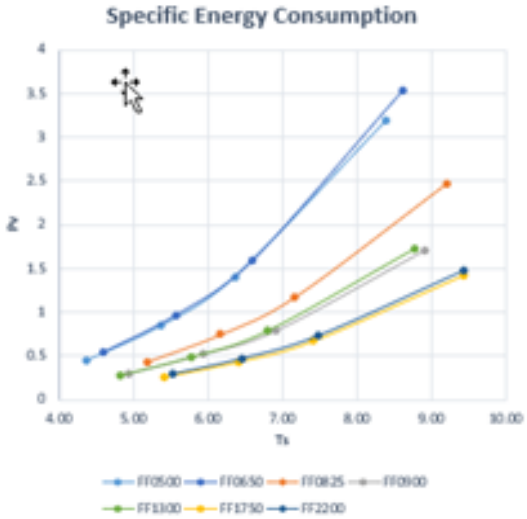
Microbubble

Microbubble testing was completed at Boliden Area Concentrator in Sweden. Analysis is ongoing.

RPM Control

Initial work on control consisted of CFD to understand mixing and pumping of the selected rotors. This gave expected limits of operation in an industrial plant. Plant trials are scheduled at Kennecott or Cobre Panama in Q1 2020.





Task 1.3 Water management

Task 1.3 is aiming to address the growing need for water balance and quality management at mine sites, by utilizing a simulator based on-line monitoring tool developed and tailored for this task. The heart of the system is based on Outotec's HSC Chemistry™ software and, more specifically, its dynamic simulation engine. It will allow for modelling the whole chain of water usage. The planned concept supports also the development of new business models, for example by allowing for remote diagnostics and related support services. System development with Keliber Oy (a mining company that is opening a new battery grade lithium mine in Finland) has been started in order to evaluate current plant design entity. Keliber's plant is now in the engineering phase and this is the final stage to assess and make changes to water balance prior construction begins.

Improved process and verification of process choices

Main targets of the work are to verify that current water handling methods are capable to treat waters in various hydrological situations (heavy rains, droughts, snow melting etc.) and process conditions (different ore qualities and process upsets). In addition to these, water handling processes are under development and work is also aimed to verify design choices for proper equipment selection and sizing. It is expected that by demonstrating current treatment capabilities unnecessary raw water intake can be minimized and internal circulation loops maximized, reducing total water consumption and effluent volumes.

WP2: BALL MILLING PROCESS WITH INCREASED YIELD AND EFFICIENCY (A COLELLA, MBN)

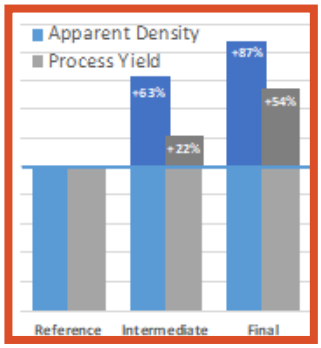
Task 1.1 Grinding process improvements

Powder particles produced by mechanical alloying do not usually meet the morphology targets needed for AM, spraying or MIM. Ball milled powders are angular in shape because of flattening during high energy impacts between particles and mill balls. MBN have developed specific processing techniques that acts during ball milling and in post processing to increase the rheological properties of its powder materials making it suitable for the different downstream processing.

During SUPREME project, MBN have developed the processing procedures to produce efficiently powder suitable for the MIM processing of diamond tools cutting sectors. The MBN ferrous based powder and feedstock allow to reach full density (>99%) at lower sintering temperature when compared to current benchmark (Cobalt alloys) and to obtain the mechanical properties (i.e. hardness and toughness) required by the application. This characteristic makes the MBN powder perfectly suited for the production of stone cutting tools with the great benefit of not using Critical Raw Materials such as Cobalt.

The project results have shown that the production yield in the PSD required by MIM was increased together with a remarkable improvement of powder morphology to obtain a feedstock with a higher powder content thus promoting a better sintering behavior and densification of final part. The project contributed to further develop powder conveying system to simplify the charge/discharge steps lowering the overall handling time by about 50%.The progress performed in the project is reported in the table below which resumes the improvement against the standard production route according to the main efficiency performance indexes of powder and production process.

Performance index for powder production		Supreme vs standard powder
Process Yield for MIM		
Improvement	%	*+53%*
Apparent Density		
Improvement	%	*+87%*
Specific Energy		
Improvement (Savings)	%	-16.6%



Task 1.3 Water management

The objective of SUPREME work package 3 is to increase the yield and productivity of several 3D manufacturing processes: laser metal deposition (LMD), plasma metal deposition (PMD), and laser powder bed fusion (L-PBF).

Two examples demonstrating the possibility of extending the classical use conditions of powders in additive manufacturing processes are presented in this newsletter: (i) using irregular powder with a large particle size distribution in a PMD process and (ii) reusing un-fused powders in an L-PBF process.

PMD process advances in using new powder classes (RHP)

The granulometry optimisation of powders is a key factor to reduce the environmental impact in additive manufacturing. One of the decisive next steps in plasma metal deposition (PMD) manufacturing technique is to process irregular powder with a large particle size distribution (PSD).

It is known from previous experiments that the shape does not affect the material properties if the powder has no inner porosity. On the other hand, the capability of feeding material and the mass flow rate are strongly dependent on the material shape and size.

