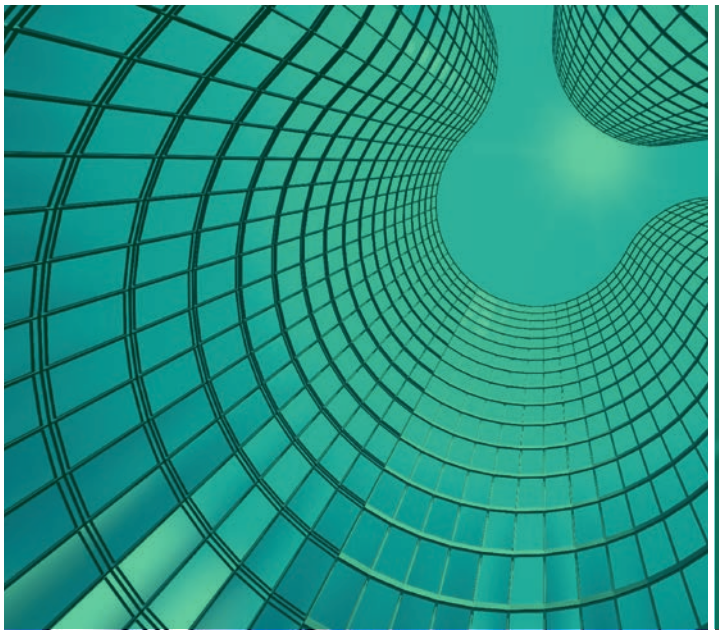
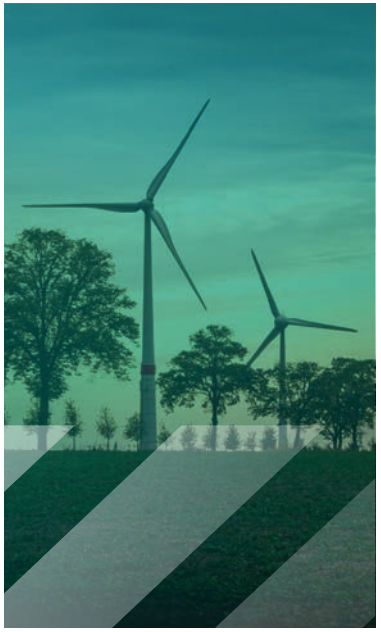
ANNUAL REPORT

2022





CRM GROUP

FOR A BETTER FUTURE


CRM GROUP

CONTENTS

Foreword 4

Company Members 6

Active Members of CRM 6

Associated Members of CRM 6

Organisation 8

Board of Directors of CRM 8

Iron and Steel Committee of CRM 9

Quality Management 10

Leadership team 11

Key figures 12

Report on technical activities 13

Circular economy - Towards a sustainable metals industry 15

Energy shift - The pathway to a CO_2-neutral industry and renewable energy 22

Advanced manufacturing - Driven by industry and active on all the value chain 30

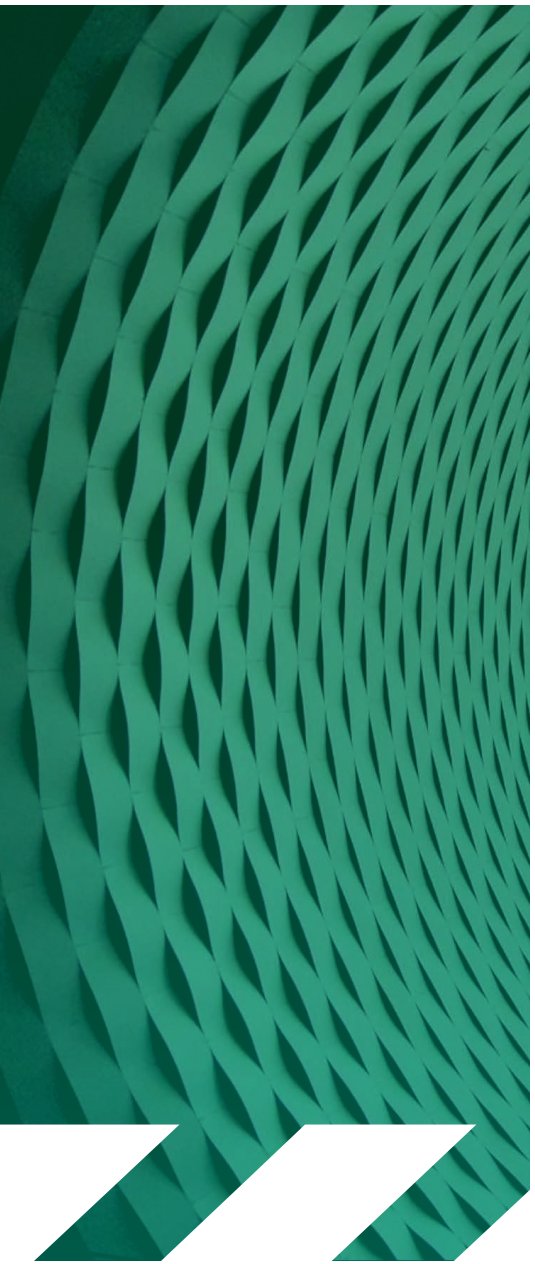
Digitalisation - Industry 4.0 and smart products 35

Industrial processes, solutions & services - Serving the industry in multiple sectors 40

Dissemination, events and partnerships 45

Publications & conferences 2022 49

FOREWORD



CRM is an independent not-for-profit organisation that provides technological R&D innovation in the fields of metal and steel production processes, product development and a wide range of metal applications, using a truly holistic product-process-application approach and focusing on industrial implementation of its developments. More than ever, the vast majority of CRM's developments focus on key societal challenges such as the circular economy, energy transition and digital transformation.

CRM is supported by more than 45 industrial members, ranging from international steel groups (ArcelorMittal and Tata Steel), raw material suppliers, non-ferrous metal producers, OEM's, metal transforming companies, to members from the chemical, aeronautical, defence, energy and recycling sectors. Each year CRM welcomes prestigious new members that are leading companies in their domain. In 2022 AGC, Suez and Simaform joined our organisation. CRM also delivered various services to more than 285 non-member customers.

At CRM, health and safety is the key priority. In 2022 an increased number of safety events were reported, despite the significant progress that was achieved in terms of implementation of safety procedures, an increased involvement and awareness of the entire staff and the organisation of focused Tool Box Meetings which communicate safety information, good practices and safety instructions widely in the organisation. CRM will remain strongly committed to target a sustainable and constant zero accident performance.

CRM considers that it can only realise its full innovation potential by making full use of all talents regardless of gender identity or expression, sexual orientation, religion, age or any other aspect that makes each person unique. Therefore, CRM initiated the process to create and implement a Gender Equality Plan (GEP) and more broadly a diversity inclusion policy.

CRM is committed to reach the Sustainable Development Goals adopted by the United Nations. The SDG's will be completely integrated in CRM's strategic plan, both at the level of our research programs as on the level of CRM's organisation as such. A certification procedure to be officially recognised as a Sustainable Entrepreneurial Organisation has been launched in 2022. Furthermore, after a pilot experience in one of our research facilities, CRM continues to assess its total carbon footprint and will engage in a carbon footprint reduction plan.

To fulfil its mission, CRM is organised around 6 research units that are backed up by a world class material characterisation laboratory:

1 | **Metal production and recycling (MPR):** covering raw material processing, carbon neutral iron & steel making, melting & refining, by-products treatment & valorisation

2 | **Energy & Low Impact Manufacturing Industry (ELIMIN):** focusing on the development of energy efficient and low CO_2 emitting production technologies and CCU applications

3 | **Metal processing and metallurgy:** including casting & solidification, rolling & thermal treatment, material science & hybrid manufacturing and process control & measurement

4 | **Advanced & smart surface solutions (A3S):** ranging from functional coatings and smart surfaces including printed electronics on steel to surfaces for renewable energy applications and hydrogen and electrochemistry

5 | **Innovative designs and assembly solutions (IDEAS)** in the fields of Civil engineering, Construction, Assembly & Testing

6 | **Industrial solutions (IS):** embracing in-house Engineering, finishing & metallic coating processes, organic coating and sandwich panels products & continuous annealing and/or coating pilot line

In 2022, the global economy experienced brutal inflation levels, largely induced by a steep increase of energy-prices after the Russian invasion of Ukraine. The inflationary economy led to a significant impact on CRM's cost structure, as in Belgium salaries are automatically indexed based on the CPI. A focused cost reduction and an energy consumption reduction plan were therefore initiated in order to limit the total cost increase of CRM's services.

As in 2021, in 2022 CRM kept the pace in implementing its strategic plan. This plan aims to build R&D capabilities and generate associated project portfolios to address key societal challenges and to deliver technological solutions that can be applied in a wide range of industrial sectors.

A strong program renewal has been obtained with a main focus on research programs and projects that target the Sustainable Development Goals. For example, CRM successfully started the Relaunch & Resilience Programs with notably the Reverse Metallurgy+ program related to circular economy activities and the HECO2 program (Hydrogen, Electrification and low CO_2-emission) aiming at decarbonisation of the heavy Industry.

At European or regional level, CRM has continued to invest in partnerships with other research organisations, emphasising its ability to leverage the advantages of open innovation for its members and customers.

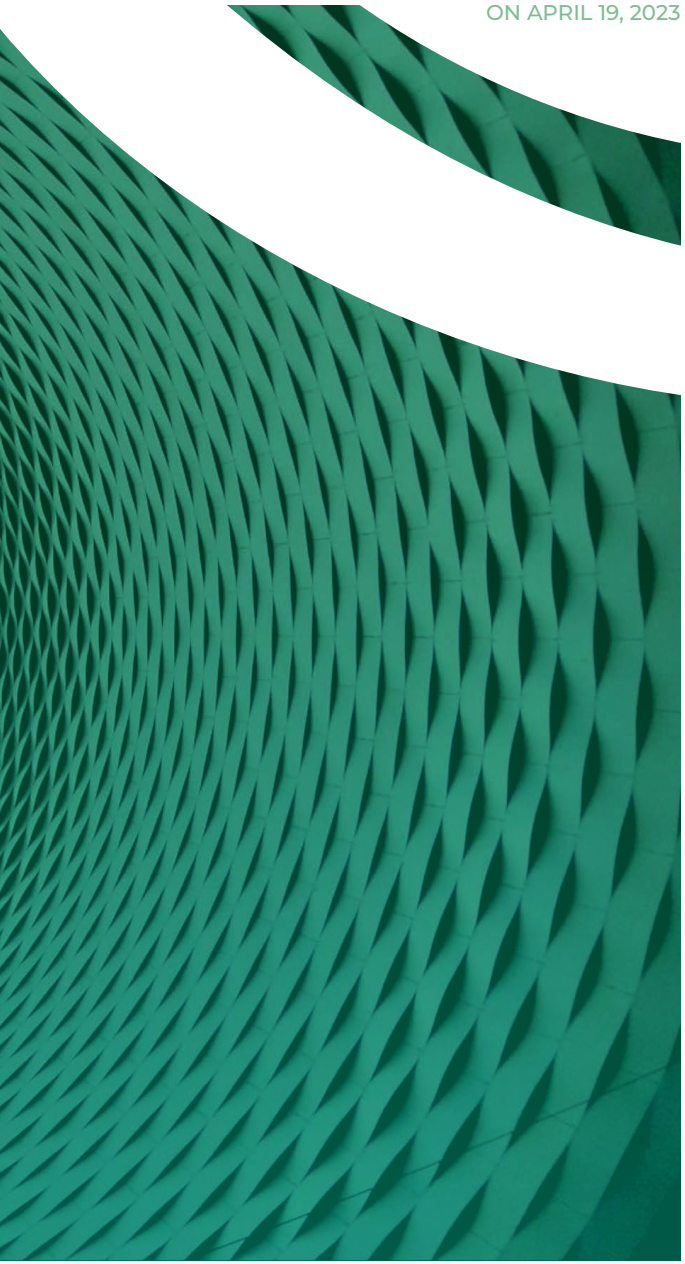
The present annual report highlights the main achievements of the year 2022.

Thinus Van Den Berg
President CRM

Joeri NEUTJENS
General Manager CRM

COMPANY MEMBERS

ON APRIL 19, 2023



Active Members of CRM

ARCELORMITTAL S.A.	G.D. Luxembourg
TATA STEEL Nederland BV	The Netherlands

An updated list of the subsidiaries considered as Active Members is available on the internet site of CRM.

THE MAIN AFFILIATED COMPANIES ARE:

ARCELORMITTAL Group:

ARCELORMITTAL BELGIUM N.V.	Belgium
ARCELORMITTAL CONSTRUCTION FRANCE S.A.	France
ARCELORMITTAL FRANCE S.A.	France
ARCELORMITTAL LUXEMBOURG S.A.	G.D. Luxembourg
INDUSTEEL BELGIUM S.A.	Belgium

TATA STEEL:

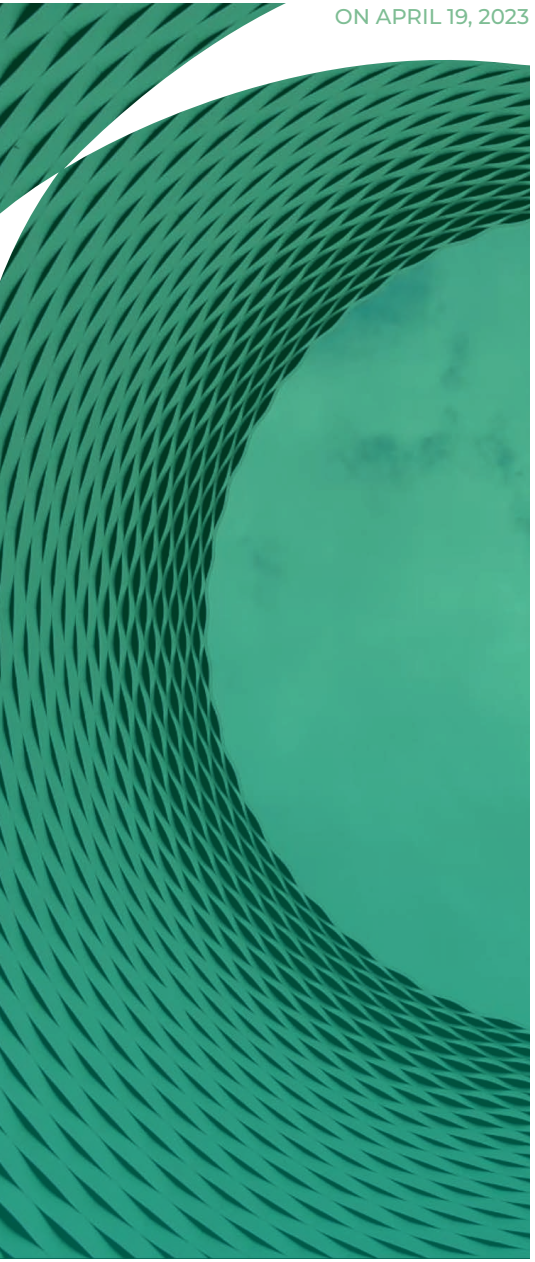
TATA STEEL IJMUIDEN BV	The Netherlands
TATA STEEL NEDERLAND TECHNOLOGY BV	The Netherlands

Associated Members of CRM

AGC Glass Europe	Belgium
AIR LIQUIDE INDUSTRIES BELGIUM S.A.	Belgium
AMEPA GmbH	Germany
AMETEK LAND	United Kingdom
APERAM Stainless France S.A.S.	France
ATELIERS DE LA MEUSE	Belgium
AURUBIS OLEN	Belgium
BASF SE	Germany
BEKAERT N.V. / S.A.	Belgium
BIOCARBON INDUSTRIES Sàrl	G.D. Luxembourg
CBR S.A.	Belgium
COMET TRAITEMENTS S.A.	Belgium
DE LEUZE S.A.	Belgium
DREVER INTERNATIONAL S.A.	Belgium
DUFERCO S.A.	Switzerland
EMG Automation GmbH	Germany
EQUANS	Belgium
E.S.W. A.G.	Austria
FONDERIES MARICHAL, KETIN & Cie S.A.	Belgium
HERAEUS ELECTRO-NITE INTERNATIONAL N.V.	Belgium
HERSTAL S.A.	Belgium
HYDROMETAL	Belgium
INDUCTOTHERM S.A.	Belgium
INSTITUT BELGE DE LA SOUDURE asbl	Belgium
INTERNATIONAL MANGANESE INSTITUTE	France
JOHN COCKERILL S.A.	Belgium
LHOIST Recherche & Développement S.A.	Belgium
LIBERTY LIEGE-DUDELANGE S.A.	Belgium
MAGOTTEAUX INTERNATIONAL S.A.	Belgium
MATÉRIAUX CÉRAMIQUES S.A. (FIVEN)	Belgium
NLMK CLABECQ S.A. – Plates	Belgium
NLMK LA LOUVIÈRE S.A. – Strips	Belgium
ORBIX SOLUTIONS S.P.R.L	Belgium
PAUL WURTH S.A.	G.D. Luxembourg
PHARMA TECHNOLOGY S.A.	Belgium
PRAYON S.A.	Belgium
PRIMETALS TECHNOLOGIES AUSTRIA GmbH	Austria
RECYDEL S.A.	Belgium
RESA S.A.	Belgium
R-TECH S.A.	Belgium
SABCA	Belgium
SAFRAN AERO BOOSTERS S.A.	Belgium
SARCLAD Ltd	United Kingdom
SIMAFORM S.A.	G.D. Luxembourg
SONACA	Belgium
SUEZ	France
TECforLime	Belgium
THY-MARCINELLE S.A.	Belgium
TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT sarl	G.D. Luxembourg
WESTINGHOUSE ELECTRIC BELGIUM S.A.	Belgium

ORGANISATION

ON APRIL 19, 2023



Board of Directors of CRM

PRESIDENT

Thinus VAN DEN BERG, CFO - Global Research and Development, ARCELORMITTAL

VICE-PRESIDENTS

Vincent RITMAN, Director R&D Europe, TATA STEEL
Jean-Luc THIRION, General Manager Global Research and Development, ARCELORMITTAL

DIRECTORS

Ivan AERTS, Adviseur, Centrale der Metaalbewerkers van België
Philippe COIGNE, Directeur Général, Groupement de la Sidérurgie (GSV)
Nicolas DE ABAJO MARTINEZ, Head of Global R&D Centres and Performance Optimization, ARCELORMITTAL
Joao FELIX DA SILVA, Executive President, Member of the John Cockerill Executive Committe, John Cockerill Industry
André FOUARGE, CTO Finishing, ARCELORMITTAL Europe - Flat Products
Leo KESTENS, Professor, Universiteit Gent
Carel KLEEMANS, Technical Director, TATA STEEL Mainland Europe
Anne MERTENS, Associate professor, ULiège
Lahoucine OURHRIBEL, Secrétaire Général, ACV-CSC METEA
Nicoleta POPA, Head of Construction applications, Infrastructures and Long Products, ARCELORMITTAL Global R&D
Ilja PORTEGIES ZWART, Head of Technical Packaging Steel, TATA STEEL
Pedro PRENDES, Global R&D Process Portfolio Leader, ARCELORMITTAL
Mario SINNAEVE, R&D - Quality Control Manager, S.A. des Fonderies Marichal, Ketin & Cie
Sven VANDEPUTTE, Managing Director, OCAS N.V.
Hans VAN DER WEIJDE, Director Programmes TATA STEEL Europe R&D, TATA STEEL
Manfred VAN VLIERBERGHE, CEO ARCELORMITTAL Belgium
Michael VENTURI, Secrétaire Général Adjoint, MWB-FGTB
Laurent WENKIN, Coordinateur Normalisation et Compétitivité, SPF Economie, PME, Classes moyennes et Energie

OBSERVERS

Jean-François HEUSE, Inspecteur Général ff, Département de la Recherche et du développement technologique, Service Public de Wallonie
Yvon MASYN, Adviseur, Vlaams Agentschap Innoveren en Ondernemen
Joeri NEUTJENS, Directeur Général, CRM

AUDITOR

Anne DORTHU

Iron and Steel Committee of CRM

Members

ARCELORMITTAL

Jean-Paul ALLEMAND
Marc DI FANT
Eric HESS
Thierry IUNG
Pedro PRENDES
Mayte RODRIGUEZ
Sven VANDEPUTTE

TATA STEEL

Jochem GROOT
Carel KLEEMANS
Christophe PELLETIER
Hans VAN DER WEIJDE

CRM

Joeri NEUTJENS
Griet LANNOO
Eric SILBERBERG

QUALITY MANAGEMENT

The CRM is accredited **ISO 17025** for calibration & testing and certified **ISO 9001:2015** for all its activities.

