ANNUAL REPORT 2021

CRM GROUP

FOR A BETTER FUTURE



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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-processapplication approach and focussing on industrial implementation of its developments. More than ever, the vast majority of CRM's developments focus on key societal challenges such as the energy transition or 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 aeronautical, defence, energy and recycling sectors. Each year CRM welcomes prestigious new members that are leading companies in their domain. In 2021 CRM also delivered various services to more than 285 non-member customers.

At CRM Group, health and safety remained, with more focus, the first priority in 2021. Safety results were once again significantly improved. As was the case for 2020, sanitary measures to face the COVID pandemic were continuously updated, adapted and strictly applied. Regarding safety, VCA-training sessions were rolled-out for the full workforce, allowing to envisage an ISO45001 certification. This certification will testify the strong commitment of CRM regarding Health and Safety performance.

CRM Group 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 Group initiated the process to create and implement a Gender Equality Plan (GEP) and more broadly a diversity inclusion policy.

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

- Metal production and recycling (MPR): covering raw material processing, melting & refining, by-products treatment & valorisation
- 2 Energy & Low Impact Manufacturing Industry (ELIMIN): focussing on the development of energy efficient and low CO₂ emitting production technologies and CCU applications
- 3 Metal processing and metallurgy: including casting & solidification, rolling & thermal treatment, product metallurgy and process control & measurement

- Advanced & smart surface solutions (A3S): ranging from functional coatings and smart surfaces including printed electronics on steel to surfaces for renewable energy applications
- 5 Innovative designs and assembly solutions (IDEAS) in the fields of Civil engineering, Construction, Assembly & Testing and Hybrid manufacturing
- 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

The year 2021 has been earmarked by some main events: the persistence of the covid-pandemic for a second year in a row, a strong pick-up of the economy, the relaunch & resilience plans at European, Belgian and regional levels and last but not least during the last quarter of the year a steep increase of inflation and energy prices. CRM has demonstrated during 2021 excellent adaptability and resilience by rapidly adjusting to growth opportunities after managing low activity levels in 2020. In this context, 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.

The deliberate focus on a series of project calls in these areas, has generated for a second year in a row a record high budget of new funded R&D projects. For example, CRM succeeded to secure 4 out of 6 RFCS proposed projects. CRM is also a premium R&D partner in the Relaunch & Resilience plans and engaged in 5 Strategic Innovation Initiatives in Wallonia.

At European or regional level, CRM has continued to invest in partnerships with other research organisations, emphasizing 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 2021.

Thinus Van Den Berg President CRM Joeri NEUTJENS General Manager CRM

COMPANY MEMBERS

ON APRIL 20, 2022



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 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
CARMEUSE S.A.	Belgium
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
THY-MARCINELLE S.A.	Belgium
TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT sarl	G.D. Luxembourg
WESTINGHOUSE ELECTRIC BELGIUM S.A.	

ORGANISATION

ON APRIL 20, 2022

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) 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 Greg LUDKOVSKY, Vice-President of Global R&D, ARCELORMITTAL Anne MERTENS, Associate professor, ULiège Nicoleta POPA, Head of Construction applications, Infrastructures and Long Products, ARCELORMITTAL Global R&D IIja 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 Gabriel SMAL, Secrétaire Général, ACV-CSC METEA 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 Michel BABBIT Marc DI FANT Eric HESS 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.



LEADERSHIP TEAM



KEY FIGURES









EMPOWERING THE **ROLE OF METALS** TOWARDS A BETTER FUTURE.

At CRM Group, we strive to ensure that our technological developments contribute to the sustainable production and use of metals with the climate neutrality and reduction of greenhouse gas emissions as prime objective. Our research is structured around five platforms, namely

- Energy Shift
- Circular Economy
- Digitalisation
- Advanced Manufacturing
- and
- Construction

for the development of new production processes, new products as well as solutions responding to industrial & societal needs. CRM Group develops R&D solutions to make industries cleaner, smarter, more competitive and more efficient in the shortest timeframe possible. As independent and non-profit research organisation, we are partnering with local and international industrial actors active in different sectors and all along the value chains to respond to current and future challenges of industrials and society to make them more sustainable, resilient and thus better prepared for the challenges and opportunities of the green and digital transitions.

Thanks to our extensive network of members, customers and partner research organisations and our experience in participating to and coordinating multi-partner projects, we can lead or support consortia in the preparation and the realisation of private or public funded research and pilot and demonstration projects.