Thanks to developments carried out on the framework of the SUPREME project, RHP is able to process irregular water atomised powder with a wide PSD of 50 -150 µm (see fig. below showing feeding characteristics of 17 4PH stainless steel with two different PSDs). For better feeding behaviour, a stirring device has been used to avoid clogging of materials in the reservoir. Processing more than 2.2 kg/hr is possible which is far beyond the objectives that were set at the beginning of the project (i.e. more than 1 kg/hr). The mass flow rate is almost independent from the PSD

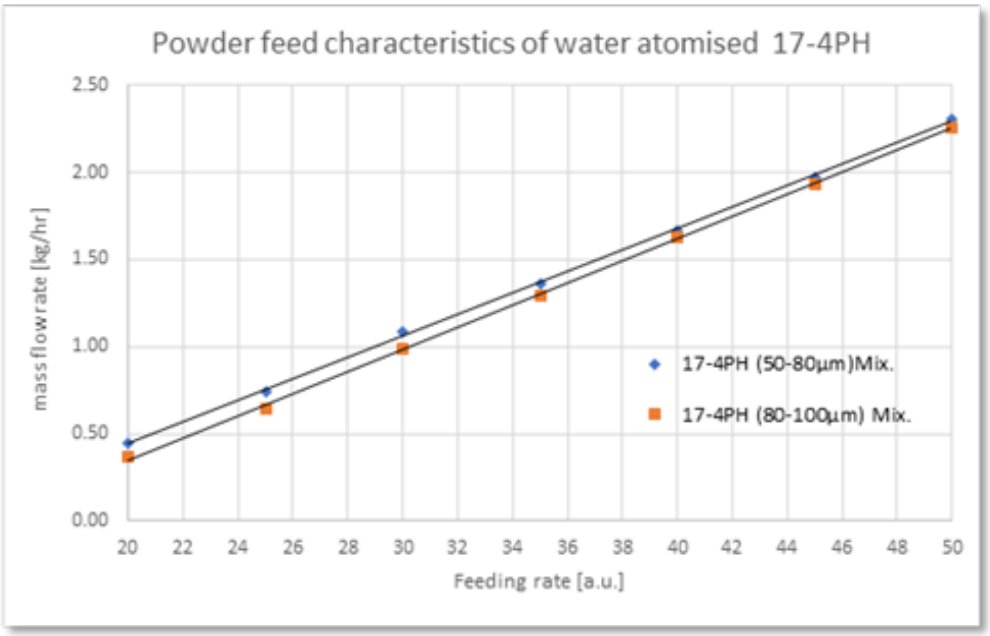


Fig 10: Powder feed characteristics of water atomised 17-4PH

Impact of powder reuse in L-PBF process (IDONIAL)

One of the main advantages of the Laser Powder Bed Fusion (L-PBF) process is the possibility of theoretically reusing all the non-fused powder but this methodology induces a gradual change of the powders. Reuse practices vary due to the difficulty of quantifying the impact of powder evolution: single use, sieving of the non-fused powder, addition of fresh powder to the sieved fraction…

To benefit from the reuse possibility and thereby reduce fresh raw material consumption, it is necessary to guarantee the useful properties of the parts (density, mechanical properties…) throughout the reuse cycles.

The study was carried out at IDONIAL on two types of ferrous-based powders (gas-atomized 316L steel from ASL and water-atomized 17-4PH steel from GKN) using a M280 EOS L-PBF machine. This work is a complement to the CEA tests (316L on ProX200 3D Systems machine) and the WEAREADDITIVE/ PRISMADD tests (In625 on ProX300 3D Systems machine). The target is to characterize the changes during a dozen reuses of a powder batch.

A reference manufacturing was designed by IDONIAL (fig. 11). Powder samples were collected throughout the reuse cycles and bulkspecimens were manufactured.

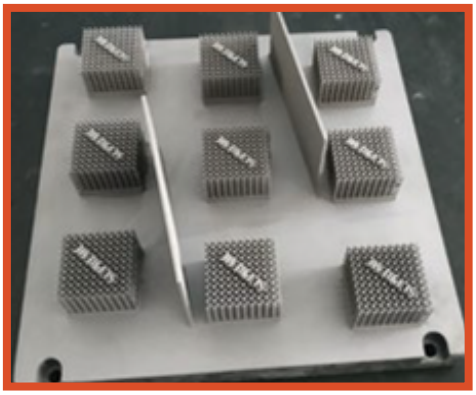


fig. 11: iteration reference model

Characterizations were carried out :

- on powder samples: chemical analysis, particles size distribution (PSD), flowability,
- and on bulk specimens: density (Archimedes'), tensile tests, impact strength test (Charpy).

The main results correlate the evolution of the chemical composition to the operating atmosphere with an increase of oxygen in particular. The variations of PSD for the two powders, with a slight increase on D50 (+ 5% after 12 cycles) and D90 (+ 10% after 12 cycles), can be explained by the layering technology with a recoating system which tends to push large particles out of the plate. The impact of changes in composition for the case of water-atomized 17-4PH is also reflected in the tensile properties with a sharp decrease of the elongation parameter (- 80%) at the end of the cycles. Moreover, whatever the cycle for the 17-4PH powder, ultimate tensile strength and yield strength are below the minimum value given by the standard for wrought product.