BQA

CERTIFICAT DU SYSTEME DE MANAGEMENT DE QUALITE

ISO 9001 : 2015

Par la présente, BQA sa déclare que le système de management de la qualité de la société ***CRM Group***

CRM GROUP

dont les sites des sociétés sont établis
Avenue du Bois Saint-Jean, 21 B27 – Quartier Polytech 4 - 4000 Liège et Rue du Bois Saint Jean, 8 – 4102 Ougrée et Rue du Chéra, 200 – 4000 Liège
et Technologiepark 903c – 9052 Zwijnaarde – Belgique
pour ***CRM asbl*** *– Centre for Research in Metallurgy asbl, et par*
Allée de l'Innovation, 1 B 57 – Quartier Polytech 3 – 4000 Liège et Rue Sompré, 1 – 4400 Flemalle – Belgique
pour ***AC&CS scrl*** *– Advanced Coatings and Construction Solutions scrl,*
a été examiné le 28-05-2018 et a été jugé conforme à la norme ISO 9001, édition 2015 pour le domaine d'application suivant:

Recherche appliquée et activités associées telles que les essais, l'étalonnage et l'expertise.

Ce certificat est délivré par BQA sa conformément à son manuel de qualité relatif à la certification de système et après conclusion du contrat de certification N° CER_CDP_QMS_16-04-2021_336_F aux termes desquels la firme accepte un contrôle régulier de son système de management.
Certificat N° BQA_QMS_C_2006336
Date d'émission 2021-04-12
Valable jusqu'au 2024-05-27

BELAC
019-QMS

D. SIMOENS
Directeur

Toute personne ayant connaissance de l'emploi abusif de ce certificat doit en avertir BQA sa. Ce certificat ne peut être divulgué que dans son intégralité.
BQA sa - Technologiepark Zwijnaarde 70 - 9052 Gent-Zwijnaarde

Organisme belge d'Accréditation
Belgische Accreditatieinstelling
Belgische Akkreditierungsstelle
Belgian Accreditation Body

EA MLA Signatory

Accreditation Certificate No. 267-CAL

In compliance with the provisions of the Royal Decree of 31 January 2006 setting up BELAC, the Accreditation Board hereby declares to have granted accreditation conform the requirements of the standard EN ISO/IEC 17025:2017 to:

CENTRE DE RECHERCHES METALLURGIQUES ASBL - CENTRUM VOOR RESEARCH IN DE METALLURGIE vzw C.R.M.
Rue Ravenstein 4
1000 Bruxelles

The body demonstrated the competence to perform the activities in the activity sites, as described in the scope of accreditation 267-CAL which is an integral part of the present certificate.

The current version of the scope of accreditation is available at www.belac.be.

This certificate remains valid as long as the body continues to meet the accreditation conditions.

The Chair of the Accreditation Board BELAC,

Maureen LOGGHE

Version : **10**
Validity period : **2023-03-16 - 2027-10-27**

Original version of this certificate is in French.

BELAC

Organisme belge d'Accréditation
Belgische Accreditatieinstelling
Belgische Akkreditierungsstelle
Belgian Accreditation Body

EA MLA Signatory

Accreditation Certificate No. 267-TEST

In compliance with the provisions of the Royal Decree of 31 January 2006 setting up BELAC, the Accreditation Board hereby declares to have granted accreditation conform the requirements of the standard EN ISO/IEC 17025:2017 to:

CENTRE DE RECHERCHES METALLURGIQUES ASBL - CENTRUM VOOR RESEARCH IN DE METALLURGIE vzw C.R.M.
Rue Ravenstein 4
1000 Bruxelles

The body demonstrated the competence to perform the activities in the activity sites, as described in the scope of accreditation 267-TEST which is an integral part of the present certificate.

The current version of the scope of accreditation is available at www.belac.be.

This certificate remains valid as long as the body continues to meet the accreditation conditions.

The Chair of the Accreditation Board BELAC,

Maureen LOGGHE

Version : **9**
Validity period : **2023-03-16 - 2027-10-27**

Original version of this certificate is in French.

.be

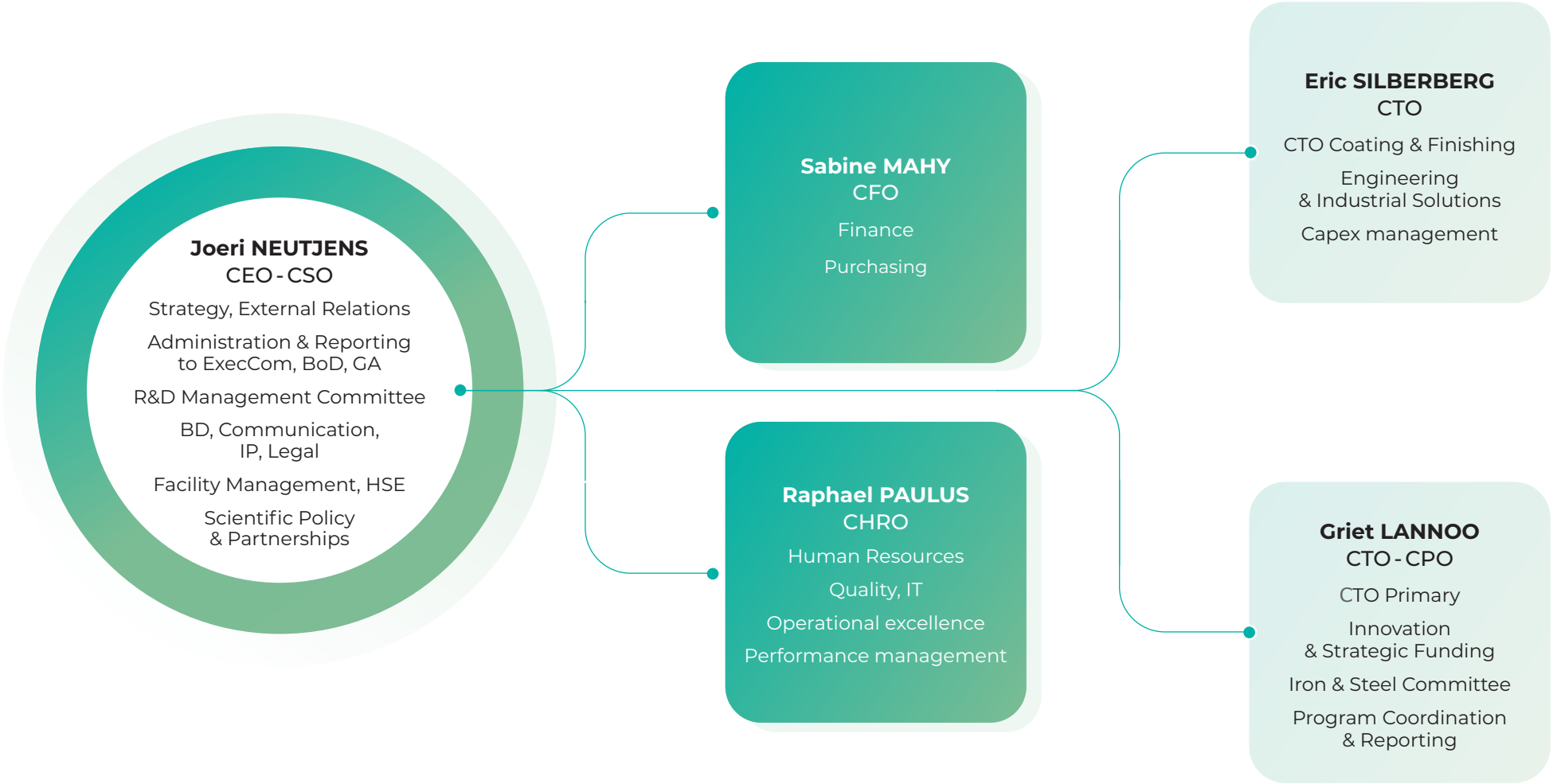
BELAC

BELAC

BELAC

BELAC 6-319 RD-2020

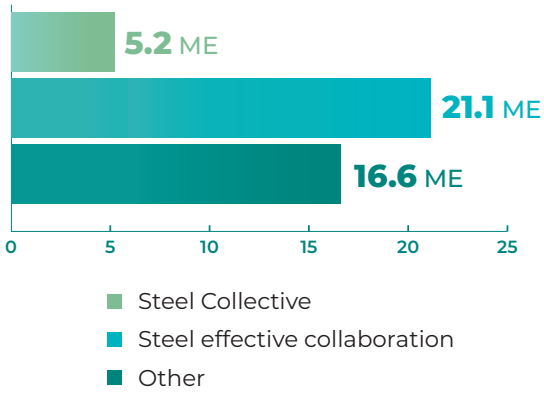
LEADERSHIP TEAM



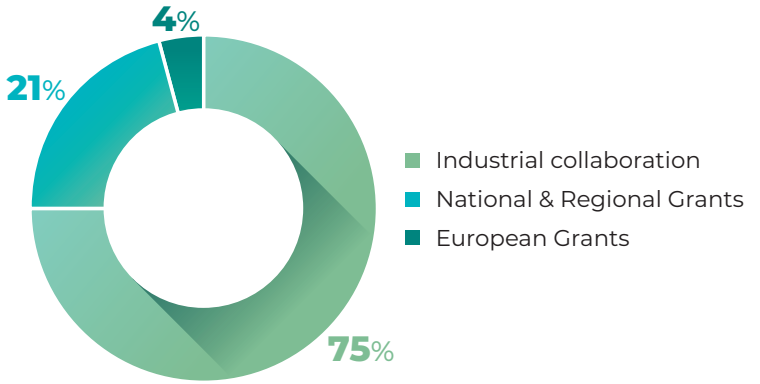
CEO: Chief Executive Officer • **CPO:** Chef Program Officer • **CFO:** Chief Financial Officer • **CSO:** Chief Scientific Officer • **CHRO:** Chief Human Resource Officer • **CTO:** Chief Technical Officer

KEY FIGURES

INCOME BY PROGRAM

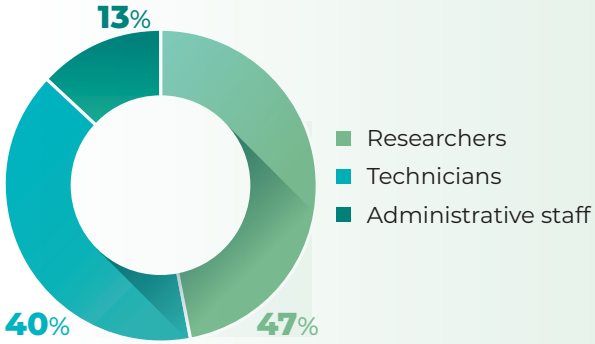


INCOME BY FINANCING

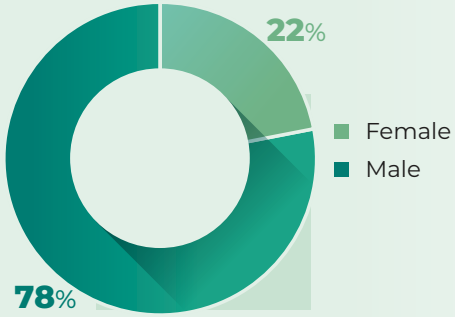


TOTAL INCOME (CRM ASBL):
42,9 Mio. EUR

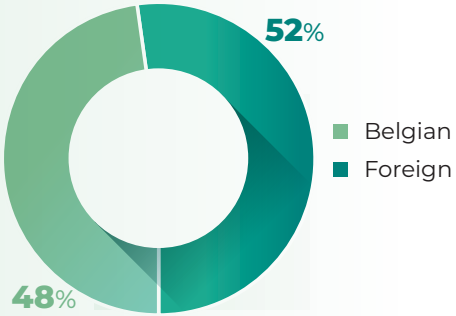
CRM GROUP: 277 PEOPLE



GENDER BALANCE



DIVERSITY BALANCE



REPORT ON TECHNICAL ACTIVITIES

CRM Group empowers the role of metals in the societal, environmental and economical challenges striving towards a better future.

Innovation Loop

Based our well recognised track record for innovation in metal's related production processes, products and solutions, we are developing solutions not only for the steel industry but for a **multitude of sectors** all along the value chain of metals.

Our main target remains developing and implementing innovative solutions that respond to the needs of our member and customers companies. Current major challenges are related to the **energy transition** and **the circularity** of our economy. 2022 was hence marked by the acceptance and the launch of two major project portfolios supported by the Walloon Region & the European Union in the frame of the NextGenerationEU recovery and resilience plan on the decarbonisation of the energy intensive industries (HECO2) and the circular economy (Reverse Metallurgy +). These initiatives will enable CRM Group to further valorise its metal competences towards various sectors in Wallonia, Belgium and internationally.

The transition towards a more sustainable industry is backboned and accelerated by the full integration of the **digital technologies**. CRM Group is therefore embracing and approaching in a global and integrated way the use of sensors, improved process control, digital twins and artificial intelligence making processes more efficient & sustainable.

The capacity of CRM Group to develop new processes and manufacturing routes, including **advanced and hybrid manufacturing** and our **innovations and services to industry to make the processes more** energy & resource **efficient** are also illustrated in this report highlighting the 2022 activities.

The innovation at CRM Group all along the value chain of metallic materials is perfectly demonstrated in our Innovation Loop. A collaborative work, illustrating how we draw on our past and our skills in the steel industry to develop and renew our areas of expertise and our technologies in order to meet societal challenges and the changing needs of our customers to create a better future.

CRM group gratefully thanks it industrials members and research partners as well as the funding authorities for their collaboration & support.

CIRCULAR ECONOMY

TOWARDS A **SUSTAINABLE** METALS INDUSTRY

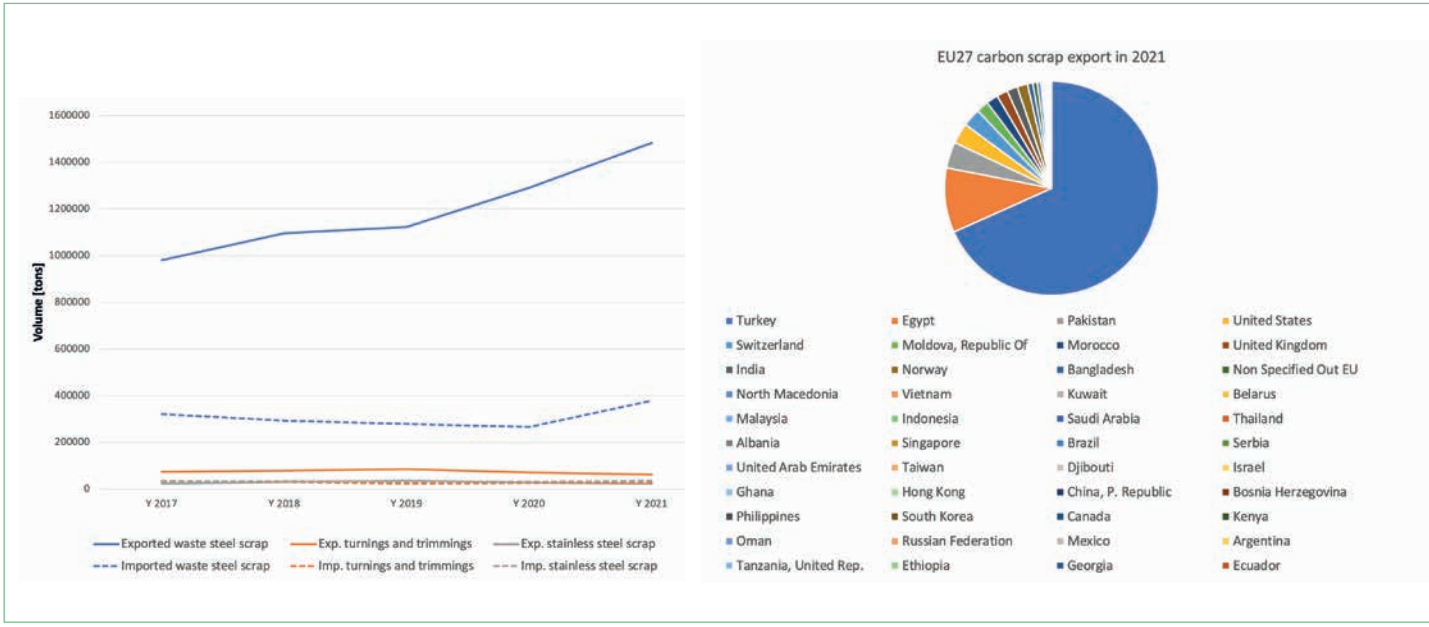
"Our process-product-applications approach, part of our DNA, gives us an unparalleled vision and unique capabilities about circularity issues with colleagues conceiving new multilayered components for batteries or electrolysers already anticipating second life or recyclability at end of life. Resource efficiency and eco-design concepts are highly integrated in our daily work at CRM Group, which is acknowledged by our clients, and also a strong motivation for our talented researchers."

Bernard Vanderheyden
Platform coordinator Circular Economy

Increased ferreous scrap recycling

To increase the steel scrap recycling capacity and energy efficiency, while keeping competitiveness of the steelmaking sector, innovative technologies to 'clean' the scrap before it reaches the steel furnaces need to be implemented.

To this aim, CRM Group is coordinating the Horizon Europe funded project 'CAESAR' aiming to reduce impurities in post-consumer scrap before melting together with better classified scrap, **to increase the use of scrap**

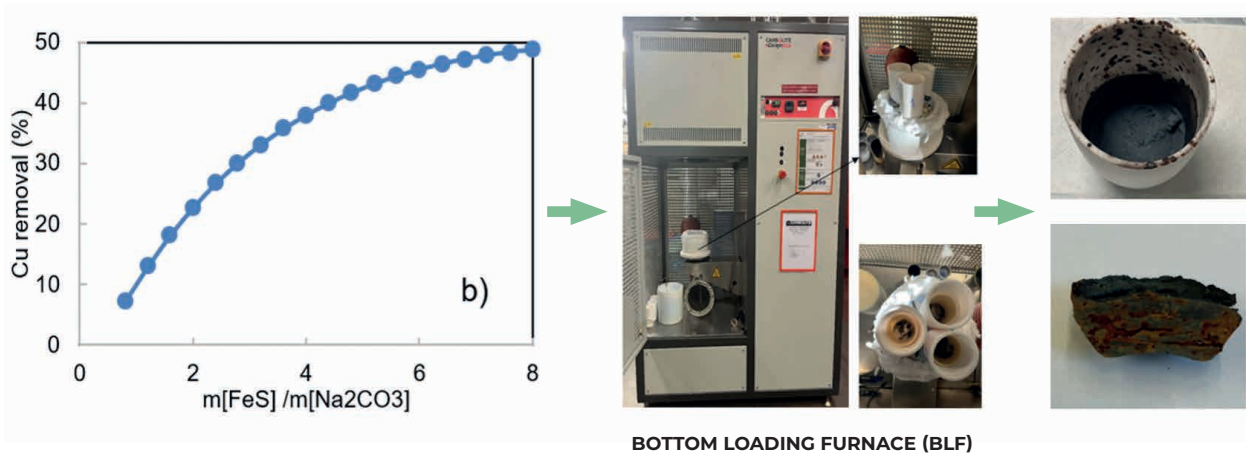


Mapping of scrap streams

achieving the same quality of the finished product. The project has started in the second half of 2022 with a **mapping of the scrap market and especially the identification of scrap streams leaving Europe**.