As an applied research centre based in Liège and Gent, CRM Group employs 265 technicians, engineers and PhDs operating unique simulators, characterisation laboratories and pilot lines to fully test, to characterise and to de-risk the solutions before implementing them industrially worldwide. This 2021 activity report illustrates how our more than 70-years of expertise, updated lab & pilot facilities and innovation spirit resulted in some major achievements. CRM gratefully thanks its industrial and research partners as well as the funding authorities for their collaboration and support.

































CIRCULAR ECONOMY

TOWARDS A **SUSTAINABLE** METALS INDUSTRY

The need to secure the critical raw material supply and to reduce the footprint of the metals industry drives the circular economy. In this section we illustrate how at CRM Group we bridge the circular economy activities with the energy and digital transitions as well as with advanced manufacturing.

The steel industry faces the ambitious challenge to drastically reduce the CO_2 -emissions to become climate-neutral. The iron & steel manufacturing route will undergo radical transformations to strongly reduce the footprint of the integrated blast furnace (BF)-basic oxygen furnace (BOF) process until in some cases its replacement by (Hydrogen) Direct Reduced Iron in combination with Electric Arc furnace (H₂-DRI-EAF) or alternative melting units. This transformation thoroughly impacts the recycling of by-products from the steel industry, actually realised for a major part in the sinter plant of the integrated BF-BOF process. By changing pathways to H_2 -DRI-EAF routes **new by-products have to be treated and new recycling methods have to be imagined, including an adequate adapted pre-processing.**

- To reduce the carbon footprint of the blast furnace route a novel way to prepare ferrous burden is investigated at CRM Group in collaboration with ArcelorMittal, Tata Steel and BASF in the RFCS funded project COACH. The energy and CO₂-intensive sintering or pelletising process is proposed to be substituted by a cold agglomeration process. In 2021 we have performed cold agglomeration trials to compare de-airing extrusion with rollcompaction. The produced agglomerates have systematically been assessed in terms of performance in the blast furnace by reducibility and reduction strength tests as well as with HUGE reactor trials simulating the full blast furnace shaft.
- In the frame of the Walloon R&D programme "Reverse Metallurgy", a pre-conditioning, deoiling and hardening process of oily mill scale sludge (waste from steel slabs rolling) was developed for the recovery of ferrous oxide content through a thermo-oxidative treatment, which is autothermal and CO₂-capture ready. Ferrous oxides pellets have been produced in pilot trials at atmospheric and high pressure and are under characterisation to assess their use as raw materials at the blast furnace, at the DRI plant or at the basic oxygen furnace.



Recovery of ferrous oxide from oily mill sludges (left) through the production of ferrous oxide pellets (right).



OM furnace in operation for carbo-thermic reduction of Fe/Zn residues and cooled down metallized sample after the test

Within the same 'Reverse Metallurgy' project, CRM Group has commissioned its unique electrically heated laboratory furnace aiming at valorising Fe/Zn bearing waste like shredder residues or EAF dust by carbo-thermic reduction, producing DRI while removing Zn (recovered as ZnO in the offgas). Compared to the conventional use of gas burners, electric heating offers the advantage of a drastically reduced generation of CO₂ as well as volumes of gas to be treated. First promising results have been obtained with shredder residues. Although steel is already the most recycled material, increasing the **recycling of steel and the usage of lower quality scrap** is compulsory to reduce further the impact of the steel industry.

To enhance the scrap usage, scrap treatment and cleaning campaigns have been carried out in the frame of the Walloon Reverse Metallurgy program as well as the Flemish Cleanscrap project. Promising results have been achieved for decoating and degalvanising under vacuum or conditioned atmosphere in our 200L



NEW 2L PRECONDITIONING FURNACE (VACUUM AND CONTROLLED ATMOSPHERE)

Scrap pre-treatment and cleaning

thermal preconditioning furnace; dezincing rates above 90% were obtained. A new smaller furnace with 2L capacity, also able to work under vacuum or controlled atmosphere, has been set up for pre-screening trials on various small samples. Other new capabilities have been added, namely characterisation techniques for a better quantification of the dezincing rate, a.o. based on μ -XRF and a dedicated off-gas post-combustion system in order to allow trials on coated materials with a high organic content.



both the production of high-quality more steel products in the EAF as well as the increase of scrap rate at the converter will be further investigated in the Horizon Europe project CAESAR (CirculArity Enhancements by Low quality Scrap Analysis and Refinement). Scrap sorting & cleaning based on innovative combination of best available technologies will be developed and implemented in an industrial demonstrator (TRL 8). Beyond its activities of project coordinator CRM will perform melting trials to assess the impact of the cleaning & sorting technologies, support steelmakers in industrial trials and study valorisation routes of non-ferrous (in particular in aluminium or copper industries) and non-metallic residues.