For 316-L, the influence over tensile parameters is much less noticeable. Actually, it is worth noticing that the variation of values does not relate with cycle number, meaning they fluctuate randomly on a stable interval. Hence, the elongation at break remains stable (± 5%) all over the 12 cycles. The yield strength parameter behaves analogously, even with less dispersion (± 0,3%).

This remarkable difference in values between both materials is attributed to particle morphology, being 17-4PH water atomized while 316-L is gas atomized. This manifests on the process itself by either the sieving or recoating stages.

WP4: HIP INCONEL 625 GOOD RESULTS AT TWI AND MIM OF CUTTING TOOLS AT TECNALIA (I. AGOTE, TECNALIA)

The progress in the development of the HIP process for the manufacturing of Inconel 625 parts and MIM process for the processing of diamond-based composites is reported.

Development of HIP process for Inco625 processing:

During this activity different types of powders produced within the SUPREME consortium have been tested: water atomised (WA), gas atomised (nitrogen:NGA and argon: AGA), and plasma atomised (PA) powders. The powders chemistry as well as the PSD are key factor to obtain high quality final parts. Depending the powder source, the interstitials and minor elements content (such as Al, Si and Ti) vary substantially. When comparing the chemical composition of the powders against the nominal Inco 625 composition, it was found that some of the powders (nitrogen gas atomised and water atomised) presented out of range O, N and Si contents and very low Al and Ti content. This had a major effect in the mechanical properties of the final parts. Argon gas atomised and Plasma atomised powders presented the most adequate chemistry, being the plasma atomised one the most promising.

The HIP conditions were optimised for all the powders and the mechanical properties as well as the microstructures was evaluated. Figure 13 shows the tensile properties of as-builts parts obtained using the four different powders. As it can be seen WA powders gave the poorest values of YS, UTS and elongation. The other three powders showed quite similar values for YS and UTS, however PA powder gave the largest elongation.

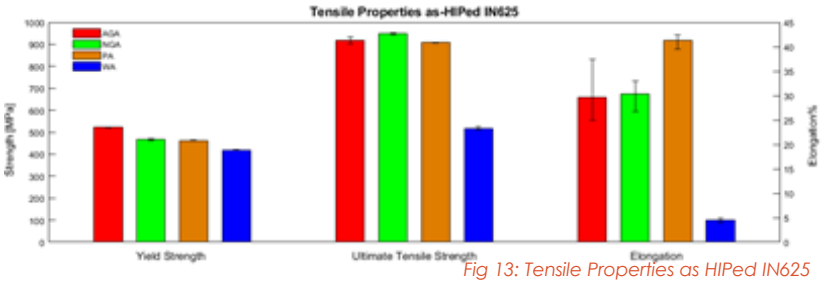


Fig 13: Tensile Properties as HIPed IN625

Next figure shows the results obtained in Charpy tests. It can be appreciated that the PA powder showed the best results among all the tested powders. Again WA powder showed the lowest values.

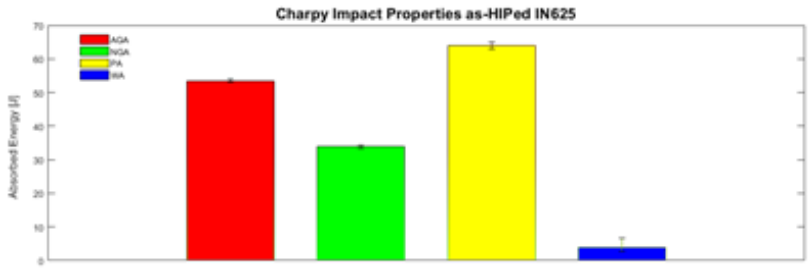


Fig 14: Charpy Impact Properties as HIPed IN625

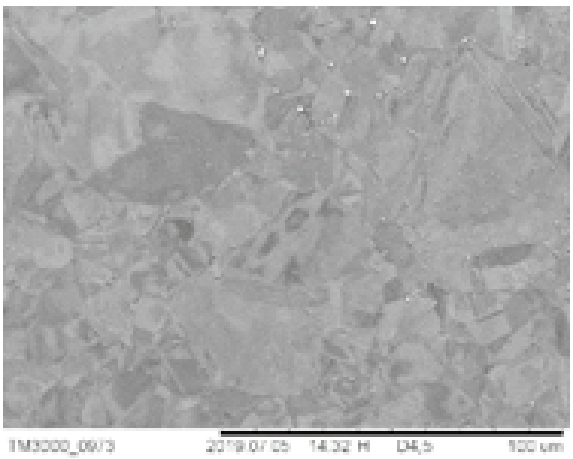


Fig 15: Microstructure obtained in PA samples

The microstructural analysis of these parts revealed that parts obtained with PA powders showed negligible PPBs (Prior Particles Boundaries) compared to the other three powders. This fact certainly confirms the obtained mechanical properties. Figure below (Fig 15) illustrated the microstructure obtained in PA samples.

The obtained good results using the PA allows facing the next steps in this activity that it will be the manufacturing of the final prototypes.