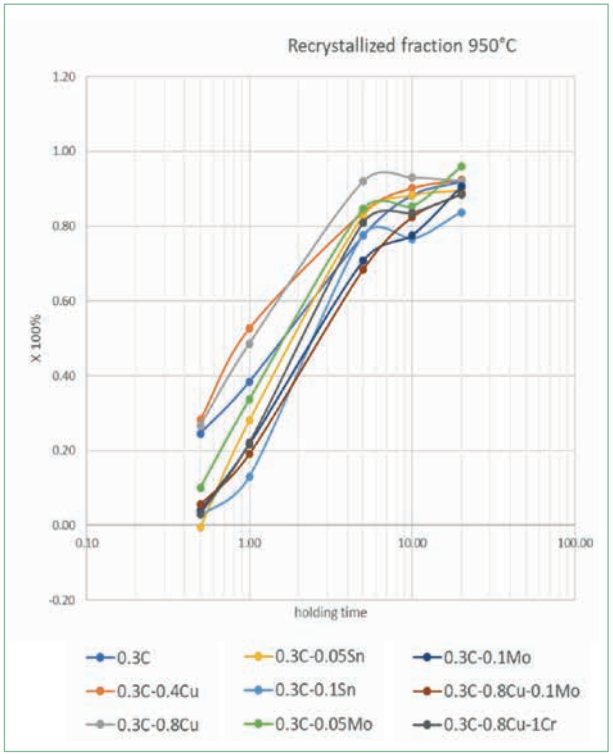
- As Cu is considered as a very harmful element in steel, amongst others because it may result in hot shortness when the material is hot-rolled, CRM Group is also looking for **innovative process options to improve Cu removal at liquid stage**. Based on a deep literature survey, three promising routes have been identified for Cu-removal in liquid stage. The thermodynamic feasibility of these methods was first checked by thermochemical (Factsage) simulation before launching experiments. Lab scale trials in the Bottom Loading Furnace have meanwhile started. The most promising results will be used to provide data and design the process to be further proposed for pilot scale testing.

- For the **removal of Zn & organic coatings from galvanised scrap** while recovering the pure Zn by thermal pre-conditioning in a vacuum furnace, the pilot furnace has been modified by replacing the plate condenser by a casting system allowing the casting of the recovered zinc in a mould. This modification to the process does not only allow easier recovery of the zinc in the form of an ingot, it fits also better with an industrial continuous process solution.



Thermochemical calculation (left) and Bottom Loading Furnace trials to assess the Cu removal in liquid phase

The growing recirculation of scrap will result in a substantial **increase of residual and tramp elements**. Both can **modify the response of steel to thermomechanical treatment** such as rolling or **change its properties** through their impact on the microstructure. The impact of Cu, Sn Cr, Mo and Ni has therefore been studied on the high temperature austenite phase present in the first stage of hot rolling of steels. The impact of the residuals on the kinetics of static and dynamic

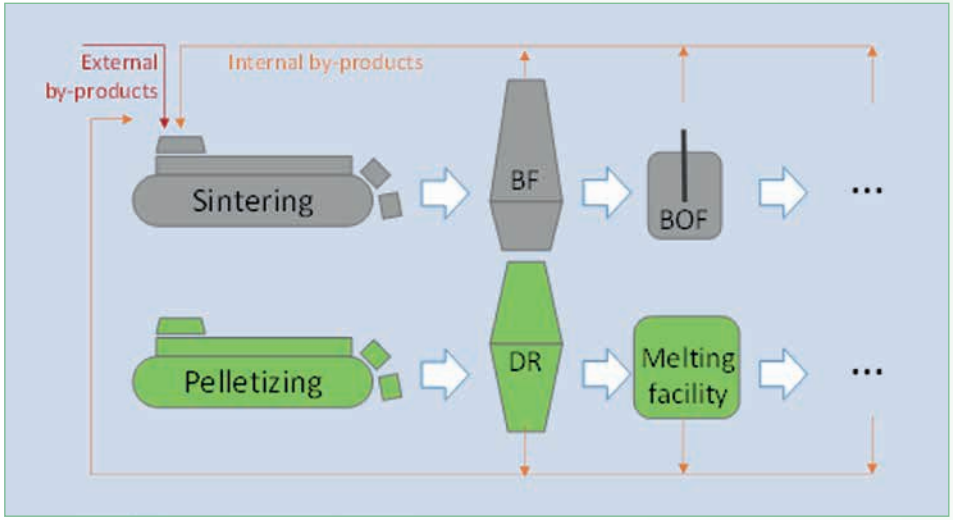


Static recrystallised fracture at 950°C as a function of residuals content and holding time between the passes

recrystallisation for different temperatures was studied using double hit experiments and continuous torsion tests respectively. The study allowed collecting numerous information on the behavior of the steel microstructure constituents polluted by individual and combined residuals. A database of thermodynamic data was developed which can be used to model the behavior of steels containing different residual levels.

Enhanced recycling through waste processing

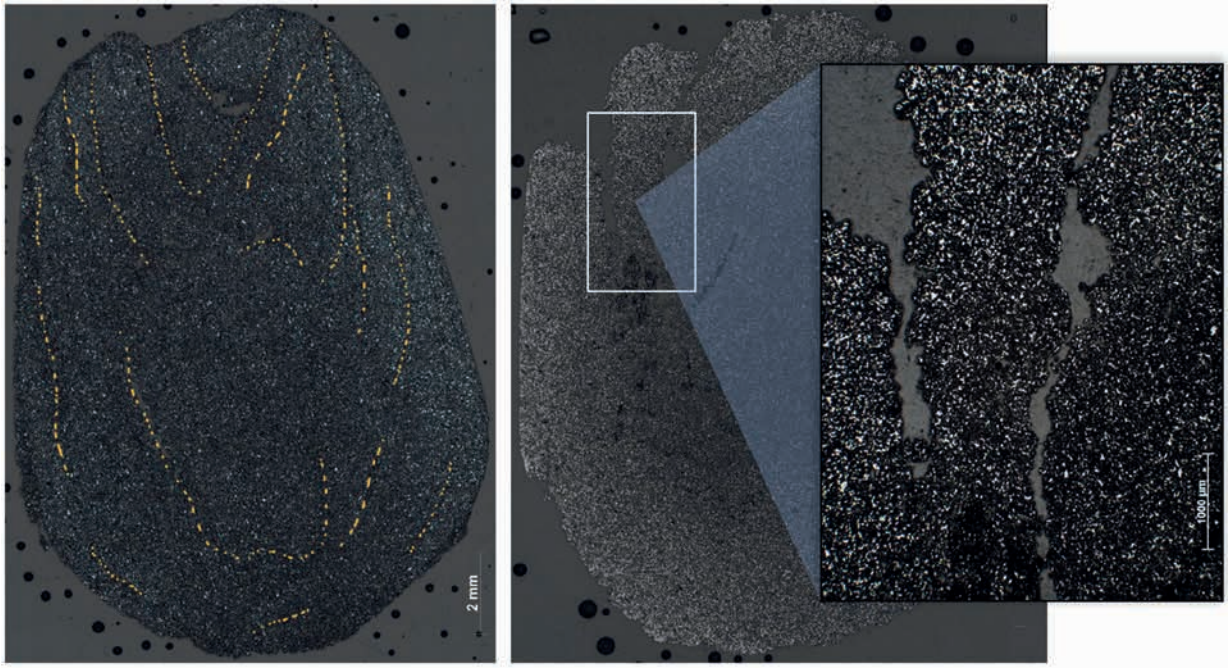
Steel industry generates significant amounts of by-products, which are for the largest part already valorised by internal recycling or external use. **The sintering plant**, a key asset for **internal recycling of by-products**, needs innovative solutions to deal with more challenging materials (finer and lower quality raw materials and by-products) without any detrimental impact on the productivity, sinter quality, pollutant emissions (dust and gas) and by-products recyclability. In 2022, we have demonstrated in the RFCS funded project SinByOSe that **selective pre-processing of the by-products** before introduction to the main sinter raw mix positively influences the productivity of the sinter plant. Furthermore, for mill scale and BOF sludge, the selective pre-processing reduces the CO_2 and NOx emissions. In the upcoming transition from Blast Furnace to Direct Reduction route, the amount of sinter strands available for internal by-products recycling will progressively decrease; meaning a need for higher recycling rate in the remaining ones. A new project (TRANSinter) will start in July 2023 to evaluate how to manage it, considering both routes by-products of both routes.



Transition from BF to DR route requiring increased recycling in remaining sinter plants

A promising alternative way to recycle steelmaking by-products is the **cold briquetting of by-products** for recycling in the blast furnace. In this way the energy & CO_2 intensive sinter plant could be substitued. In recent activities, the focus was placed on cement-free agglomerates and two technologies were assessed: the roll-press briquetting and the vacuum extrusion. Both technologies were able to produce agglomerates suitable to undergo Blast Furnace shaft conditions while using only 1% of organic binder, developed on purpose by BASF (COACH RFCS funded project).

To quantify the iron oxidation states of (partially) reduced materials, including cold bonded agglomerates and DRI, **advanced characterisation methodologies** based on optical microscopy have been developed such as illustrated on a cold



Characterisation of cold bonded briquettes for blast furnace applications :
Left = cold bonded briquets before reduction | Right = after reduction representative of a blast Furnace shaft

bonded briquet before and after partial reduction, highlighting pathways which will induce cracks after reduction.

At the crossroad of circular economy and energy shift within the 'Reverse Metallurgy' project, CRM Group has pursued its collaboration with its member company Comet Traitements on carrying out carbo-thermic reduction tests on **char and Fe-Zn bearing waste** from their Post Shredding Plant aiming to **produce DRI** while removing Zn using an **electrically heated laboratory furnace**.

The test campaigns carried out confirmed the effectiveness of char, produced by their "Phoenix" process from light shredded residue, as reducing agent instead of coal, resulting in a positive impact in terms of carbon footprint and natural resources consumption of the process. The research also focused on optimising the economic efficiency of the process by acting on various factors such as the reuse of part of the unreduced material, the spatial arrangement of the fresh and recycled material in the crucible and the density of the charged material to increase the thermal conductivity of the sample and, ultimately, to accelerate the kinetics of DRI production.

Carbo-thermic reduction tests on shedder residues to produce DRI; from left to right: crucible fed with compacted material, carbo-thermic reduction ongoing, produced DRI

Pilot plasma furnace

Pyrometallurgical processes remain efficient and sustainable processes **to recover and recycle critical raw materials**. To test the recycling of new types of waste generated by the green economy, electrical and electronic waste, battery residues, catalysts, permanent magnets, ... and the recovery of metals with a high strategic value, rare earths and other precious materials that are essential to the functioning of the digital industry, CRM Group erected a **highly versatile pilot plasma furnace**. This unique tool, funded by the Walloon Region within the Reverse Metallurgy project, is implemented on the industrial site of Hydrometal (Engis). The start-up of the equipment is planned in 2023.

The first purpose of the furnace will be **the recovery of critical raw materials via various processes including melting, smelting and fuming**, in collaboration with Hydrometal. Beyond this first application, the equipment will also support the development of the **new emerging steelmaking routes (hydrogenreduced DRI melted in electric arc furnace, smelting furnace...)**. As a research tool, the furnace will be **highly instrumented (gas analysis, dust emission, temperatures...) and a digital twin will be developed** in the frame of the PyroTeCniC project to have a full understanding of the phenomena occurring during the process.

Pilot plasma furnace

Innovation to boost circular eco-systems

CRM Group was already among the initiators of the **Reverse Metallurgy** partnership, federating industrial, academic and research actors around an Innovation Platform, aiming to develop unique technologies for the recycling of metals through advanced sorting as well as hydro- and **pyro-metallurgical treatments**, and to create value for regional economy and companies. In 2022, this first Walloon eco-system of nine partners seized the opportunity of the **European Relaunch and Resilience Plan** to renew its strategic plan and launch **Reverse Metallurgy+ (RM+)**; an ambitious innovation portfolio extended to more than thirty partners in total (22 companies, 4 university research groups and 6 RTO's), reinforcing the available expertise and covering more completely circular economy value chains in line with the mega-trends of **digital and energy transitions** as well as **advanced manufacturing**.

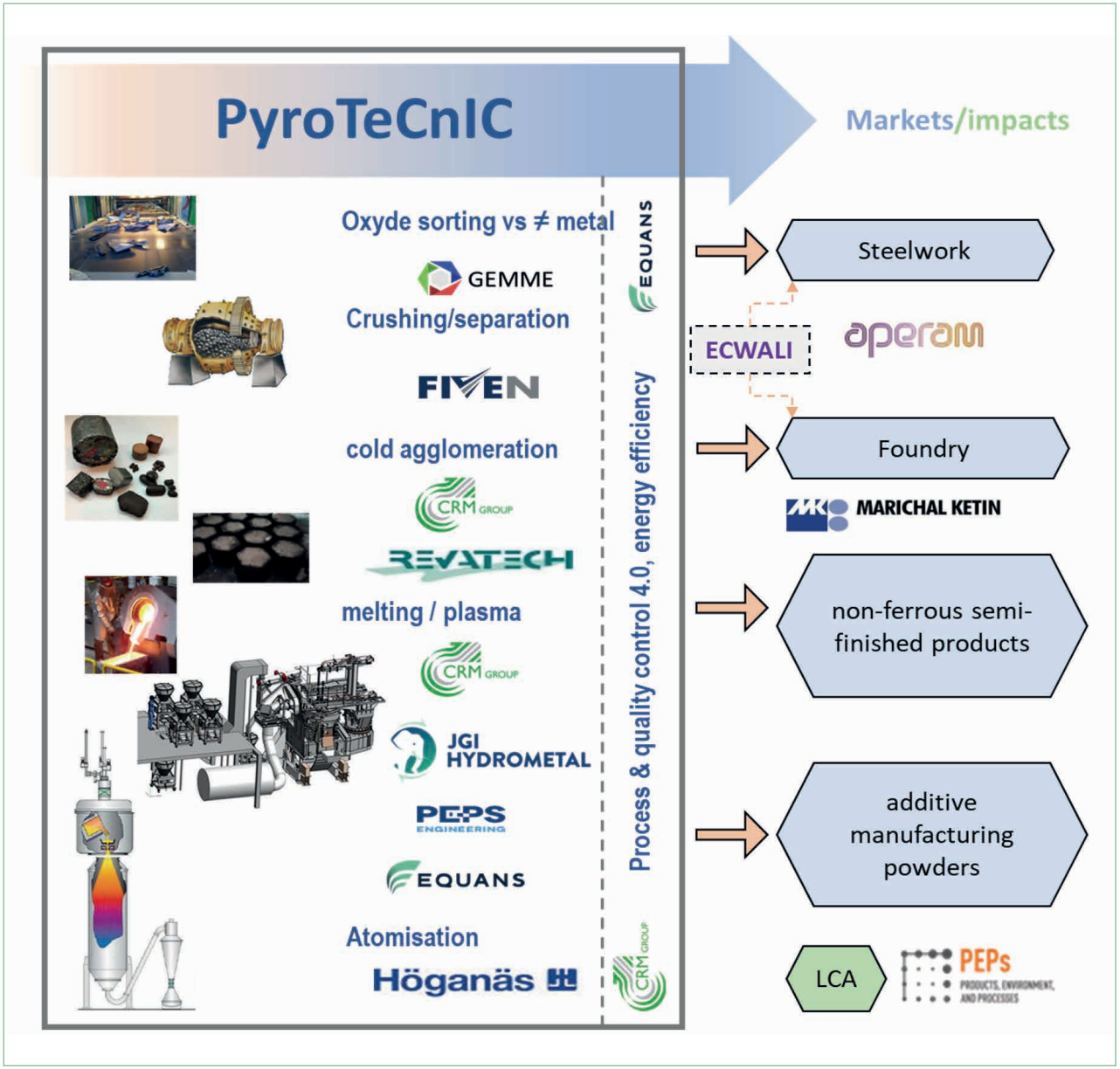
CRM Group is involved in all four RM+ mega-projects, contributing:

- in advanced sorting of aluminium and stainless steel scrap, by online **LIBS** analysis, making use of **deep learning** techniques
- in batteries recycling, by **pyrolysis** in order to allow optimal subsequent hydrometallurgical treatments

- in improved recovery of Critical Raw Materials from/for batteries, permanent magnets and catalysts, by **smart pre-conditioning** of fine residues and by pre-concentration prior to hydrometallurgical treatments through optimised **plasma furnace** treatments, assisted by the development of a **Digital Twin** (PyroTeCnIC)

- and finally, in Advanced Manufacturing, by **reuse of powders** from AM processes, development of **additive repair** and its **traceability**, and increased products longevity by **sustainable coating techniques**.

In more detail, the PyroTeCnIC project aims at valorising the Walloon know-how in pyrometallurgy, at the service of the circular economy and competitiveness: by producing locally alternative sources of alloying elements (Cr, Ni, Mo, V, W, Nb, Co...) from industrial residues, by adding a 'plasma furnace' technology to hydrometallurgy for a better recovery of critical metals, and finally by adapting the production of metallic powders by atomisation to the needs of recycling.



Schematic presentation of flow sheet and partners in the Reverse Metallurgy+ project PyroTeCnIC

Briquetted products of residues rich in alloying elements will be developed to serve as secondary raw materials with a controlled quality for Aperam (stainless steel production), Marichal Ketin (rolling rolls) and other foundries. CRM Group will support Revatech and Fiven in diversifying and massifying the supplies by synergistic combinations of different waste flows and pretreatment stages before briquetting like sorting, crushing, screening or magnetic separation.

Digitalisation will ensure high performance despite the greater intrinsic variability of the recycled materials and the complexity of the processes involved: Equans will collaborate with CRM Group to develop a Digital Twin of the plasma furnace, and CRM Group will design a specific on-line instrumentation for briquet quality control at Revatech.

Based on the large experience gained with metals circularity, CRM Group widened the scope by taking the lead of the **Walloon Initiative for Circular Materials (Win4C)**. The objective of this **Strategic Innovation Initiative WIN4C** is to anticipate the major changes that are coming in the management of our resources and in the relocation of production, repair and recycling activities on our territory. By bringing together players from the business world, research, training, the associative sector and the public sector, WIN4C aims at promoting a more circular economy and at positioning the region as the undisputed leader at the heart of Europe in the framework of metallic, mineral and polymeric materials by 2030.