Development of MIM process for diamond-based composites :

The objective of this activity was to develop the MIM process for Co free diamond-based composites. In order to achieve this, Co free metallic alloys were developed in WP2. Using this new alloy the feedstock development was carried out in WP4. One of the main aims was to increase the process yield. One way to achieve this objective was decreasing the debinding time. For this, a binder system with a high content in aqueous based compounds has bee developed. This allows decreasing notably the debinding time compared to commercial counter parts. A reduction of 30% of time in the debinding stage is obtained with the new SUPREME binder system. In order to obtain final parts with good properties it is a paramount to use a feedstock with the optimum powder content: low powder content in the feedstock will give a low viscosity feedstock which might have debinding problems and limitation to obtain high final densities. Excessive powder content in the feedstock will give a very high viscosity that could damage the tooling used in the process: moulds, machines, …

To this end, different feedstocks were prepared and rheologically characterised. Eventually the best feedstocks were identified, and the injection moulding step parameters were optimised. In parallel the debinding and sintering conditions were also optimised.

Finally, the best conditions for the lab scale diamond-based composite manufacturing were established. The next figure (Fig 16) shows an example of the part obtained.

Now the process is being implemented at industrial scale and some additional fine tuning is being conducted at DELLAS company.

Fig 16: Parts

Aeronautical and automotive use-cases development progress (Weare Additive Defense & GKN)

Aeronautical use-case

Use-case & business plan presentation

PRISMADD has selected with its end-user an Inconel 718 bracket from a plane engine bleed air supply assembly because of its high manufacturing cost by milling and its significant potential for topological optimization. The new part should have an improved performance by weight reduction for the customer and positive impact on final assembly performance and energy consumption of planes. The market volume of the use-case is estimated to 120 parts/month from 2024.

Production routes

The conventional production route (INC718-Milling) will be compared in terms of raw material & energy consumption, carbon emissions & productivity to 2 SUPREME production routes:

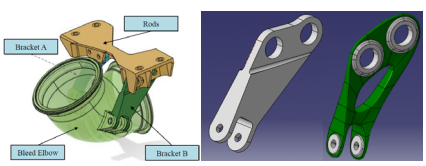
- INC625-L-PBF: Manufacturing of a prototype plate with 2 use-cases with optimized design;
- INC718-L-PBF: Manufacturing of 2 prototype plates with 2 uses-cases each (1 with optimized design, 1 with original design) & 2 serial plates with maximum number of use-cases each (1 with optimized design, 1 with original design).

The aim will be to implement SUPREME improvements over the whole INC625 production chain and compare:

- Milling & L-PBF processes;
- INC625 & INC718 performances;
- Original & optimized design performances.

Use-case design optimization

WEARE ENGINEERING carried on the topological optimization of the use-case. The end-user furnished an assembly to study and the efforts and load cases associated. Calculations were applied to the whole assembly and design optimizations done on the four parts below. Finally, the highest weight reduction was reached on the bracket A up to -30%.



Specimens & Use-case testing plans

To compare INC625 & INC718 performances by L-PBF process, an INC625 plate including specimens for spectrometry, hardness, macrography & micrography, X-Ray, dye penetrant inspection, tensile & fatigue inspections will be produced. The results will be compared to INC718 data resulting from ancient qualification campaigns with the end-user. An additional INC718 plate including specimens for macrography & micrography, tensile & fatigue inspections will be produced to evaluate the performances of 4 different furnace heat treatments which might be able to replace the HIP (high isostatic pressure) post-process subcontracted at high cost.

Finally, on the use-cases prototype & serial plates, cut-up specimens (cut directly from the use-cases) will be inspected and additional mechanical properties such as fracture toughness, crack propagation or tensile at high temperature will be evaluated.

Automotive use-case

Use-case & business plan presentation

CRF selected as Automotive use-case a bracket.

The part has been chosen considering the potential for topological optimization, therefore the new part should be lighter, meaning raw material saving and reduction of energy/fuel consumption. The new part is supposed to be iso-performance with respect to the current production one.

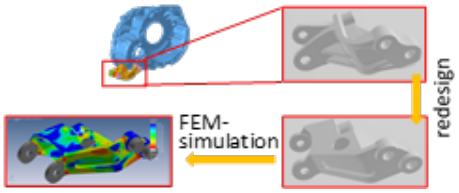
The market volume of the use-case is estimated to be with an initial production of 50K unit/year within 10 years after the project.

Production route

- The demonstrator parts will be printed with water atomized low alloy steel Ancorsteel AM4630 on the following machines:
- RENISHAW single laser (one printing job with 4 original parts, one printing job with 4 topology optimized parts)
- EOS single laser (one printing job with 4 topology optimized parts)
- EOS multilaser (one printing job with 4 topology optimized parts)
- The raw material & energy consumption, carbon emissions & productivity will be compared between different machines, different laser number and different design

Use-case design optimization

The topology redesign and FEM-simulation of the part was carried out by GKN.



Specimens & Use-case testing plans

The original material for the part is cast iron. In order to reach the comparable mechanical properties, a heat treatment will be carried out to reduce the residual stress and improve the mechanical properties. Static mechanical properties, like Hardness, ultimate tensile strength and elongation, will be compared between cast iron and AM4630. Fatigue test will be carried out on samples with and without surface postprocessing to compare the fatigue properties between these two materials.

WP6: ENVIRONMENTAL PERFORMANCES OF SUPREME PROCESSES (EMMANUELLE COR, CEA-LITEN)

The SUPREME project aims at covering the optimization of the all value chain of powder metallurgy. In order to ensure the relevance of the work done by all partners, the project is monitored by a set of Key Performance Indicators (KPIs) applied to each production route.