ENERGY SHIFT

THE PATHWAY TO A CO_2-NEUTRAL INDUSTRY AND RENEWABLE ENERGY

" CRM teams actively pool to tackle the urgent and fundamental shift that is necessary in the way our societies produce, transform and use energy. Industrial processes, mobility and construction solutions are fundamentally reinvented to reduce environmental impact, notably by integrating cleaner energy sources ranging from upgraded wastes materials to renewables at large."

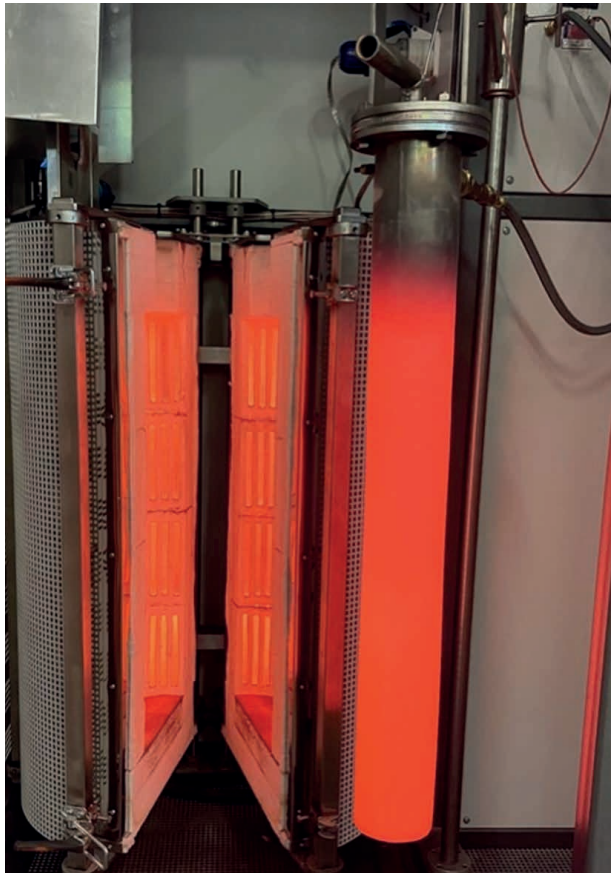
Jean Borlée
Platform coordinator Energy Shift

To support the industry and society to meet the climate ambitions, CRM Group's activities related to this 'energy shift' are organised around 4 main topics: **Industrial shift** (heat recovery in industrial processes, alternative fuels and process modifications to reduce environmental impact), **CCUS** (CO_2 Capture, Utilisation and Storage), **Hydrogen** (production, transport and storage) and **Renewables** (harvesting, storage and grid balancing).

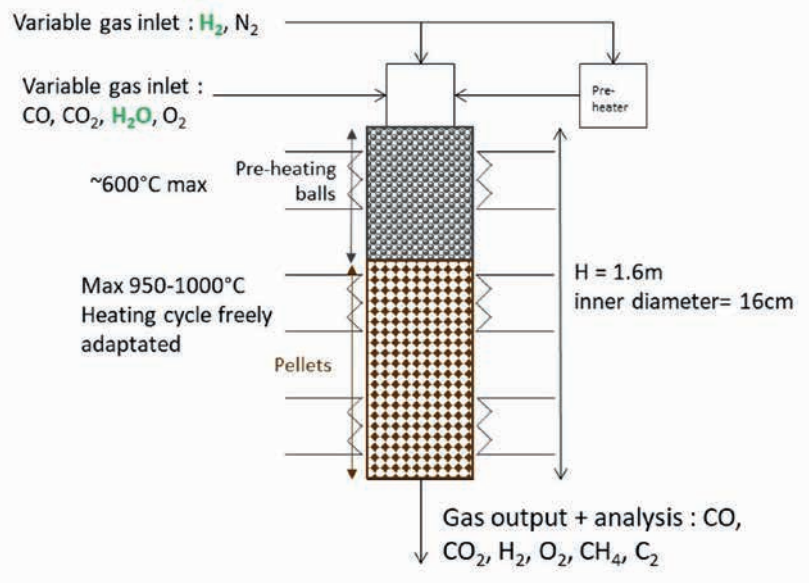
Industry looking for CO_2 emissions reduction

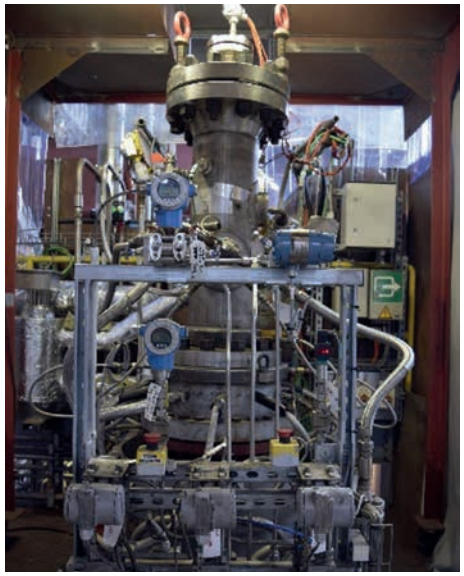
The European steel industry is facing the challenge of Carbon Neutrality by 2050. The transition from the Blast Furnace route (Coke based) to Direct Reduction route (Natural Gas and in the future hydrogen based) will play a key role in this process. In order to support our clients in the integration of the **Direct Reduction route** in their plants, we are adapting our existing tools and new ones are being developed.

- **Lab facilities** simulating the Blast furnace shaft have been adapted to allow simulation of reduction paths (gas composition and temperature) representative of **Direct Reduction shafts**.
- A new RFCS funded project, HBI C-Flex, will start in July 2023. Our contribution in the project is the **production of DRI samples**



Lab furnace initially designed for ISO characterisation of Blast Furnace Ferrous Burden transformed for Direct Reduction shaft simulations

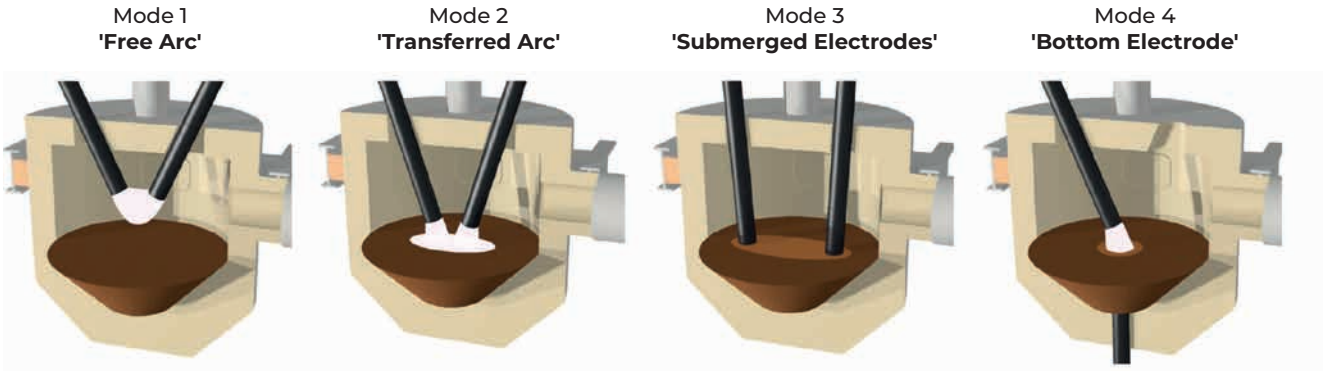




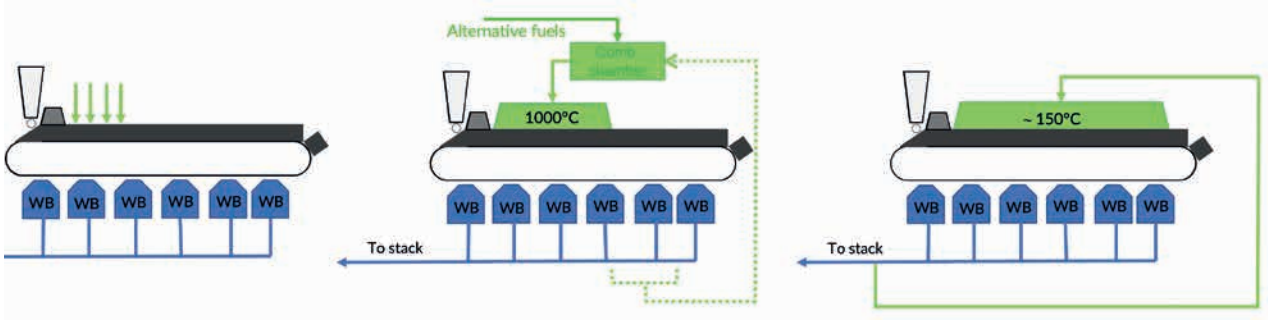
HUGE Thermo-conversion pilot facility in 'Direct Reduction' configuration and DRI produced in the Huge reactor

corresponding to different working points (pellet grades and reducing gas) which will be used for hot briquetting trials. For this purpose, the HUGE reactor is used.

- The **melting behavior of DRI** can be assessed at different scales **from lab (coffee cup size) to semi-industrial scale (Pilot plasma furnace – 1.2 t, 125 l)**. To allow deeper understanding of the process, the CRM Group's EAF dynamic model can simulate the future configurations, including low-C DRI (from hydrogen-based reduction).



Possible configuration of the versatile pilot plasma furnace with possibility to simulate EAF or other melting furnace for melting of DRI



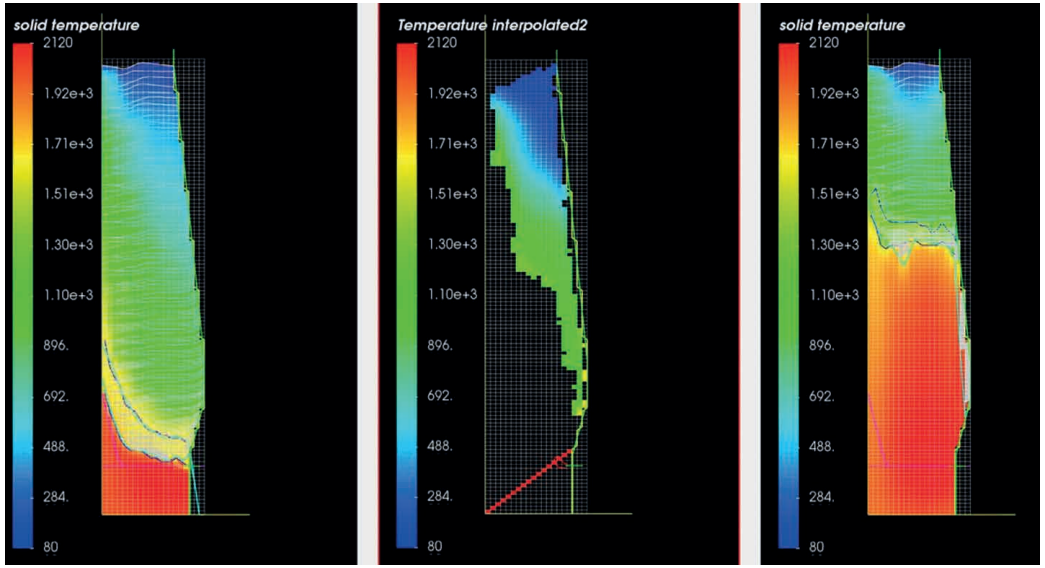
Options for reduction of soldi fuel consumption in sinter plants:
***Left** = Fuel Gas injection: Case study = BF gas injection - 10 % solid fuel saving |*
***Middle** = Hot fumes injection – VeLoSint process - 35 % solid fuel saving |*
***Right** = Waste gas recirculation (WGR) - 0 – 15% solid fuel saving*

During the transition period the remaining processes of the **Blast Furnace route** have to improve significantly the environmental performances, more particularly in terms of CO_2 emissions. CRM Group is developing solutions for the **decarbonisation of the Iron Ore sintering and the Blast Furnace processes**.

- For the **sintering process**, the TACOS RFCS funded project investigates different solutions aiming **at reducing the solid fuel consumption**.
- For the decarbonisation of the **Blast Furnace process,** the RFCS-funded H2TRANSBF project investigates solutions based on **an increased H_2 share in the reducing gas** aiming at reducing the CO_2 emissions by 30 to 35%. In this frame, our **model of the Blast Furnace process, Mogador**, is upgraded allowing reliable simulation of those new working points. For an improved fitting with industrial data, an 'autofitting' module has been developed, allowing more effective definition of reference cases for further extrapolation to new working points.

Substitution of fossil fuels by alternative reducing agents produced from biomass and/or waste materials in the industry, and specifically in the metallurgic industry, is one of the pathways to reduce the environmental impact and the carbon footprint. To support this evolution CRM Group is continuously updating and further developing its pilot and lab simulators.

- Our **batch pilot furnace** used for various **pyrolysing treatments including torrefaction and carbonisation for alternative fuel**

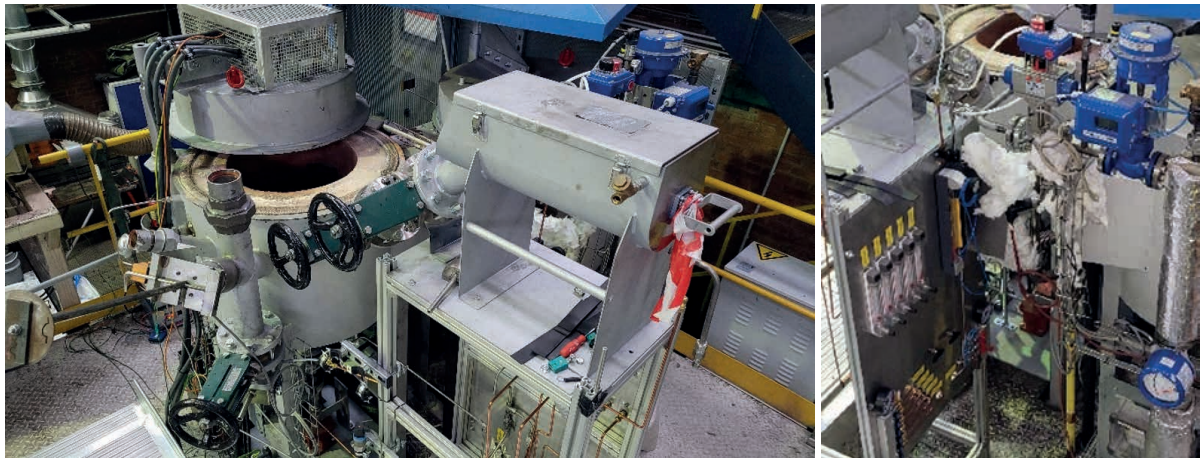


Blast furnace modelling:
Mogador results – BF Temperature map :
***Left** = After autofitting (R = 0,975) |*
***Middle** = Data from industrial measurements |*
***Right** = before autofitting*

preparation can process about 10 liters of solid materials under an oxygen-free atmosphere and controlled temperature. Inside this furnace, materials are stirred during a defined treatment time. This furnace has been successfully adapted with indirect electrical heating of the material when burner flue gases are unwanted. A top radiative heater was installed on the openable roof of the furnace. Necessary power supply and temperature controls were set up and connected. This furnace can now be operated either with the gas burner or with the radiative heater. Nitrogen inputs into the furnace and related flowrate measurement were improved for the sake of inertisation and pyrolysis gas flushing.

- Further **upscaling of torrefaction process** has been carried out in the **pilot rotary kiln** equipped with indirect electrical heating. Continuous feeding of waste wood from construction was treated at a stable temperature with a controlled residence time. The cooling of torrefaction gas and condensation of vapors were also achieved. Characterisation of the char produced indicates that the quality criteria were met.

Pilot rotary kiln



Upgraded BATCH18" pilot facility upgrade for pyrolysing treatments

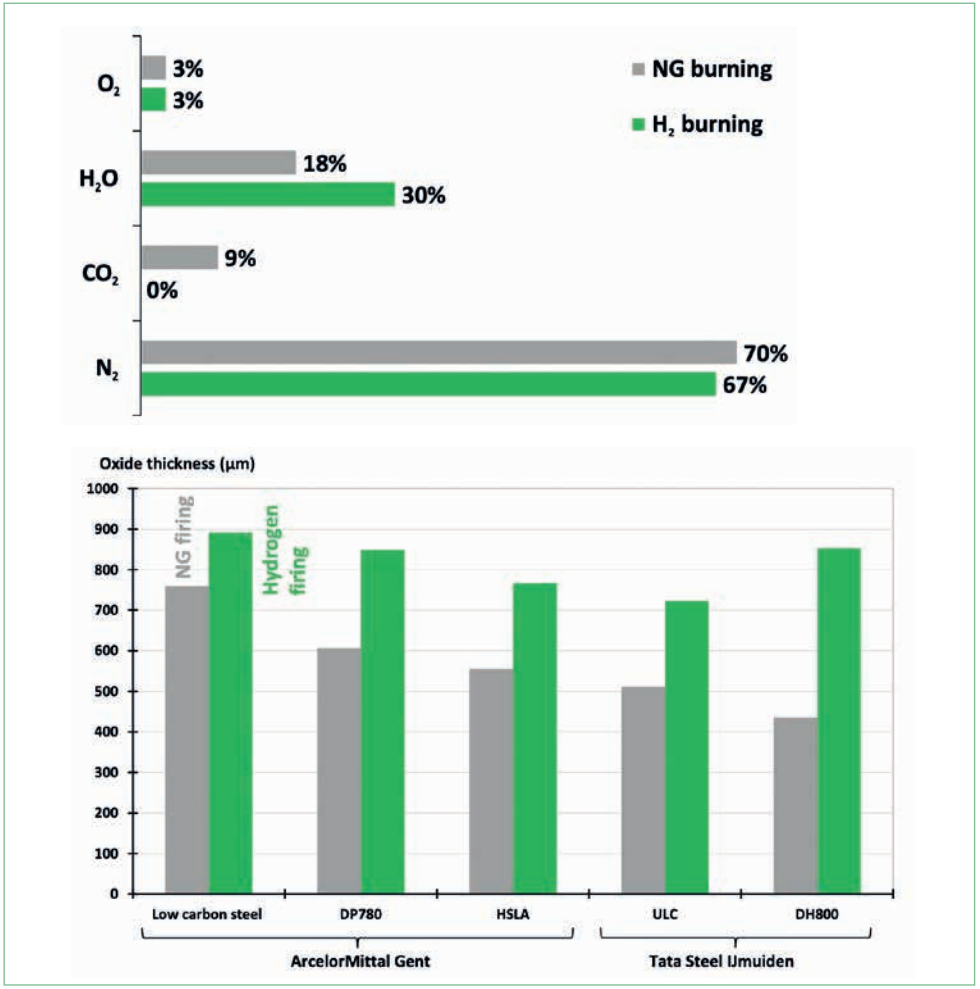
To decarbonise industrial heating processes such as in the iron & steel or glass industry or for the thermal treatment of solid waste, CRM Group is considering alternative fuels for the burners as well as the electrification of industrial furnaces:

- Within the HECO2 project, a Walloon initiative aiming at accelerating the decarbonisation of the Walloon energy intensive industry and supported by the EU relaunch and resilience plan, AGC Glass Europe intends **to transform the float glass furnace towards a hybrid furnace supplied by natural gas and electrical power**. The thermal heterogeneity induced

by electric heating can be detrimental for the product quality as well as for the lifespan of facilities. CRM Group will therefore develop a vision system allowing to monitor the glass bath temperature distribution. The thermal mapping will provide a better understanding of the impacts of this new heating method (hot spots, bath movements), support the modelling tools and the process control to guarantee performances equivalent to those obtained with conventional heating, while minimizing the risk of premature degradation of the installation.

- Another activity running in the HECO2 portfolio concerns the partial **electrification of the slab reheating furnace of Aperam**. Given our expertise in metrology and material science, we are supporting Aperam by characterising heating elements lifecycle through several analysis during and after equipment operation. In order to allow the observation during operation, an instrumented pilot furnace simulating the industrial conditions will be set up and monitored in our facilities. The conversion of the equalisation zone from heating by natural gas burners to electric heating elements will produce an increase in air inlets due to its location close to the discharging area, this will affect the oxidation of products. A second objective is therefore to evaluate the impact of this change of atmosphere on the quality of the products.

- Substituting natural gas burning by **hydrogen burning** is another way to reduce the CO_2 emissions of a slab reheating furnace. By doing so, the furnace atmosphere will change and it has been shown, in collaboration with ArcelorMittal and Tata Steel, that oxide growth during reheating increases significantly as a consequence of the higher humidity. The impact on descaling and strip surface quality is currently under assessment.



Decarbonisation of reheating furnace:

***Top** = Stoichiometry of air combustion of NG and H_2*

***Bottom** = Impact of the hydrogen firing in the slab reheating furnace on the oxide thickness*

- The ambition of the EU funded RFCS big-ticket project FullH2Reheat is to demonstrate, at the ArcelorMittal Belval plant in Luxembourg, an innovative **combustion system working with hydrogen** instead of natural gas to produce without any quality impact High Adde Value (HAV) long products such as sheet piles, rails, heavy sections or merchant bars. CRM Group will support ArcelorMittal Belval plant with an assessment of the **possible impact on the oxidation and surface quality as well as the potential degradation of the material properties due to hydrogen firing**. Sections will be processed in the pilot line (reheating, descaling & hot rolling) and then air cooled in order to obtain a repeatable thermal processing cycle and therefore a controlled microstructure of the final steel sample.

CO_2 capture in industrial processes and storage & usage (CCUS)

Although the prime objective is to avoid the emissions of CO_2, the **capture of CO_2 on industrial fumes** followed by purification and finally utilisation and/or storage of the pure CO_2 is expected to remain an important pathway in most industries. We are therefore currently revamping **a semi-industrial CO_2 capture pilot plant "PiCaSSo"** within the frame of the HECO2 project, based on the absorption technology with amine solvent, able to process up to 1000 Nm^3/h of flue gas. Our teams are renovating and improving the current installation with new instrumentation, circulating pumps and gas recycling section. Heating and cooling system was also handled with exchangers and steam generator refurbishment. PiCaSSo will offer to our industrial partners a tool to assess **CO_2 absorption technology at large scale** for their application and help them to achieve their CO_2 emission reduction goals. The development of this pilot is done in parallel with the development of two other CO_2 capture pilot plants, one dedicated to absorption process (PSA, TSA, etc) and one which will be mobile, to be used directly on partners' industrial site. Together, both pilots will procure a complete large-scale trial solution for CO_2 capture process development in dedicated application. In parallel, we started in collaboration with the industrial partners Aperam, AGC, Carmeuse and Prayon the characterisation of emissions (sources, concentration, fluctuations, pollutants, etc) which will allow the selection of suitable capture technologies, implementation details and consumption rates for each industrial sector/plant. Preliminary study of buffering options, when needed on highly fluctuating sources (e.g. AOD process and reheating furnaces) have also started.

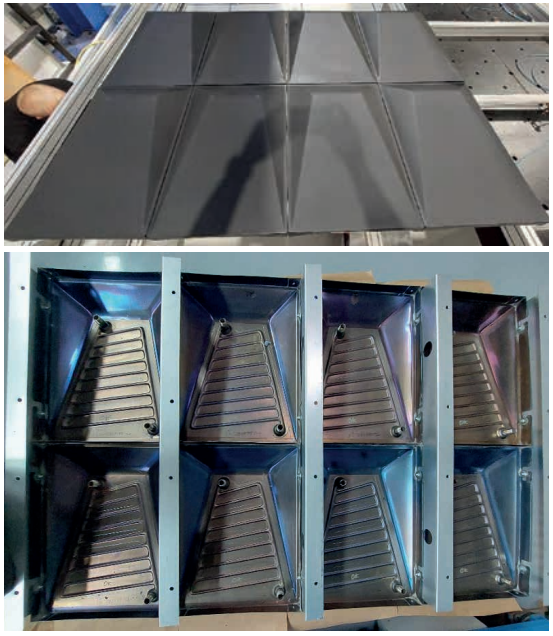
PiCaSSo Carbon Capture

CO_2 capture in industrial processes

Renewable energy solutions

Thanks to its outstanding know-how in material selection & processing, CRM Group is the preferred partner for the selection and development of new materials & designs:

- In the domain of solar thermal energy CRM Group is taking part in a project focusing on the development of **customised 3D solar active facade panels**. For the assembly of the all-sheet metal 3D complex shape collector, the laser welding proved to be an efficient method. The use of solgel painting spray revealed an efficient and low-cost way to deposit the solar absorbing layer on a complex shaped surface. The high solar absorptance and high emissivity of the solar layer can generate a high thermal efficiency of the solar collector at low temperature.



Picture of the solar collector as manufactured (1.6 m² size): front side (top) and back side (bottom)

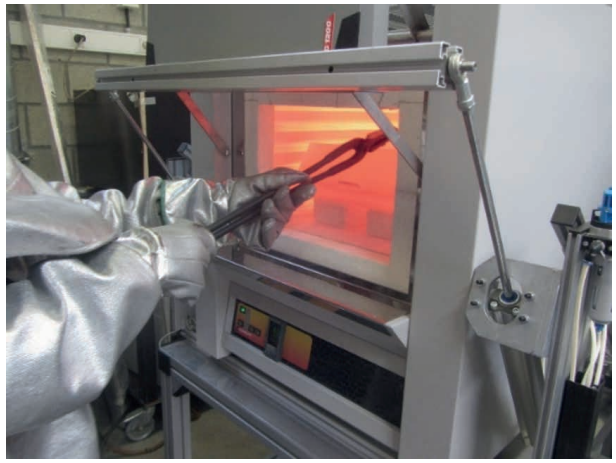
- Electric vehicles are powered by **batteries**, being the essential part of EV. With the fast increasing demand for **electric vehicles**, new solutions are needed to develop **cost-effective**, **robust solid-state lithium metal battery** with in situ hybrid electrolyte comprising sustainable materials. This is targeted in the Horizon Europe funded SEATBELT project. The cells are produced by a low-cost solvent-free extrusion process comprising a combination of innovative materials: thin Li metal, hybrid electrolyte, a safe cathode active material without critical materials (LFMP) and very thin Al current collector. CRM Group takes part in the material battery development working on thin Li anode; the interlayer between solid electrolyte and Lithium as well as on a thin protected Al current collector. We are also active in the recycling process in particular in the purification of recycled Li.

SEAT BELT
Solid-statE lithium metal bAttery wiTh in situ hyBrid ELecTrolyte

- Fully in line with its Sustainable Development Goals, CRM Group is part of a Walloon project 'SOCCER' aiming to implement **social inclusive renewable energy communities**: this project is based on a living laboratory to develop a guide to good civic practices and to identify the key success factors for the attention of stakeholders (citizen authorities, public, businesses, associations and non-profit sector) to implement Renewable Energy Communities (RECs) including low revenues public. We especially work on the assessment of the environmental impact, based on a GHG balance type approach, for the energy transition measures implemented within the two selected RECs under implementation in Wallonia.

Hydrogen

With the increased use, transport and storage of hydrogen, the **control of the hydrogen embrittlement** risk and innovative solutions to reduce this risk are topics of increasing interest, such as for example in automotive high-strength steels. Dedicated charging tests on large samples sizes (up to 120 x 200mm) have been developed at CRM Group: electrolytically with cathodic charging or gaseous charging through heat treatments in a controlled atmosphere. The development of tight coatings to avoid hydrogen diffusion is also studied. We have a large set of different mechanical tests available in order to identify the most critical and most relevant mechanical testing depending on the material and the application.



Tailor made controlled atmosphere furnace for hydrogen gaseous charging to assess hydrogen embrittlement

The **production of green hydrogen** at acceptable cost is key for the decarbonisation needs. Relying on its expertise on new advanced materials, coatings and electrochemistry and in collaboration with John Cockerill, CRM Group continues the improvement of the alkine electrolyser technology to optimise both performance and cost.

With hydrogen now considered globally as the energy carrier of the future, the extent to which these decarbonised technologies will have an impact on the economy will depend on technological advances and the costs associated with their implementation. To achieve this, reducing the cost and increasing the efficiency of each component of the value chain from production to use is essential. CRM Group, together with UCLouvain and TWEED initiated and leads the **Strategic Innovation Initiative e-WallonHY** aiming to develop a green hydrogen economy in Wallonia. The initiative covers the various components of the value chain, from the production of green hydrogen (power-to-H2), to storage and transport, and up to its use in the most promising applications for this high-purity hydrogen, namely mobility (H2-to-Mobility), buildings (H2-to-building) and specific industrial processes (H2-to-Industry; excluding e-fuels).

Prototype alkaline electrolyser

ADVANCED MANUFACTURING

“ Each day, we develop innovative manufacturing solutions for our industrial partners thanks to our unique Direct Metal Deposition and coating tools. The development of green and sustainable manufacturing takes also a larger part of our time with big efforts devoted to repair of existing parts and development of innovative coatings to enhance the lifetime of products.”

Cédric Georges
Platform coordinator Advanced Manufacturing

Equipped with the unique advanced manufacturing platform dedicated to produce, repair and surface finish of parts, CRM Group serves the industry with the development of new and innovative solutions. Different sectors such as manufacturing, energy, defense, construction, aeronautic and aerospace industries are approached.

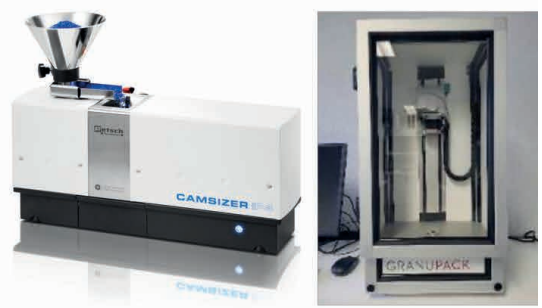
To do so CRM Group pools together its material science competences, unique versatile equipment for Direct Energy Deposition, surface finishing expertise and its extensive characterisation tools to cover many aspects of the Advanced Manufacturing value chain such as the development of new alloys, the industrialisation of the manufacturing processes, the surface treatments, the assembly of complex parts made by additive manufacturing as well as repair.

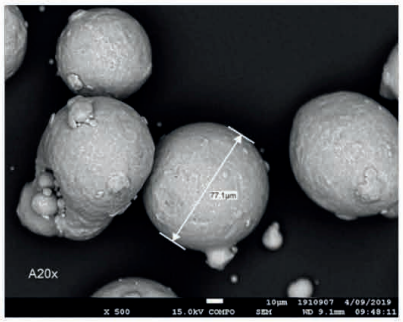
To fully exploit the advantages of additive manufacturing the development of tailor-made alloys is a must. CRM Group is therefore continuing its **development of customised alloys** and completed its already **complete set of powder characterisation tools**, in particular with equipment to characterise the powder processability.

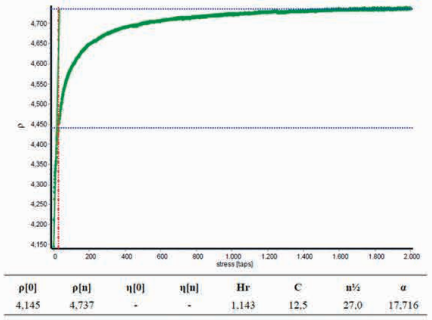
- In the framework of an ESA funded project, CRM Group coordinates the effort of a consortium formed by SABCA, KUL and 3DSystems **to develop novel high strength aluminium alloys**

Type	Powder chemistry-µStructure
Powder size	Granumetry - Laser (Occhio)
	Granulometry and morphology - Optical (Camsizer X2, P4 and Litesizer500)
	Sieving
	Optical Microscopy
	Electronic microscopy (SEM/SAM)
Powder chemistry-µStructure	Optical Microscopy
	Electronic microscopy (SEM/SAM)
	Phases (Raman, XRD)
	ICP, CSNOH, XRF, µ-XRF
	Humidity
	True density (gaz pycnometre)
Powder processability	Hall flow behavior
	Density free and packed
	Avalanche behavior
	Angle repose tester
	Loose bulk density tester
	Pourability Tester

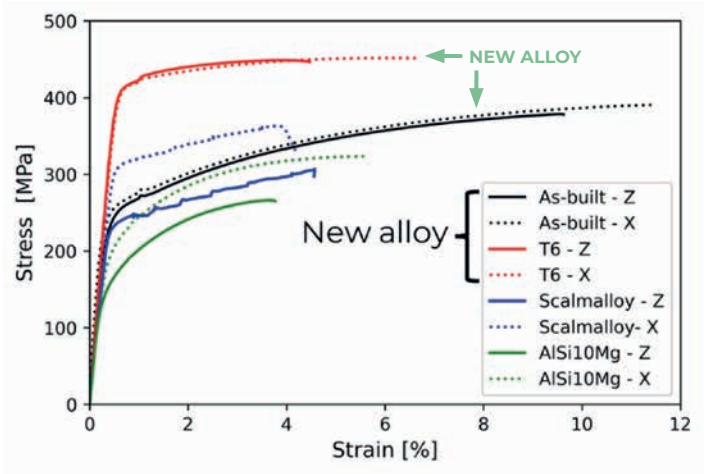
Complete set of powder characterisation tools available at CRM Group

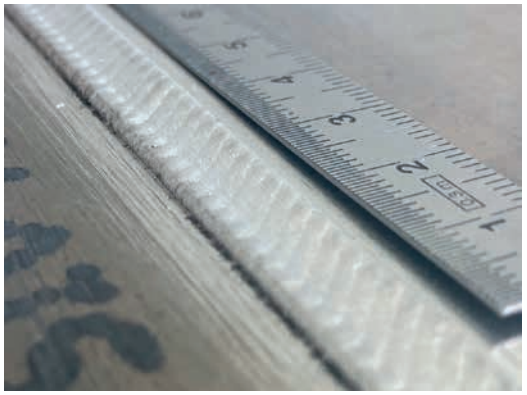






ρ[0]	ρ[n]	η[0]	η[n]	Hr	C	n½	α
4,145	4,737	-	-	1,143	12,5	27,0	17,716





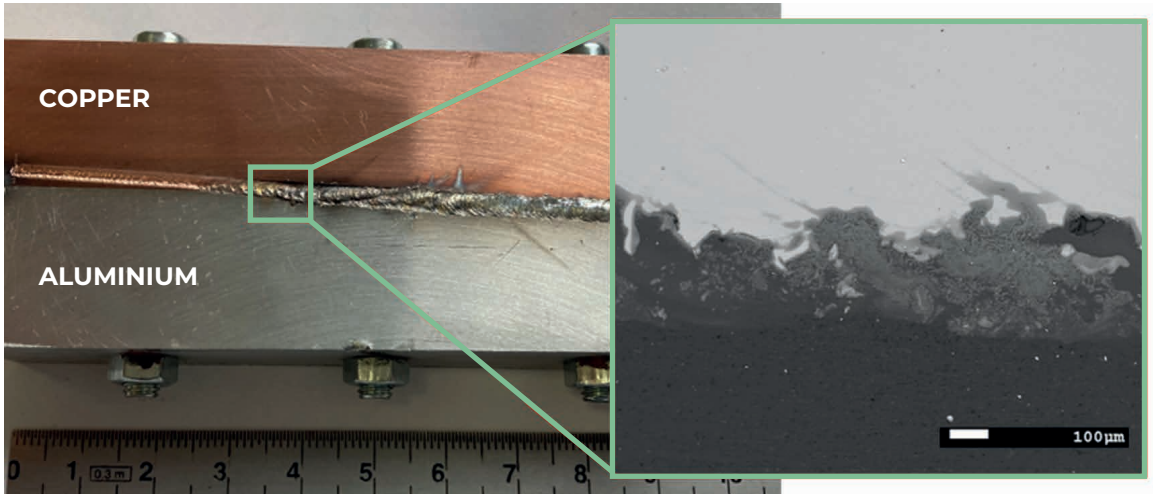
Improved performances of the newly developed Al-alloy tailored for additive manufacturing

compatible with additive manufacturing. New tailored compositions are required to overcome the issues related to solidification cracking. CRM Group has successfully tested those alloys using Direct Energy Deposition (DED) and promising results were obtained compared to the currently used Al-alloys in additive manufacturing: low porosity, high strength and low anisotropy. This novel alloy enables other developments such as the repair of structural aluminium components thanks to its good performance.

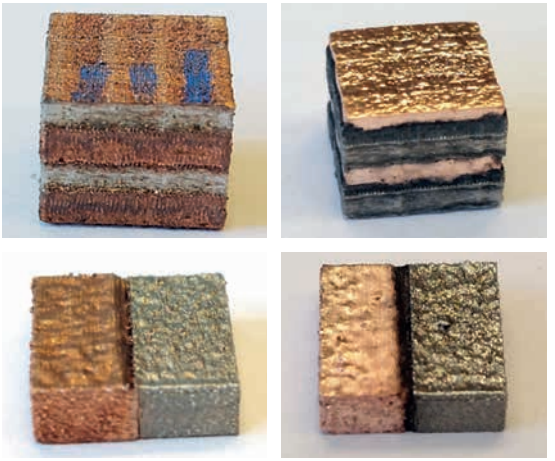
- In the frame of DIAMANTS project, CRM Group is investigating the impact of different thermal treatments on a new **high-performance nickel-based alloy for additive manufacturing**. In parallel a mechanical property profile from room temperature to 250°C on AlSi10Mg and Scalmalloy® built by powder bed additive manufacturing is being investigated. For all our studies, the samples are built by Any-Shape.

Advanced and hybrid manufacturing open doors for multimaterial printing or joining

- **Multimaterial printing** is the next big step in additive manufacturing, allowing us to move from topological optimisation to functional optimisation. However, not every couple of material is compatible with this technology due to the formation of undesired phases. In collaboration with UCLouvain and Aerosint, we



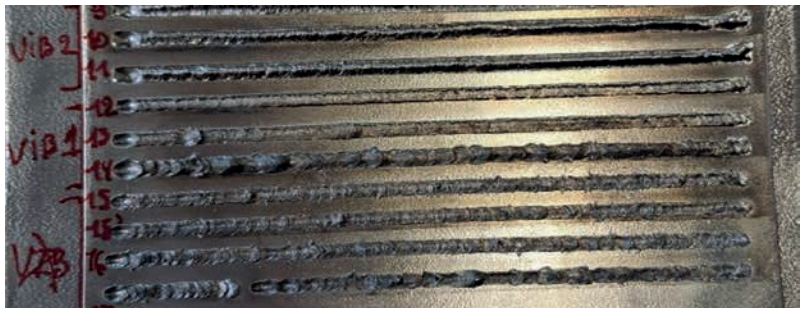
Study of the interaction between Cu and Al alloys during multimaterial printing



Multimaterials additive manufactured parts before and after homogeneous chemical polishing

want to acquire knowledge in the interaction of different couples of materials at very high laser processing speeds such as found in Laser Powder Bed Fusion techniques.