A total of 48 KPIs has been identified for the project and grouped in six types:

- ►Resource optimization (R)
- ►Energy optimization (E)
- ►CO_2 reduction (CO_2)
- ►Production Rate optimization (PR)
- ►Lifetime improvement (LT)
- ►Cost optimization (€)

For the calculation of each KPIs, a data collection among all SUPREME partners is managed by CEA. The Life Cycle Analysis methodology is used to calculate KPIs related to CO_2 emissions

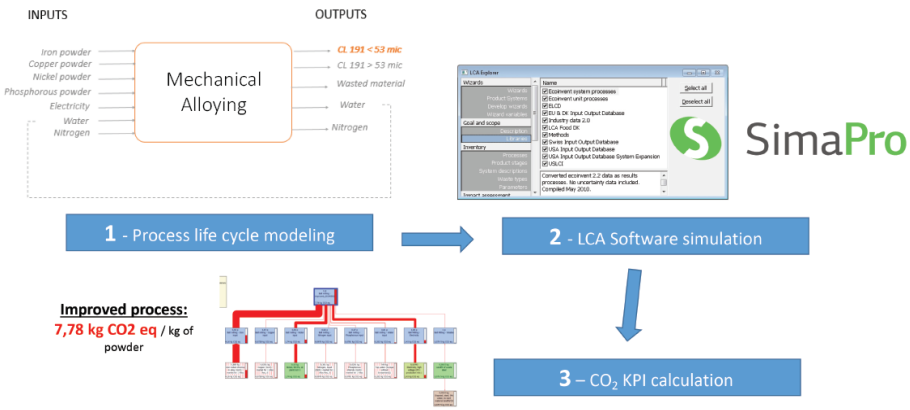


Figure 17: Methodology used for MBN-Mechanical Alloying CO_2 KPI calculation

as well as the ones related to resource and energy optimization. First results on environmental performance of Mechanical Alloying process (MBN) and Gas atomization (ASL) processes are available. An improvement of 32% of CO_2 emissions is attained for Mechanical Alloying process and a reduction of 4% for N_2 consumption in Gas Atomization process, thanks to the progresses made in the project. These results will be used by CEA to propose eco-innovative tools for the environmental optimization of the SUPREME powder metallurgy value chain.

PROGRESS ON SENSOR SYSTEM AND PROCESS CONTROL PLATFORM INSTALLATION (G. CHALKIAS, IRIS)

The digitalization of industrial production and the efficient management of data collected from different sources at the factory floor is a hot topic, especially in the context of the digital revolution and Industry 4.0. This poses a particular challenge for established European industries which cannot keep up with the rhythm of change in digital technologies. They thus find themselves often producing more data than they can handle and, in many cases, have accumulated too many different and often incompatible digital technologies, spanning several decades of haphazard upgrades and additions to their digital arsenal. In order to address some of these problems IRIS has developed PATBox, a flexible and scalable software platform for production data management that is able to operate between the "Edge" and the "Cloud".

Over the last months IRIS made significant progress in developing the process monitoring system, including sensors selection, procurement and testing as well as adapting our proprietary software to communicate with all the data sources in the factory floor, process the respective data and show the information to the end-user. In the context of SUPREME PATBox will have to establish parallel communications with up to 18 data systems at a time including PLC systems, sensors (e.g. power meters, gas flow meters and scales), and FTP servers using protocols like OPC DA, OPC UA, and MODBUS-RTU.

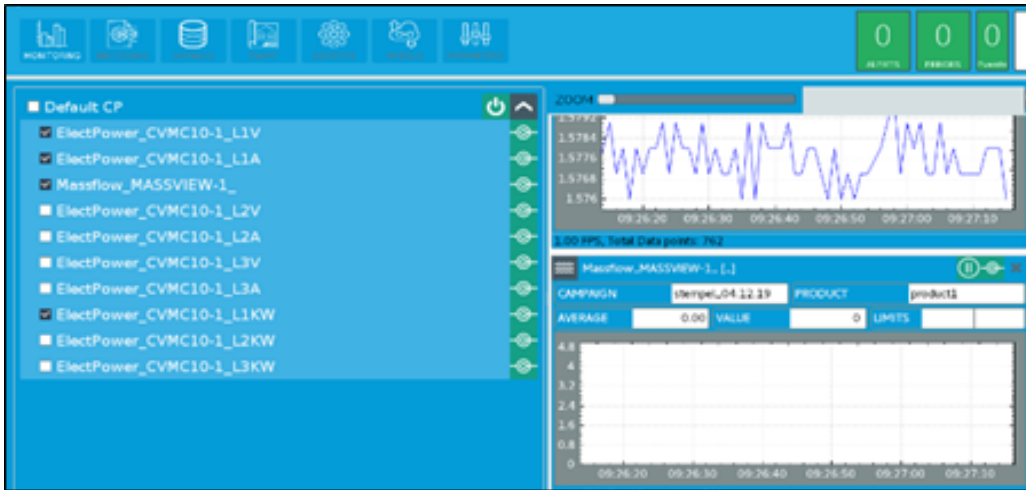


Fig 18: List of the 4 main measurements: voltage, current, power and flow

During the first week of December 2019, IRIS engineers Ioannis Kakogiannos and Mario Mula visited GKN´s facilities in Radevormwald, Germany to complete the installation of the process monitoring system, designed and developed by IRIS. The aim of the installed system is to determine and compare the efficiency of several 3D printers, both commercial and prototypes by monitoring energy consumption, material throughput, waste production and yield. The first application was decided to be at the L-PBF RENISHAW 3D printer.