- Supported by European Space Agency and in collaboration with Redwire Space, Raytech and Sirris, we are developing **joining solutions for aluminium and titanium parts manufactured by additive methods**. Reducing the presence of porosities is the main challenge during welding of additive manufactured parts. Different welding solutions are therefore first assessed on flat samples to identify the way to obtain good quality welds. In the second phase, the design and welding of complex samples and representative breadboards will be realised.



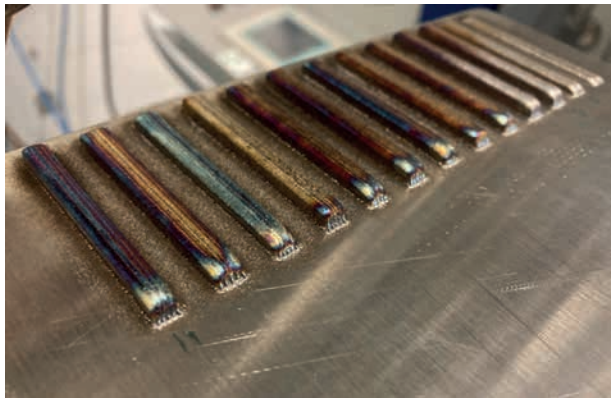
Study on joining additive printed components - Lap-joint electron beam welding trials, testing different welding parameters with and without vibration of the beam

- Another challenge linked to multimaterial parts concerns the surface finishing. In the Fissel project, CRM Group renders the surface finishing of additive manufactured parts more efficient. Special attention is paid to the investigation of self-limiting elimination of support structures, localised surface finishing, multimaterial surface finishing and the development of predictive tools. In the scope of this project, different solutions and conditions were identified to achieve a homogeneous (uniform dissolution of both materials) or a heterogeneous (selective dissolution of one material) **multimaterial (Cu alloy-steel) surface finish by chemical polishing**.

At the crossroad of our Circular Economy and Advanced Manufacturing platforms

- We are **transforming titanium machining chips into powder that can be used in Additive Manufacturing processes**. In the European project Varetit, a multistep process has been developed: with at first, a specific treatment of hydrogenation which makes the titanium brittle, the titanium is subsequently fine grinded. After removal of the hydrogen, the powder is ready to be used. The impact of the functionalisation of the powder is studied in parallel.

- Within the Reverse Metallurgy + portfolio (RM+), **REMADE (REcycled MAterials for aDvancEd manufacturing technologies)** includes 15 partners among which 11 industrial companies for the **production of cheap metallic powders with reduced environmental impacts** for various innovative manufacturing technologies (3D manufacturing, thermal spray, direct metal deposition, ...). **Repair** is an essential aspect of circular economy strategy to extend the life of products and materials. CRM Group first focuses its activities in the REMADE project on the development of **repair solutions for the energy sector** by the determination of the process window for the repair of defects with lasercladding on steel parts.



View of various deposition tracks by lasercladding to determine the process window for the repair of steel parts for energy sector

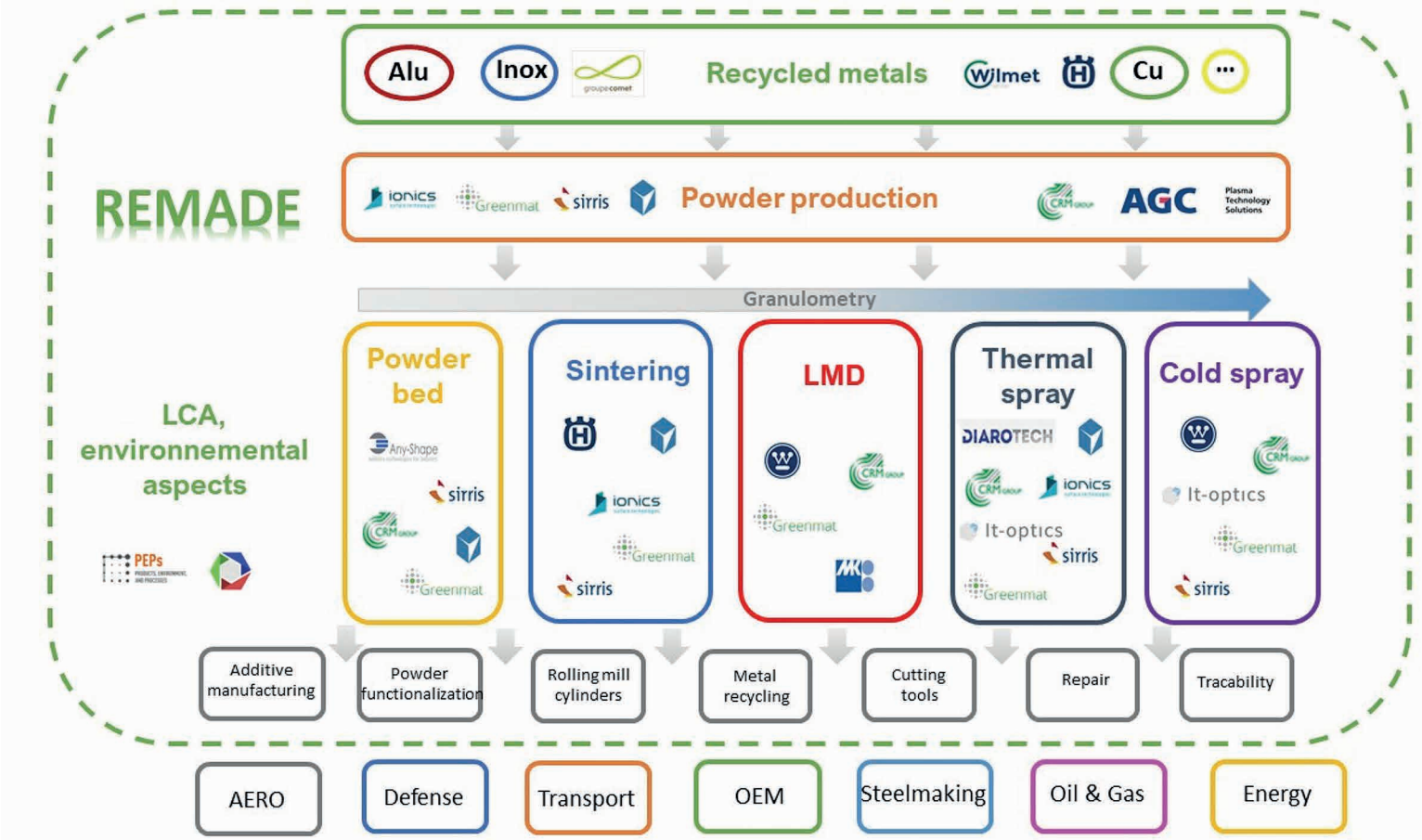
Size : few centimeters

Hydrogenation - Fine grinding - Dehydrogenation - Functionalisation

PSD : d10=18µm; d90=136

Transformation Ti machining chips into powder for additive manufacturing

- CRM Group has been deeply involved in the preparation of the **Strategic Innovation Initiative 'MADEINWAL'** (Advanced Products & Manufacturing in Wallonia). The initiative, led by Sirris, aims at bringing together a maximum number of innovation initiatives covering the entire "Manufacturing" value chain with the aim of (re)developing the Walloon industrial economy.



Layout of the project in terms of applications, sectors and partners

DIGITALISATION

INDUSTRY 4.0 AND **SMART PRODUCTS**

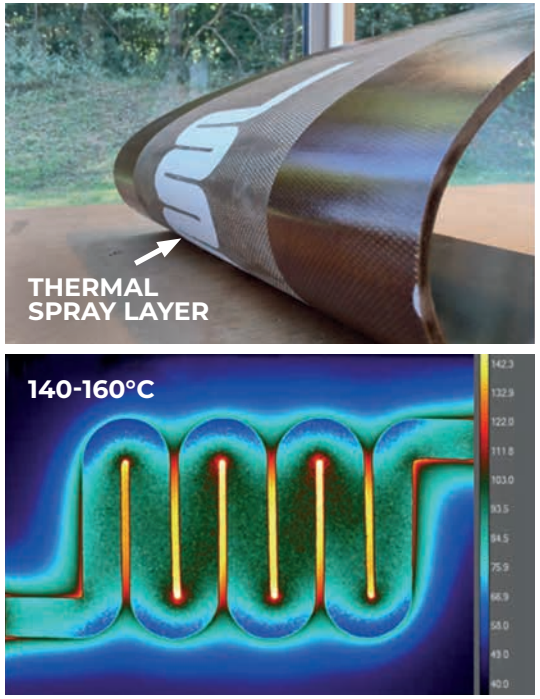
"Wisely used, we believe that digital technologies are fabulous tools to empower the energy transition, the circular economy, the advanced manufacturing and the industrial efficiency. Therefore, we develop innovative smart products and sensors meeting specific demands and we integrate customised IoT and AI solutions in the processes and products of our customers to create more value."

Catherine Archambeau
Platform coordinator Digitalisation

Connected and interactive products

CRM Group has developed an unique expertise to **embed smart sensors on 3D objects, by printed and structural electronics technologies** for demanding applications. Electronic functions can be conformable, flexible or directly integrated in the structure of any object. Thanks to the unique skills developed, our solutions can face the difficult requirements of printed electronics under severe environment: very high temperature, antennas in a metallic environment, corrosive environments, product circularity, etc. This responds to a multisectoral demand (metals industry, aeronautics, automotive, defense, construction, ...), which can take advantage of eco-design and growing connected and interactive products.

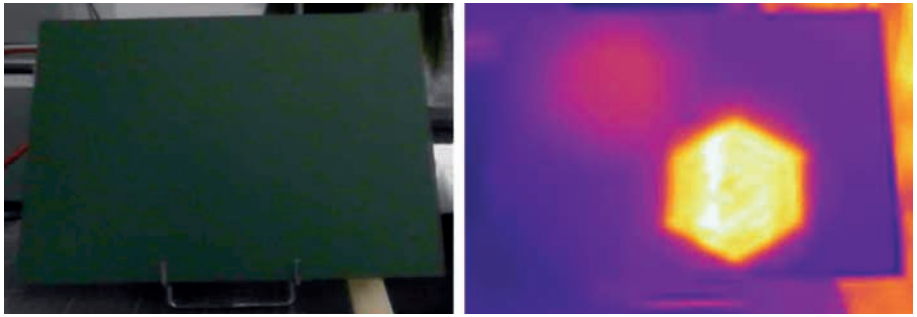
In the frame of the Wings (Wallonia Innovation for Green Skies) project, we have developed for Sonaca an innovative and new manufacturing process for the production of the Ice Protection Systems on leading edge. Heating material deposition strategies on a 2D or 3D composite surface by thermal spray wire arc process and by screen printing have been investigated. The feasibility of both technologies has been proven and the performance was validated with InfraRed (IR) camera and proved that the solutions allowed for achieving the necessary temperature range for deicing.



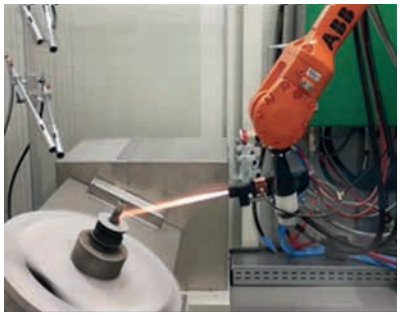
Direct deposition by thermal spray of heating elements for deicing applications on composite materials

For John Cockerill, CRM Group is developing **smart stealth solutions** in the thermal infrared band for the **defense sector** in the frame of the Mecatech cluster, VIRGA project. The innovative solution relies on **low emissivity coatings** able to decrease the IR thermal signature of an object and make its detection by IR sensors harder. As well as on **activable heating patterns based on printed electronics technology** that can modify the shape and appearance of the object in IR range. After the preparation of the prototypes showing the ability to design on-demand shapes in IR through the activation of small pixels, we are now investigating the up-scaling of the solution with representative sizes of pixels for real environments, supporting materials (including polymer composites) and manufacturing techniques. In addition, part of the activities is dedicated to the set-up of a **smart control of the IR stealth solution**. In collaboration with Helmo Gramme University College of Liège, we are testing **AI algorithms** able to decide the most suitable appearance that should be activated depending on the object's surroundings. The integration of AI will help to provide an adaptive camouflage solution.

In the additive manufacturing technology, additively manufactured 3D surface need close monitoring for the temperature, stress, vibration, corrosive environment, etc. for its well-being and extended operation lifetimes. Although sensors (printed on Kapton or chip format) are available for accessing these critical parameters, **directly printing such a sensor on the 3D object and its data management by IoT technology** offers added advantage in in-situ monitoring (also in difficult to reach parts), workspace optimisation and human intervention free operation. We are tackling this need in the project **Additively Manufactured Component with Embedded Sensor** (ACES) funded by the Walloon government. The main challenges to overcome to print directly on the surface of additively manufactured components are the reduction of surface roughness and the electrical isolation of the surface by dielectric coating. We can handle these challenges thanks to our long expertise in surface treatment of metallic surfaces and printed sensors on unconventional surfaces. Robotised thermal spray or electrostatic spray technologies are used to create **Resistance Temperature Detection (RTD) sensor on 3D parts**. Three layers - dielectric, sensor and encapsulation – are deposited with these technologies. Laser ablation (scribing) is used to define the resistive track structure of a width around 450 µm in the sensor layer. To avoid expensive laser scribing steps, masking technique on 3D object is also evaluated.



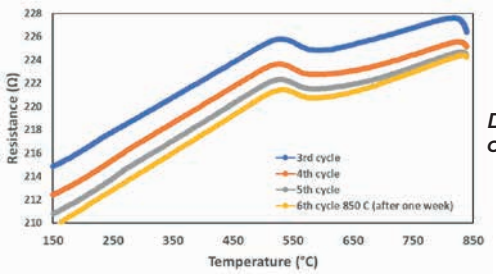
View of a coated polymer composite panel with integrated printed heating pixels, simultaneously observed in the visible range (left) and in IR (right)



Thermal spray

Electrostatic spray

Temperature sensor

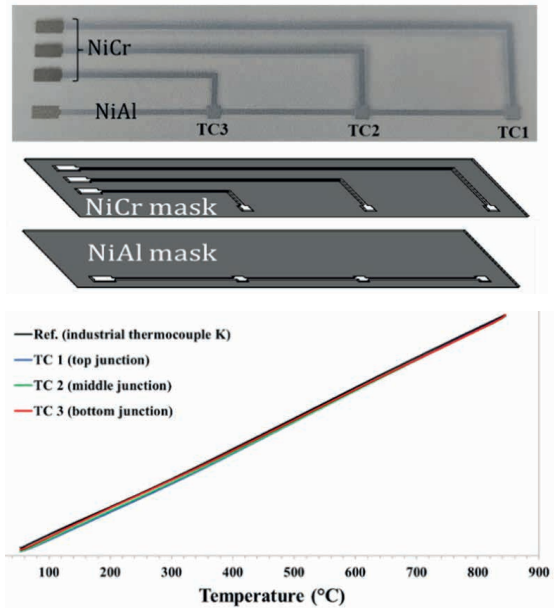


Data output

Coating technologies evaluated to treat 3D surfaces and typical RTD sensor manufactured on these surfaces

Another application of **printed temperature sensors** concerns the monitoring of furnaces, such as austenisation furnaces. Again temperatures up to 1000 °C and the oxidising atmosphere result in very demanding requirements. In the Horizon2020 HiPerMat project, CRM Group is investigating two solutions:

- Printed Thermocouples: a unique design with multiple measuring points (hot junctions) arranged along the length of the probe allow determining the temperature at different points along its length of the object. The composition of the thermo-elements was chosen to assemble a K-type thermocouple deposited by the plasma spray technique. The three-junction thermocouple architecture shows the potential to print several measurement points on the same object. The voltages generated by the 3 junctions of the multipoint thermocouple are similar and they are comparable with the industrial K thermocouple. This confirms the high potential of the plasma sprayed thermocouples to provide trustworthy electrical information compatible with the existing thermocouples reading devices.

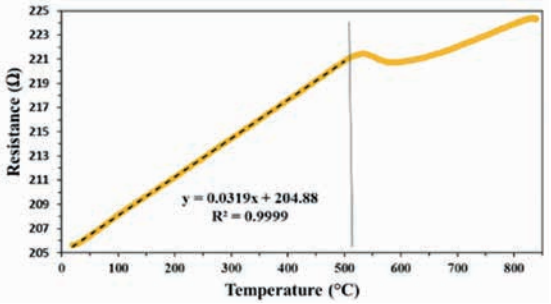


Printed thermocouples for application in furnace:

***Top** = Multipoint thermocouple printed on steel using plasma spray masks*

***Bottom** = Thermoelectric voltage response of the multipoint thermocouple in comparison with an industrial thermocouple*

- Printed Resistance Temperature Detection (RTD): we succeeded in printing a surface architecture of an RTD system on stainless steel by depositing only one sensitive resistive layer based on NiCr by plasma spraying and thereby simplifying the coating architecture. The RTD sensor reveals the potential use of the plasma sprayed RTD in the temperature range from room temperature to 500 °C.



***Top** = Printed RTD with a serpentine structure on SiC tube*

***Bottom** = Resistance variation of RTD tracks with oven temperature variation from room temperature to 850 °C*

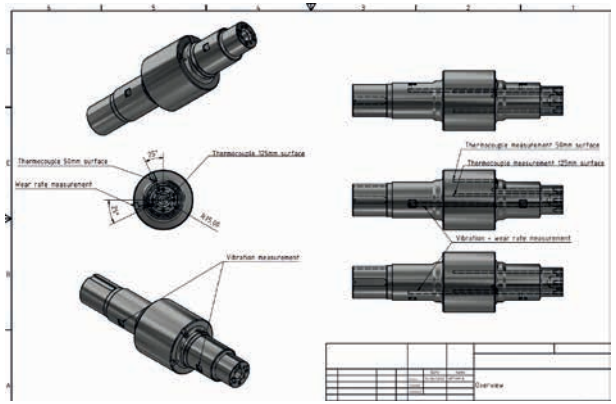
Possible applications for RFID traceability of metallic components: sandwich panels, metallic foils, sheet piles

A last application of printed electronics concerns **the traceability of metallic parts or components (e-passport)** by the integration of advanced RFID solutions to increase **logistics and stock management**, as well as product traceability and **quality control and the circularity of components**. In collaboration with ArcelorMittal, CRM Group is developing customised solutions for a variety of applications such as **metallic foils, sandwich panel products and sheet pile long products**. Indeed, via its RFID microchip, the tag can contain the specific serial number of the object on which it is located – allowing its unique identification – but also a web address returning all the documents relating to the object (technical sheet, installation and maintenance sheets, production history...) and information to optimise the reuse of components such as sheet piles avoiding downgrading, as well as for its recyclability at the end of life. The role of CRM Group is to demonstrate wireless communication and product connectivity at distances from 1 up to several meters and ID reading functionality compatible with RFID standards (operating frequencies, signal strength and communication protocol compatible with RFID standard).

Industry4.0

The successful implementation of Industry4.0 relies on **smart sensors, IoT systems and Artificial Intelligence**. CRM Group is active in the development of dedicated sensors to capture data with high precision and in harsh environments.

- In collaboration with Marichal Ketin, Pepps Engineering, UCLouvain and Taipro engineering and funded by the Mecatech cluster, we intend to transform the existing rolling mill work roll into a **connected work roll**. The objective is to identify each work roll, track its usage, monitor wear to ensure high-quality products leaving the mill, detect misuse, and predict or detect internal roll faults to prevent incidents. To accomplish this, numerous sensors will be integrated into a work roll that can communicate and transmit data to a cloud platform, allowing for a digital twin of the work rolls.