The system installed consists of a power analyzer, a gas mass flow meter and the data acquisition and processing platform (PATBox). The power analyzer, connected in the power supply of the machine provides the system with data such as voltage, current, power consumption etc. On the other hand, the gas mass flow meter measures the flow of Nitrogen from the source to the accumulator of the machine. The above-mentioned values are acquired, processed and displayed through PATBox´s GUI which also gives the option to the user to extract them as .csv files or upload them to an FTP server for further analysis by LCA software (conducted by CEA).

So far, the system has been through several trials and, on February 2020 the system was used during a real time production printing process. In the following weeks, installation of a process monitoring system will be performed at ASL´s facilities, thus concluding an important part of SUPREME project.

MEET SEVERAL PARTNERS (DELLAS, IDONIAL, MBN, TECNALIA)

DELLAS

An example of leading-edge excellence in the stone cutting sector since 1973, in 40 years of activity, Dellas Spa has reached a leading position in the international market of the production and sale of diamond tools for marble, granite and engineered stone.

Founded in Desenzano del Garda in 1973, in 1982 the company moved to Lugo di Valpantena, where it can still be found today. The Valpantena area and the nearby town of Valpolicella have always been famous as a district specialized in cutting local, national and international marble and granite. This move therefore allowed Dellas to get closer to the heart of stone

Fig 19: DELLAS

processing activities, constantly test its products and obtain immediate feedback as to their performance. The nearby companies have therefore become an "extended test laboratory" for its tools.

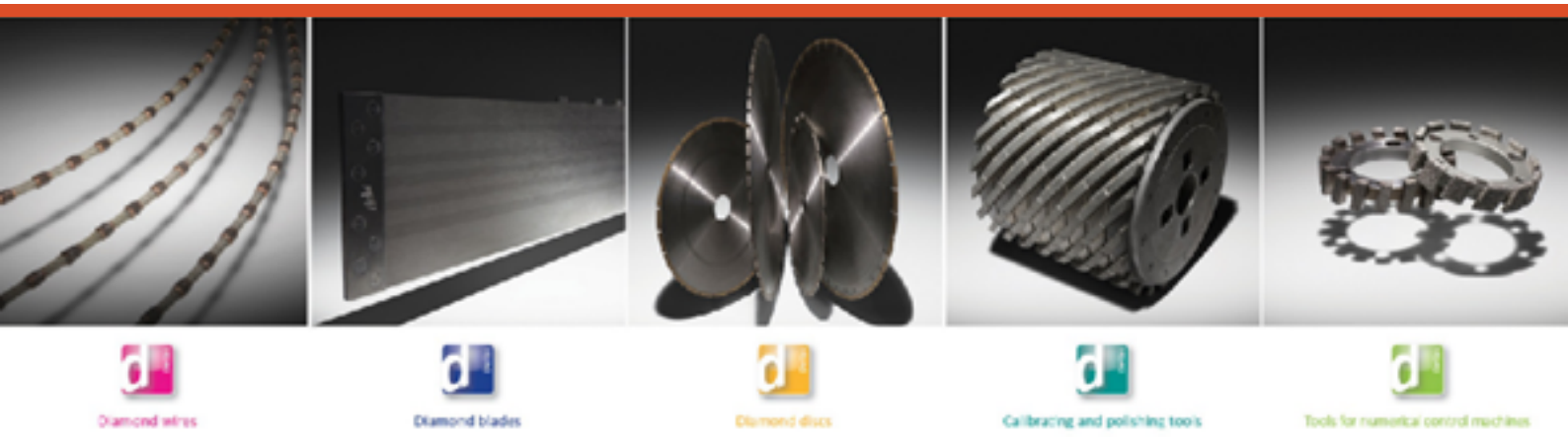
Over the years it has proven to be strategically advantageous to set up assembly centres around the world in collaboration with local industrial suppliers. Dellas can therefore provide a presence and prompt assistance over large areas while assuring costs are local kept competitively down. The company has trade and assistance

setups in 30 countries, counting a total of 62 dealers/agents

The company has set up a materials research and analysis centre at its headquarters. It is the high-tech heart of the company. Research, an area in which the company continually invests part of its profits, has always been considered a fundamental part of the production cycle, necessary for maintaining competitiveness on the global market: As well as samples of the most common and widely used stones, the Dellas laboratory also contains thousands of samples of marble, granite and engineering stone from all over the world. Each element is carefully preserved and catalogued by type and place of origin. It is a unique database on the morphological characteristics of the material and is essential for developing blades, discs and tools capable of operating with maximum efficiency and precision.

A new initiative begun in 2013 concerns research and development for the making of diamond tools using DIM (Diamond Injection Molding) technology: among the advantages that can be drawn from this kind of technology is also the high series complex parts manufacturing increasing productivity and efficiency as compared with traditional technologies.