- To master the strip flatness and avoid difficulties during coiling the control of the wear of the pinch roll before the down-coiler is essential. Hence CRM Group developed in the 'ROLLPROF' project, funded by the European Commission in the RFCS program, a profile measurement system. This system underwent in house technical engineering, construction, assembly, and software development before being installed on a pinch roll at the entry of a coiler at ArcelorMittal Dunkirk. The successful

installation of the measurement beam means that the device is now able to measure the roll's profile and wear during production for several months. The final results will be available in 2023.

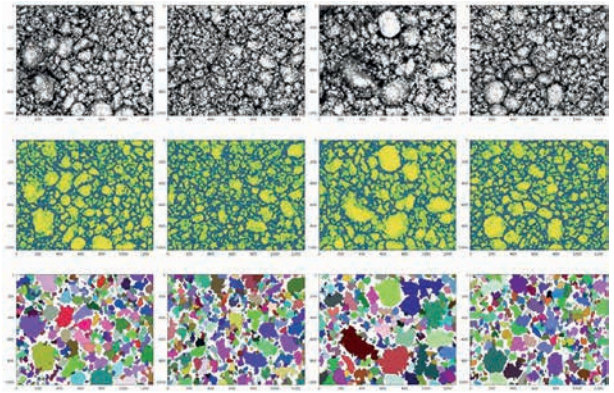
Profile measurement system installed to measure the wear of the pinch roll at downcoiler

- The requirements regarding coating quality, especially for exposed parts, are steadily increasing. To satisfy these requirements at the exit of the galvanising line, the perfect cleanliness of the substrate surface after cleaning at the entry of the galvanising line in terms of carbon pollution and iron fines must be ensured. The LIBS-based CleanEx sensor is a **high-sensitive on-line device evaluating surface pollution level at the exit of the cleaning section before galvanising**. After first test on our pilot line, the sensor prototype has been fitted to Tata Steel SEGAL galvanising line to validate the method industrially. The method can differentiate surface carbon from iron fines pollutions without any contact with the product (working distance is approximately 300mm). Different trial campaigns have been conducted introducing **variations in the cleaning section parameters**. The results show that the CleanEx unit is able to follow **both iron fines and surface carbon pollution levels** when modifications of the cleaning section were applied.

CleanEx prototype fitted to industrial galvanising line at Tata Steel SEGAL

By completing our expertise in sensors development with our skills in **artificial intelligence and data processing**, we now offer a global approach to help our partners not only to collect data but also to get the most out of it. Within our research projects, we 've worked on various industrial problems going from process optimisation to image segmentation using lightweight algorithms. Some examples to illustrate these developments:

- The combination of our process know-how, a dedicated developed sensor and the use of an UNET neural network allows determining on-line and in real-time the cold permeability of the sinter. Such an information is crucial to cope with the variation of input materials in the sintering process. Convolution neural network allows the segmentation of the grains and correlating in real-time the grain-size to the cold permeability.



Grain segmentation using a Unet neural network to determine on-line and in real time the cold permeability of the sinter

- For supporting the operators in the quality control of parts, we have developed a software program that helps the operator identifying defects using the data from NDT sensors. It also allows the data collection to improve the UNET-based defect detection model on which it is based, in order to evolve towards an autonomous solution. Thanks to its micro-service architecture, this software is scalable, flexible and cloud ready.

INDUSTRIAL PROCESSES, SOLUTIONS & SERVICES

SERVING THE INDUSTRY IN MULTIPLE SECTORS

"Our 75 years of experience in metallic materials is at the service of multiple sectors to solve your problem and turn ideas into industrial solutions"

Griet Lannoo
CTO

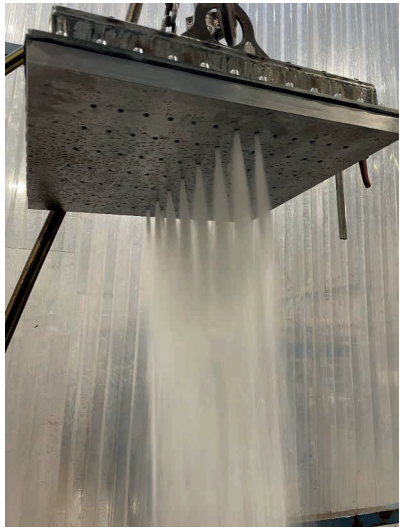
Building on our know-how on industrial production processes as well as on metallic materials, CRM Group supports companies active in **multiple sectors** for the optimisation and innovation of production processes and with the development of new solutions. This service may take form in research projects but may also consist of services such as (on-site) characterisations and measurements, failure analysis or simulations to **transform our materials expertise into an answer to your question**.

Industrial solutions and services for steel industry

In the steel industry, optimising process efficiency and improving product quality will contribute to a more resource and energy efficient steel industry.

Improved cooling performance allows indeed reducing water and electricity consumption, increases the lifetime of the work roll or enables saving on alloying elements:

- A temperature gradient in the semi-finished product highly affects the control of the process (strip steering in the finishing mill and rolling incidents such as cobbles), as well as the final product properties. To correct in real time transfer bar temperature distortions during production CRM Group is, within the EU RFCS funded project SMARTCOOL, and together with the ArcelorMittal Gent and Tata Steel Ijmuiden hot strip mills, developing a **selective transfer bar cooling** which is intelligently controlled. The implementation of a smart controlled actuator at the transfer bar cooling, controlled by a robust temperature profile measurement, will allow reaching these objectives.

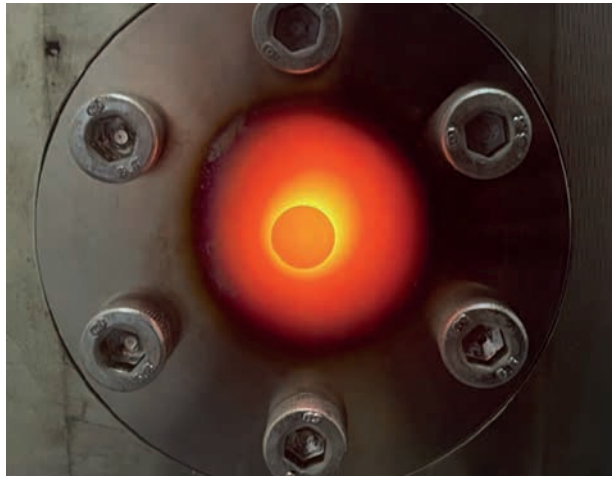


Selective transfer bar cooling prototype under testing at the cooling platform

- In the past year, CRM Group continued to deploy and promote the **TEMPCORE technology** via technical audits and technical assistance to the plants. TEMPCORE is the Quench and Self

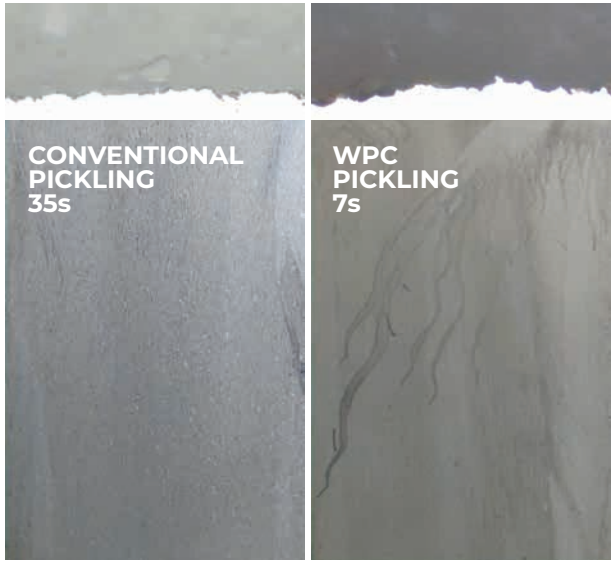
Tempering (QST) of rebars to get high-strength weldable rebars (grade 500 MPa) without costly additional elements like Vanadium, Titanium or Niobium.

- To enhance characterisation and understanding of the heat transfer of the different cooling strategies, a new high temperature cooling sensor has been developed. With the help of multiple integrated thermocouples, the heat flux and heat transfer coefficient can be measured and calculated. Thanks to the high temperature range (from RT up to ± 1000°C), all process and product cooling from the finishing mill down to the runout table and coiler can be characterised.



Characterisation of heat flux and heat transfer coefficient at high temperatures

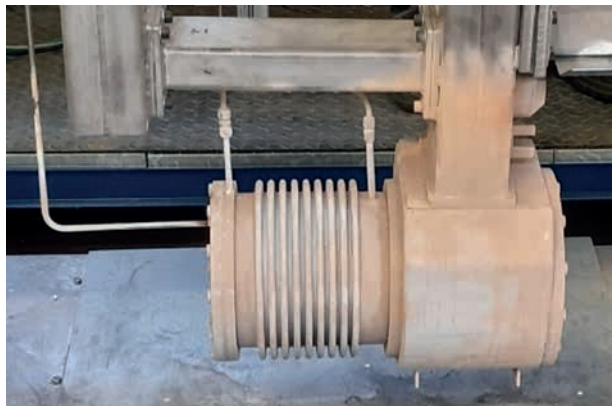
The know-how of high performance cooling has also been transposed to pickling. Based on the principle of Water Pillow Cushion (WPC) cooling, used for highly efficient cooling in the steel industry (strip and long product cooling, roll cooling); we designed and constructed a new pickling prototype to **improve the pickling process**. Thanks to the very high turbulence created between the header and the strip surface by the WPC concept, tests with a first prototype have shown that the pickling time of a conventional low alloyed steel can be reduced by factor 3 to 5 compared to standard deep tank pickling technology.



Potential for enhancing pickling operating by WPC pickling: sample pickled with WPC technology for 7s results in the same surface state as the sample pickled for 35s in the reference deep tank conditions.

In the field of coating, increasing the speed of a **hot dip galvanising line** is a technical challenge that needs improvements both at the level of the immersed equipment as well as related to the strip stabilisation at wiper level. Both aspects have been tackled in the EU RFCS project HighSpeedGalvanising:

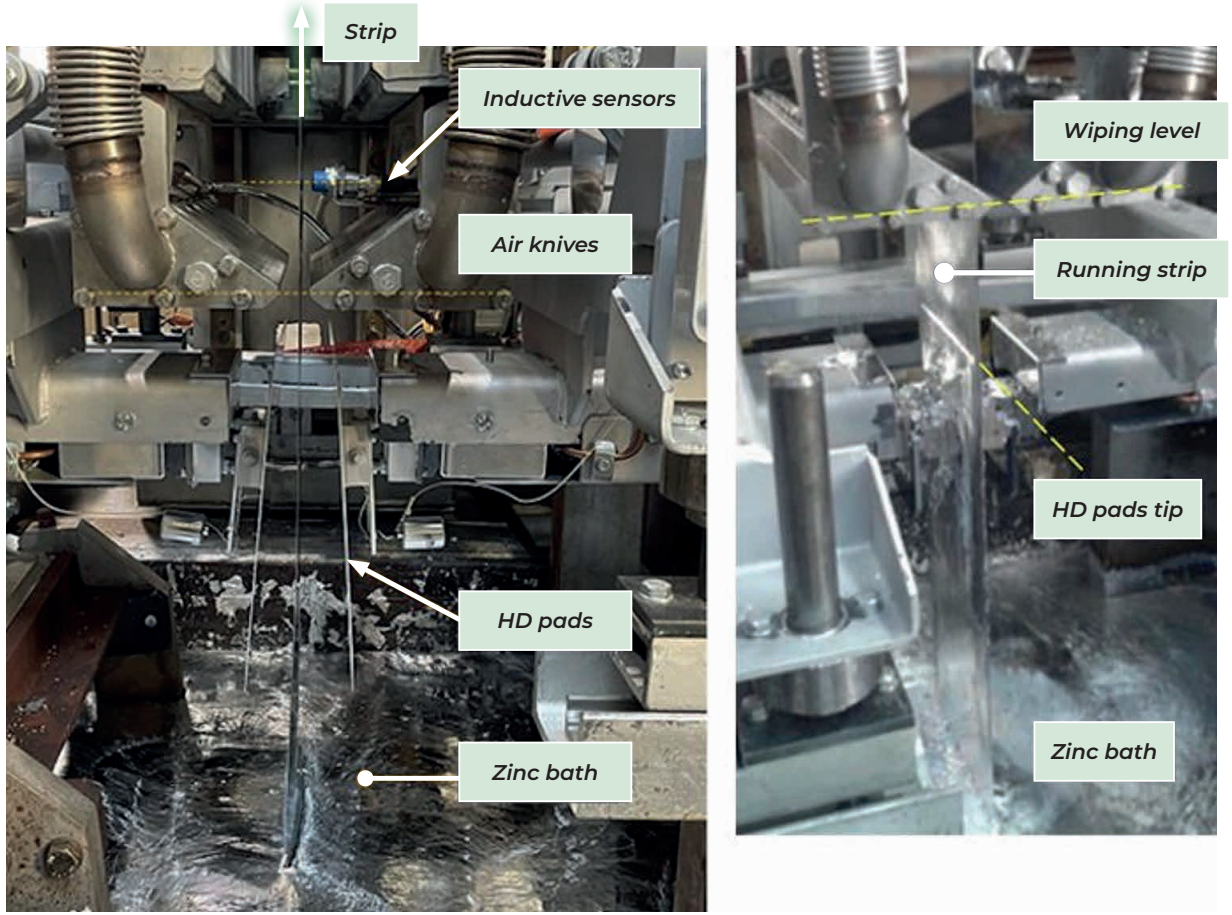
- One of the difficulties is linked to the wear-induced vibrations from bearings of immersed rolls resulting in defects on the coated strip, product downgrading and frequent hardware changes impacting the line productivity. A solution developed at CRM Group for reducing and delaying this vibration occurrences consisted in removing the rotation device of the immersed rolls (bearings) from the highly corrosive zinc melt by use of a special sealing system. This system is based on springs action. It has been tested at our facilities in a standalone pot. The trial ran for six weeks without any issue, completely fulfilling our expectations, and was stopped before the potential ruin of the simulator, for helping us evaluating potential pros and cons met with this prototype. Adding some strip tension to a double-sided bearing will be our next goal before going to the industrial level. The device is also exceptionally performing regarding to **wear and corrosion thanks to a boriding treatment**. Boriding is a thermochemical treatment based on the diffusion of boron into a metallic surface to



Protecting bellow of high temperature tight bearing with boride layer for immersed roll in galvanising line

form borides. The process confers an increased hardness, wear resistance and corrosion resistance in different media (acids, liquid metals...) and contributes to a longer service life of the treated parts, depending on the applications and materials. These outstanding properties have indeed been demonstrated on the galvanisation hardware, were the protecting bellow has been dipped in GI melt for 6 weeks without any damages.

- Regarding the **strip stabilisation at wiping level**, we have recently pushed the limits on our annealing & hot-hip galvanising pilot line using the patented concept of Hydro-Dynamic Pads placed very close to wiping level (10-40 mm) under damping parameters optimised thanks to a dedicated Finite Element model. At the pilot line we could achieve a flat and stable strip between air knives with extremely low strip vibrations (< 0.2 mm-RMS) and reduced final coating thickness variations (< 0.5 µm-RMS) even under forced strip vibrations, close to strip resonance at low industrial speed (Z150 - 80 m/min).

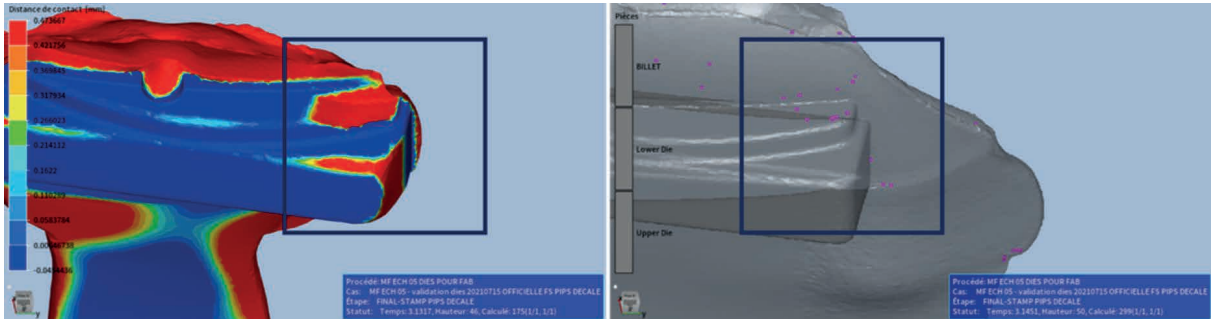


Strip stabilisation at wiping level with Hydro-Dynamic pads placed very close to wiping level

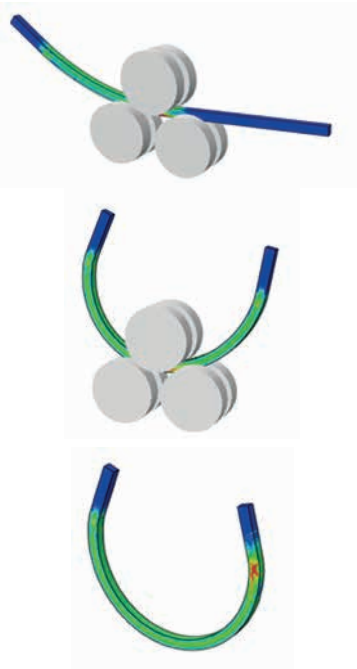
Solutions for the aeronautics industry

Also, for the **aeronautics industry** our competences of materials, the way to produce and process them, have supported for example Safran and Sonaca to optimise their production processes in the frame of the Walloon Initiative for Green Skies (Wings):

- As already reported in an earlier section an innovative and **new manufacturing process for the production of the Ice Protection Systems** on leading edge by directly printing the heating elements on the composite material has been validated.
- In support to Safran that will industrialise and build a new blade factory 'Safran Blades' in the Walloon region, we have performed simulations and experimental work for the **titanium alloy forging of motor blades**. Since there are hundreds of blades in the compressor; an efficient digital production process is indeed key and we contributed with simulations and experimental work to review all the hot forging and treatment steps (simulation of hot forging of Ti blades) .
- CRM Group has also developed competencies in the **dynamic bending of high-strength bars**. Multiple rolls are indeed necessary to bend such bars to reach the desired curved shape. The successive steps are successfully simulated and the final residual strains are used for further steps in the simulation chain of the process of Sonaca.



Simulation of hot forging of Ti blades for aeronautics industry



Simulation of hot forging of Ti blades for aeronautics industry

- Another activity focused on **the recycling of the HF/HNO_3 mixed acid used for the pickling of Ti alloys** when the dissolved Ti concentrations in the bath is too high. The identified method (diffusion dialysis) is a membrane separation process based on diffusion. It is a continuous process that recycles the spent acid in a fresh solution while rejecting metallic ions in the waste solution. The tests performed with a modified cell showed that the process allows the recycling of > 50 % of the spent acid, while blocking > 85 % of the dissolved Ti.

Serving the energy sector

Knowledge about the instantaneous uniform corrosion rate is of utmost importance for corrosion prevention. Over the last decades, electrochemical corrosion testing has been widely used to quickly characterise the **corrosion resistance of metallic materials** at or near ambient temperature. Recent developments undertaken by CRM Group now allow this technique to be applied **at very high temperatures and under controlled atmospheres**. The electrolytes studied consist of chloride and nitrate salt. The outcome of the tests is used to determine or regulate the amount of inhibitor strictly necessary to maintain the corrosion at an acceptable level, to perform rapid classification of material in a specific corrosive environment, or to determine the influence of temperature and the atmosphere overlying the molten salt such as used in **concentrated solar plants**.