DELLAS Spa was founded as a manufacturer of diamond cutting disks and blades. An increasingly comprehensive range capable of meeting all industry requirements, from the extraction of the material from the quarry to cutting and polishing, as well as perfectly precise and detailed material machining and finishing, so the range produced has been expanded over the years with three lines: diamond wires, polishing and calibration tools, and tools for computer-controlled



IDONIAL

An example of leading-edge IDONIAL is a private, independent, non-profit, multisectorial technology centre create as the result of a merging process of two Technology Centers, ITMA (Materials Technology Center, funded in 1990) and PRODINTEC (Industrial Design and Advanced Manufacturing Technology Center, funded in 2004). It is the largest Technology Centre in the region of Asturias and contributes to the promotion and development of the business fabric in its areas of technological specialization offering integral R&D&I solutions in the entire value chain, from materials to manufacturing processes and products. The center now has over 165 employees working at IDONIAL (19% PhDs).

IDONIAL main technological development and innovation activities deal with advanced manufacturing, digitalisation of industry and materials development and are addressed by 7 business areas: Digital industry, advanced manufacturing, engineering and simulation, steel and metallic alloys, ceramics and raw materials, surfaces, active materials and plastics, and technological services. With regard nanotechnology, IDONIAL has experience in synthesis and functionalization of nanostructures, development of functional coatings, and production process/pilots scaling up. With regards additive manufacturing (AM), IDONIAL is a specialised centre with more than 10 years' experience in AM research and development, and in helping companies to explore new business opportunities around these technologies.

Moreover, the centre has a specific department named Business Development and Strategy for designing the business strategy and carrying out technology transfer and marketing activities and, hence, it possesses a wide experience in developing networking activities and dissemination actions.

Fig 20 & 21 L-PBF (left) and MIM (right) equipment at IDONIAL facilities (Gijón, Asturias)

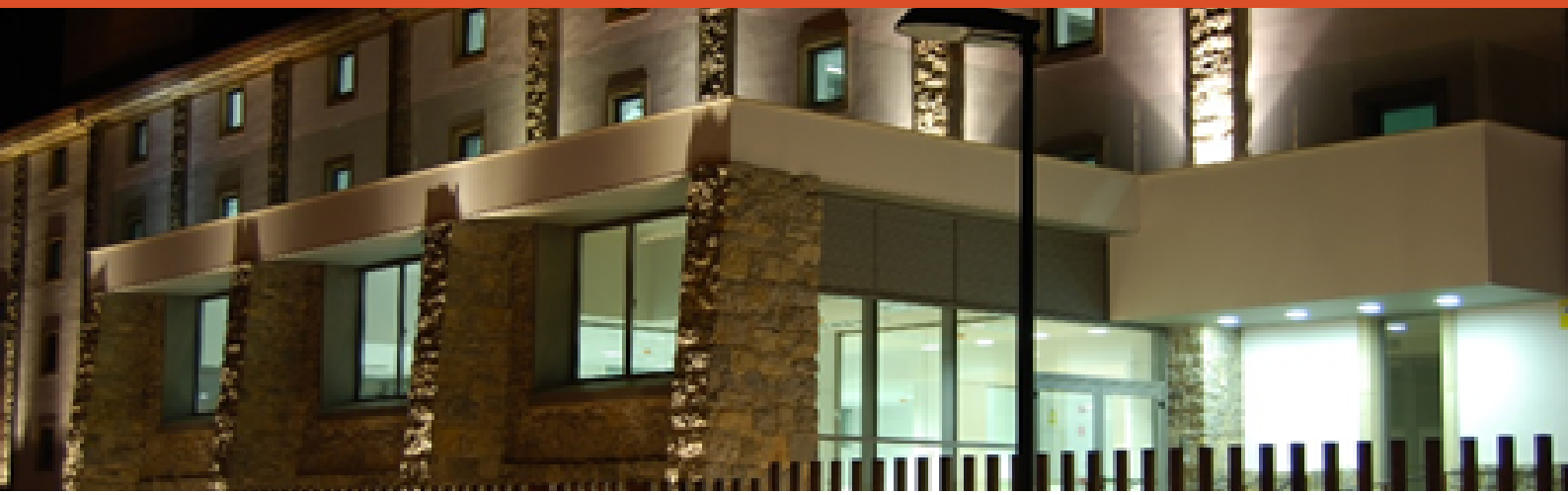
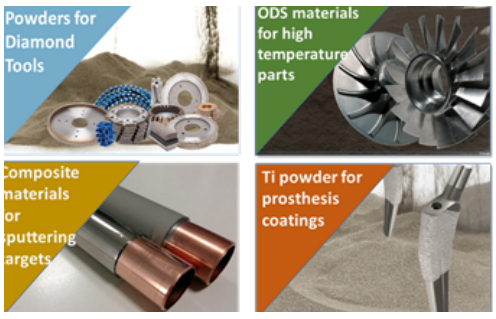


Fig 22: IDONIAL HQ in Gijón (Asturias)

IDONIAL has wide experience in European research programmes as, for instance, H2020, FP, EUREKA, Era-Nets and INTERREG where it works in close collaboration with industrial partners, research institutes and public administration around Europe. Moreover, the centre actively participates in several European Technology Platforms and belongs to the governing bodies of the Additive Manufacturing and Nanotechnology innovation ones. The centre develops its activities in several facilities located in Spain, specifically Gijon, Aviles, Llanera and Madrid.