Electrochemical corrosion testing at very high temperatures and under controlled atmospheres

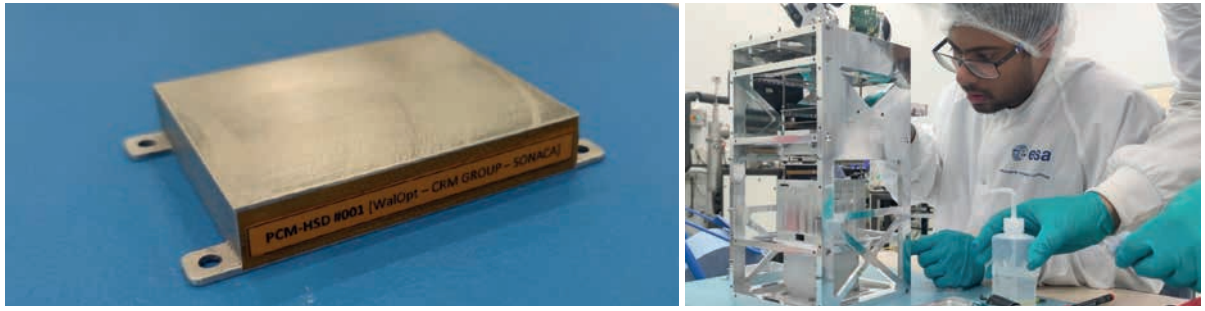
For TD WILLIAMSON FRANCE SA, active in the design, development and manufacturing of equipment for onshore and offshore applications, we have instrumented their equipment with stress jauges kits to determine the main strain directions and stress levels achieved during a pressurisation test up to 115 bar. These measurements make it possible to validate the simulations carried out by company.

On-site instrumentation of components for energy application

Solutions for aerospace

As illustrated already in previous sections, CRM Group is also actively involved in development of new solutions for the aerospace industry such as the development of new alloys for additive manufacturing or joining solutions for parts produced by additive manufacturing.

Another solution worthwhile to mention is the development of **phase change material heat storage devices (PCM-HSD)**. This PCM-HSD aims to stabilise the temperature of electronic units to be used in the space industry. In 2022, CRM Group was associated in the development of a unit for an extra-planetarian mission. 2023 will be a great year for PCM activities as one of those units was selected and mounted on ESA YPSAT and will be flown on the inaugural flight of the new Ariane 6 rocket for qualification testing.



Phase Change Materials Heat Storage Devices: View of the PCM-HSD (left) and mounting of the PCM-HSD in the satellite at ESA's premises (right)

DISSEMINATION, EVENTS AND PARTNERSHIPS

CRM Group teams up with industrial partners, research organisation and clusters, not only to accelerate the developments but also to widely disseminate the results.

In addition to the lectures given in the list at the end of this report, CRM Group participated actively to dissemination and training events such as :

- A masterclass course on the implementation of intensive cooling in rolling mills at the ABM in Brazil
- A training course on surface finishing of 3D printed parts organised in collaboration with Technifutur
- Training course Longlife learning on printed electronics in collaboration with HELMo Gramme
- Participation and presentation of our innovations in the field of advanced manufacturing at the Benelux Additive Manufacturing R&D Day organised by Flam3D
- The closing workshop of the IAWATHA project portfolio was hosted at and co-organised by CRM Group and dealing with the development of additive technologies in Wallonia. About sixty participants have been informed of the results of the various projects, debated during round tables and have visited the CRM Group's advanced manufacturing platform

- We have welcomed Mr Thomas Dermine, State Secretary for Economic Recovery and Strategic Investments, in charge of Science Policy, together with 25 of our industrial partners. The interesting and high quality exchanges highlighted the role and mission of the CRM Group in the EU and Walloon relaunch and resilience plan in the fields of circular economy and energy transition. The visit to our hydrogen electrolysis pilot facilities demonstrated the effectiveness of our upscaling approach.

Visit Mr Dermine, Federal Secretary of State for Recovery and Strategic Investments, responsible for Science Policy

- In collaboration with Circular Wallonia we demonstrated the ability of our Walloon ecosystem to transform research into innovation and innovation into concrete industrial achievements in the field of circular economy focused on critical raw materials and batteries with a visit to versatile plasma furnace.

- Active participation to the launch conference ‘Quinzaine de l'économie circulaire', the 1st annual conference of Circular Wallonia with CRM Group expert animating the panel group discussion on circular economy and proposing our solutions in terms of raw material supply and strategic autonomy.

- CRM Group participated together with Multitel and Sirris to the mission to the Basque Country organised by Pôle MecaTech and Wallonia Export & Investment Agency of Barcelona exchanging with several leading Basque research centers in the manufacturing.

- The first Benelux Printed Electronics day was held at CRM Group in collaboration with AFELIM. Several speakers from different companies and institutions presented their advances on this promising technology.

- Participation in April, with the Pôle MecaTech and Wallonia Export & Investment Agency (AWEX) to the collective mission in the new metallurgy sector targeting both trade and R&D in Sweden, Norway and Iceland.

- In collaboration with Wallonie-Bruxelles International - Research and Innovation participation to the IFAT worldwide in Munich and the HANNOVER MESSE. Two flagship events to enable our researchers to develop their network and promote contacts and potential partnerships with German & foreign institutes.

- Participation to the 5th edition of the VentureLab Belgium Entrepreneurs' Summit, which aimed to promote entrepreneurship among young people. This was an opportunity for the CRM Group to challenge these young people on the theme of innovation.

- Participation to the A6K Meeting of the actors of the ‘Hydrogen of Wallonia‘ where we discovered the latest recent H_2 production projects in order to stimulate future partnerships. CRM Group presented the Smart Innovation Initiative (IIS) e-WallonHY aiming at developing a green hydrogen economy in Wallonia with Université catholique de Louvain

- Visit of students with various interest such as electromechanics, mechatronics, robotics of Henallux, Industrial & Business Engineering HEC Liège, Product development Antwerp University,... for interesting and rich exchanges on topics such as metals, recycling, additive manufacturing, digitalisation and energy transition.

As a **collective research centre** recognised by the **Belgian** and **Regional Authorities**, CRM Group is member of:

Innovaders : The new identity of the UCRC (Union of Collective Research Centres), which promotes collective research, encourages cooperation and synergies and defends our common interests.

https://www.innovaders.be

Wal-Tech: An association regrouping the 19 collective research centres certified by the Walloon Region. Several platforms have been created to share experience and coordinate activities.

https://www.wal-tech.be

VLOOT (VLaamse Overkoepelende Organisatie van Technologie- & Innovatieverstrekkers). It is a structural overall collaboration between more than 20 technological and scientific innovation actors in Flanders.

https://www.vloot.be

MRC (Material Research Cluster Gent) is an initiative in which seven partners (OCAS, Gent University, Sirris, BIL, Clusta, CRM Group, SIM) share commun laboratories with a strong focus on metals. This cluster has at its disposal state-of-the-art equipment for characterisation and testing from the nanoscale to large-scale industrial components and structures and more than 200 scientists and technicians under one same roof.

https://www.mrcluster.be

SIM (Strategic Initiative for Materials), a virtual strategic research center governed by industry and academia with the objective to contribute to the competitive position of the materials industry in Flanders by means of strengthening the scientific base and building technology platforms in relevant areas, and by generating an open innovative environment for close collaboration between industry & academia.

https://www.sim-flanders.be

Flam3D is the independent platform for all stakeholders active in 3D printing and Additive Manufacturing in Belgium and The Netherlands.

https://www.flam3d.be

Flanders Metals Valley
A climate-neutral and circular metallurgical cluster in Flanders, innovative and future-oriented, recognised as an essential, competitive pillar of the Flemish industry.
Flanders Metals Valley is a catalyst for a vibrant, climate-neutral and circular metallurgical cluster in Flanders, dynamically embedded in an international industrial ecosystem.

https://flandersmetalsvalley.be

Belgian Security and Defence Industry

https://www.bsdi.be

A6K is a network of technological companies bringing together relevant players from Wallonia, Belgium and elsewhere in the fields of energy, communication and embedded systems or operational transformation towards Industry 4.0 to encourage the emergence of projects.

https://www.a6k.be/fr

At the **European level**, CRM Group takes actively part to the following organisations and platforms:

The **European Steel Technology Platform (ESTEP)** brings together all the major stakeholders in the European steel industry (steel manufacturers, universities and research institutions active in steel research, major users of steel, and public bodies like the European Commission and national governments).

https://www.estep.eu

Together with ULiège and over 120 other European industrial, academic and research partners, CRM is since 2015 a member of the KIC (Knowledge and Innovation Community) **"EIT Raw Materials"**, covering a wide range of themes like exploration, mining, efficient use of raw materials in process manufacturing industry, recycling and substitution of critical raw materials.

https://eitrawmaterials.eu

In the frame of EIT Raw Materials, a **European Pilot Plant Network for Extractive Metallurgy and Mineral Processing (Metnet)** has been created, offering to customers an access to pilot plants in order to bring ideas or concepts into industrial use. Besides CRM, the current members are Swerea MEFOS (Sweden), BRGM, CEA & ERAMET (France), GTK (Finland), ELKEM (Norway), IMN (Poland) and MPI (UK).

The four independent European steel research institutes (CRM, CSM, Swerim and VdEh-BFI) joined forces in 2011 to found **RIES**, a network that pools the complementary research areas of these institutes.

A.SPIRE is the European Association which is committed to manage and implement the Processes4Planet co-programmed Partnership.

https://www.aspire2050.eu

Hybrid 3D network, a network partner of small and medium-sized companies and research institutions from all over Germany, Belgium, Swiss and Austria active in (hybrid) additive manufacturing who want to expand their range of knowledge, share their experience with other partners, generate and implement new ideas and be upfront in the emerging field and market of hybrid additive 3D manufacturing technologies and processes.

https://www.hybrid-3d-network.eu

PROMETIA, an international non-profit association promoting innovation in mineral processing and extractive metallurgy for mining and recycling of raw materials.

https://prometia.eu

ERMA network brings together a growing number of organisations from the public and private sectors covering the entire raw materials value chain for contributing to ensure a reliable, secure and sustainable access to raw materials.

https://erma.eu

EBA250 is a platform for key stakeholders throughout the entire battery value chain.

https://www.eba250.com

AFELIM is the French printed electronics association. It represents the companies that do business in printed electronics principally in France. AFELIM represents every profession in the value chain.

AFELIM - Association française de l'électronique imprimée

LET US MENTION THAT CRM IS ALSO MEMBER OF:

WorldSteel: the International Institute of the Steel Industry,

EUROFER: the European Federation of the Steel Industry,

UWE: Union of the Walloon Enterprises

VOKA: the Flemish network of Enterprises.

PUBLICATIONS & CONFERENCES 2022

CARBON NEUTRAL METAL PRODUCTION, RECYCLING & ENERGY

L. Fourdrinier, R. Jaimes Contreras, P.-F. Bareel, J.-F. Sidler, P. Van den Bossche, L. Genot
Panel : Économie circulaire : vers des solutions en termes d'approvisionnement en matières premières et d'autonomie stratégique
Quinzaine de l'Economie Circulaire – Conférence de lancement, 30 May 2022, Namur

B. Vanderheyden
Win4C – Initiative d'Innovation Stratégique
QEC - L'Economie Circulaire Made in Wallonia, 9 June 2022, Liège

J. Mortimer, N. Vega Aguirre, J.L. Garcia Cimadevilla, Y. Xiao, F. Blaffart
Mechanisms of Polymeric Binders in the Production of Steelmaking By-Product Cold-bonded Agglomerates
2022 IBA Conference, 18-21 September 2022, Denver

F. Van Loo, M. Allen, J. Barros Lorenzo, J.L. Garcia Cimadevilla, C. Martin, J. Mortimer, N. Vega Aguirre, Y. Xiao
Cold-bonded agglomerates for blast furnace ironmaking using polymeric binders
9th EOSC European Oxygen Steelmaking Conference & 6th Clean Technologies in the steel industry (CleanTech), 17-21 October 2022, Eurogress Aachen

H. Fouarge, F. van Loo, J. Wiencke, M. Martinez Pacheco, L. Di Sante
TACOS – Towards A zero CO_2 Sintering
9th EOSC European Oxygen Steelmaking Conference & 6th Clean Technologies in the steel industry (CleanTech), 17-21 October 2022, Eurogress Aachen

N. Santos Lalla, E. F. González, H. Distefano, M. J. Paglialunga, T. Hilbert, J.-C. Pierret
Thermodynamics and kinetics modelling of the Electric Arc Furnace process. CRM EAF Model implementation in ArcelorMittal Acindar Plant
24th IAS Steel Conference, Expo IAS2022, Rosario Santa Fe Argentina, 25-27 October 2022

J. Pélerin, P.-F. Bareel, J. Neutjens, D. Entzian, F. Tholence, C. Jonasson
Reverse Metallurgy in the Spotlight
Circular Wallonia Days, 16 November 2022, La Hulpe

T. Marcon
Dismantling steps combining thermal treatment of magnets, fragmentation and classification of materials
Seminar VALOMAG, 6 Dec 2022, TU Delft

SMART & SUSTAINABLE PROCESSES & PRODUCT METALLURGY

J. Malbrancke, H. Uijtdebroeks, L. Vanhulle, K. Schutte
Development of a system to evaluate work roll degradation (ISYROLL)
AISTEch 2022, 16 - 18 May 2022 Pittsburgh

S. Flament, H. Uijtdebroeks, G. Walmag
Importance of roll oxide to increase roll life in a hot rolling mill
AISTEch 2022, 16 - 18 May 2022 Pittsburgh

T. Senart
A cost-effective Cold Roll-Forming FE model for industrial applications using LS-DYNA
Ansys Level Up 3.0 - Virtual Engineering Simulation Conference on October '22

H. Uijtdebroeks, S. Flament, P. Nyssen, X. Vanden Eynde
Oxygen depletion in the front of the finishing stands
European Oxide Scale 2022 Conference, 5-6 Dec 2022, IOM3 London

S. Flament
Importance of roll oxide formation to improve hot rolling campaigns with high quality strip surface
European Oxide Scale 2022 Conference, 5-6 Dec 2022, IOM3 London

FINISHING & COATING

M. Mandy, X. Vanden Eynde, F. Duminica, C. Georges, M. Larnicol, R. Grigorieva, T. Sturel, P. Drillet
Prevention of hydrogen uptake in Al-Si coated 22MnB5 steel using physical vapour deposition coatings
CHS² - 8th International Conference on Hot Sheet Metal forming of High Performance steel, 30 May-2 June 2022, Barcelona

S. Pace, V. Ruwet, E. Silberberg, D. Chaleix, N. Amimi
Jet Vapour Deposition: A Technical Economic Alternative To Electro-Galvanizing For Zn Coatings Of Future Steels – The Process
GALVATECH Highlight Symposium 2022 - 12th International Conference on Zinc & Zinc Alloy Coated Steel Sheet, June 13th – 14th, 2022 – Vienna

T. Defize, T. Métivier, F. Pirot, E. Uta, J. Mallégol
Radcure in coil-coating applications
Colloque PolyRay 2022 (Lyon/France 6-7 July 2022)

X. Zeng, J. Lontchi, M. Zhukova, P. Bolt, M. Smor, L. Fourdrinier, G. Li, D. Flandre
High-performance dual-mode ultra-thin broadband CdS/CIGS heterojunction photodetector on steel
Optics Express Vol. 30, Issue 8, pp. 13875-13889 (2022)

M. Hoseinpoor, T. Prošek, J. Mallégol
Corrosion behaviour of deformed coil-coated products: Correlation between field exposure and accelerated tests
EUROCORR 2022, 28 August - 1 September 2022, Berlin/Germany

M. Krid, M. Mandy, T. Sturel, R. Grigorieva, P. Drillet, P. Jacques
A better understanding of hydrogen absorption - desorption from Al-Si coated high strength steels during hot stamping process
4th International Conference on Metals & Hydrogen, 11-13 October 2022, Ghent

M. Mandy, C. Georges, T. Sturel, P. Drillet, P. Jacques
On the right use of deuterium to characterize hydrogen uptake mechanisms in bare 22MnB5 steel
4th International Conference on Metals & Hydrogen, 11-13 October 2022, Ghent

M. Mandy, F. Duminica, X. Vanden Eynde, C. Georges, R. Grigorieva, T. Sturel, P. Drillet
PVD-deposited barriers to reduce hydrogen uptake during hot stamping of Al-Si coated 22MnB5 steel
4th International Conference on Metals & Hydrogen, 11-13 October 2022, Ghent

M. Hoseinpoor, T. Prošek, J. Mallégol
Novel approach to measure water vapor permeability in pre-painted metals using adapted cup method: Correlation between permeation rate and tendency to blistering
Progress in Organic Coatings 169 (2022) 106917

HYBRID & ADDITIVE MANUFACTURING

N. Nutal
Advanced Aluminium Alloys Tailored for Additive Manufacturing Space Applications, Targeting High End Structural Spacecraft Parts
1st International Conference on Advanced Manufacturing for Air, Space and Land Transportation, 7-10 March 2022, The Netherlands

J.-F. Vanhumbeeck
Surface finishing of SLM Scalmalloy® parts using innovative electrochemical process,
1st International Conference on Advanced Manufacturing for Air, Space and Land Transportation, 7-10 March 2022, The Netherlands

N. Jiménez Mena, N. Nutal, C. Georges, A. Norman
Printing and repair of AA7xxx components using Laser Metal Deposition
ICWAM 2022, 3rd International Congress on Welding, Additive Manufacturing and Associated Non-destructive Testing, 8-9 June 2022, Online

N. Jiménez Mena, N. Nutal, C. Georges, A. Norman
Printing and repair of AA7xxx components using Laser Metal Deposition
MAMC 2022, Metal Additive Manufacturing Conference, 26-28 September, 2022, Graz, Austria

M. Jean-Baptiste, X Vanden Eynde, C. Georges
Caractérisations et post-traitements de pièces produites par fabrication additive
Workshop IAWATHA, 16 October 2022, Liège

J.-F. Vanhumbeeck
Introduction sur l'utilisation du nickel en traitements de surfaces
Journée Technique organisée par la section France-Nord/Belgique - A3TS, November 2022

J.-F. Vanhumbeeck
Comparison of the intrinsic performance of subtractive finishing technologies for printed TI6Al4V parts
Journées A3TS "Traitements et parachèvements de pièces issues de fabrication additive », 30 November – 01 December 2022, Colmar, France

C. Libioulle
Study of surface finishing strategies on multi-materials by additive manufacturing
Journées A3TS "Traitements et parachèvements de pièces issues de fabrication additive », 30 November – 01 December 2022, Colmar, France

CRM GROUP

- **AC&CS Sart-Tilman** > *Liège*
  Advanced Coatings & Construction Solutions
- **AC&CS Ivoz-Ramet** > *Flémalle*
  Advanced Coatings & Construction Solutions
- **CEWAC** > *Liège*
- **CRM Gent** > *Zwijnaarde*
  Centrum voor Research in Metallurgie
- **CRM Sart-Tilman** > *Liège*
  Centre de Recherches Métallurgiques
- **EcoTechnoPôle** > *Liège*
  ETP
- **PiMW Sart-Tilman** > *Liège*
  Pôle d'Ingénierie des Matériaux de Wallonie

T +32 (0)4 254 62 11 ◢ info@crmgroup.be

www.crmgroup.be