MBN

Founded in 1994 MBN Nanomaterialia S.p.A. (www.mbn.it) is a producer of nanostructured powder materials through a proprietary mechanical alloying process technology (Mechanomade®). With an installed industrial production capacity distributed on several production plants, MBN offers to the market advanced powder materials that are utilized in powder metallurgy, spraying and laser deposition processes. Typical output of the process is constituted by agglomerated powders in the micron-size range constituted by aggregates of nanocrystals and nanoparticles.



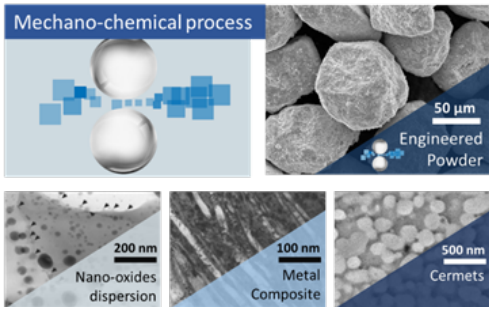
Main products lines range from ferrous alloys used as metal bond in diamond grinding tools for ceramic, stone, cement and glass industry, ODS alloys for high temperature and oxidation resistance components (aerospace, energy), Ti based alloys for VPS coating of prosthesis (biomedical), to high purity pseudo alloys for sputtering targets and thermal spraying powders for wear resistance coatings (green carbides for mechanical application).

The engineering and development of powder is totally accomplished in-house, without or partially resorting to powder end user's facilities, thanks to the availability of a prootype department including furnaces, presses, laser deposition and thermal spraying job-shop.

The Mechanical alloying process

The mechanical alloying is a solid-state powder processing technique that involves repeated cold welding, fracturing, and rewelding of powder particles in a high-energy ball mill (HEBM). This method allows production of homogeneous materials starting from blended elemental powder mixtures, acting both at physical level by alloying, dispersing and at chemical level, with activation of chemical reactions.

A wide range of mechanical alloying techniques using different types is available in the market, mostly at lab scale. MBN have developed a proprietary Mechanomade™ technology where the impacts at high velocities are controlled to avoid ball/ball collisions, and contamination levels are significantly reduced compared to other commercial mills which operate through disordered impact. The



Mechanomade™ HEBM plants in MBN give higher control on the contamination from milling means since different plant have been developed to produce Iron/Steel based alloys, Titanium based alloys, Nickel based alloys and Copper based alloys.

TECNALIA

FUNDACIÓN TECNALIA RESEARCH & INNOVATION (TECNALIA) (www.tecnalia.com) is a private, non-profit, research organisation resulting from the merger (1st January 2011) of eight research centers.

TECNALIA is the leading private research and technology organisation in Spain and the fifth largest in Europe), with a workforce of near 1,300 people (225 PhDs) and income of 110 Million € in 2017 and a portfolio with over 4,000 clients.

TECNALIA is a key agent in the ERA - European Research Area, holding position 12th among RECs and 26th overall in EC's 6th FP7 Monitoring Report 2012. In Clean Sky Programme TECNALIA has played an important role as Partner, being the leading entity in the whole

programme with regards to number of projects in which we took part. TECNALIA collaborated in 18 Clean Sky projects of ECO Design, GRA, GRC, SAGE and SGO ITDs, leading 10 of them, with a budget contribution in the Programme of nearly 4 million Euro. In FP7 TECNALIA has partnered in 377 FP7 projects, coordinating 81 of them, and in H2020 participates in 152 projects, coordinating 31 of them.

Tecnalia is also partner of the current Clean Sky JTI being responsible (alone or in consortium) of developing certain specific tasks in 4 ITDs (SGO, SAGE, GRA and ECO) over a limited period in the course of Clean Sky.

TECNALIA accreditations comprises UNE-EN-ISO 9001:2000 Certification valid for the "Management of research projects, development and technological innovation, tests realization and technological guidance service", Certification of the System of Environmental Management by ISO 14001, Accreditation as Aerospace supplier as per UNE –EN 9100, Accreditation of the technical competence for tests on metallic materials, paintings and coatings, steel reinforced concrete, corrosion, welding, metallic pipes, approval tests for accessories of galvanized iron pipes, NADCAP (National Aerospace and Defence Contractors Accreditation Program) accreditation for Materials Testing and Chemical Processing; Non Destructive Test (NDT), atmospheric Emissions (ENAC), Homologated Laboratory for "Biomedical" products Analysis (Ministry of Health), Partner of the Ministry of Environment for the control of residual waters pouring, CIT Register of Innovation and Technology Centers, OTRI.

SUPREME Project Workshop

Want to learn about innovative ways of improving the sustainability of powder metallurgy processes?

The SUPREME project aims at optimising powder metallurgy processes throughout the value chain, focusing on a combination of fast growing industrial production routes and advanced ferrous and non-ferrous metals. Join the intensive one-day workshop to learn about its main achievements!

The SUPREME experts' workshop will cover a vast range of subjects including:

- Production processes
- 3D manufacturing
- Real time monitoring of energy and resource efficency
- Use-cases & impact demonstration
- Life cycle assesment & eco-innovation

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Registration Deadline: 15 June 2020
Standard Registration: €50

Event Date: 09 July 2020
Location: Senlis, France

Find out more and book your place at: www.supreme-project.com

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