Scrap cleaning and sorting to support even

r Intensive steel scrap recycling may result in a substantial increase of residuals and tramp elements. Both can modify the response of steel to thermo-mechanical treatment or change its properties through their impact on the microstructure. Cu, Sn and Cr, Ni, Mo are to be particularly pointed out. The influence of each element on the properties of the different constituent phases is studied independently for 0.3 wt% and 0.8wt% C containing steels. In 2021 we focussed on the impact of those residuals on the high temperature austenite phase. To do so complete CCT diagrams for each of the

μ-XRF MAPPING OF RESIDUAL ZINC AFTER DECOATING TRIAL OFF-GAS POST-COMBUSTION CHAMBER OF THERMAL PRE-CONDITIONING different compositions were constructed for the determination of all critical transformation temperatures during continuous cooling: Arl, Ar3, Ael, Ae3, Ms, Mf, Bs, Bf. These temperatures indicate where phase transformations occur and which level of complex constituents -having a direct impact on the final mechanical properties- are reached. Within the RECLAMET project (co-funded by EIT Raw Materials), CRM Group is studying the recycling of Zn bearing by-products and galvanised scrap in the Hisarna process to produce a rich Zn dust directly valuable as raw material for Zn producers. In combination with HISARNA, Tata Steel intends to pre-melt additional scrap in a dedicated Scrap Melting



Impact of residual Cu on phase transformations in a 0.3%C steel : Comparison between experimental CCT's and simulated with a commercial software ones



Microgranules and extrudates of byproducts for recycling into the HISARNA process

Unit (SMU) for direct feeding to the BOF together with the HISARNA hot metal. Dust filtered from the SMU offgas would be recycled into the HISARNA process after appropriate pre-processing. In order to feed the Life Cycle Analysis, SMU simulations were performed using the CRM EAF model. Furthermore three

scrap grades provided by Tata Steel were fully characterised by melting trials in the 350kg induction furnace, in terms of composition (in particular, regarding their content in tramp elements) and of dusts emitted (a.o. zinc content). We also completed the by-products pre-processing study by comparing roll-press briquetting and stiff extrusion, which a.o. demonstrated one important advantage of extrusion, namely that the wet materials to be processed do not need to be pre-dried.

Metals are essential components in many applications and the **recycling of residues of manufacturing or end-of-life products** is crucial in the EU's circular economy strategy in order to render the sourcing and production of metals more sustainable and to secure the supply of critical raw materials.

In the frame of the GRAAL project aiming to recycle and valorise all types of domestic and industrial aluminium wastes, the "GRAAL Holding SA" (a Limited Company) has been officially created on March 7, 2022 via the partnership between Noshaq, John Cockerill and CRM. The next step is to build and implement in the Liège area the 1st Aluminium Recycling Unit (ARU) able to treat 20.000 t of wastes per year. The discussion with the industrial partner selected to operate this plant is running in order to finalise all the financial and technical aspects. This company is specialised in the collection and sorting of metallic wastes with a dedicated focus on the aluminium products.

The Valomag project, coordinated by Suez and funded by EIT Raw Materials, aims to develop an innovative industrial recycling process for Rare Earth Element magnets from endof-life products. The magnets have first to be demagnetised before fragmentation and further processing steps. CRM Group developed for that purpose an original thermal treatment based on inductive heating and already provided the other partners with more than 3 tons of demagnetized EOL products, with a yield of nearly 100% and a high quality regarding other specifications such as de-coating or minimal organics degradation. We are now **upscaling the concept**, tested up to now only in batch mode, by building a **new continuous tailormade pilot furnace**, which will be used in 2022 to optimise the process and provide data for the LCA study, as well as to support the design of a future industrial prototype.



FROM TOP LEFT TO BOTTOM: E-SCOOTER ROTOR, MAGNETS FROM A WINDMILL TURBINE, HARD DISK DRIVE, E-CAR ROTOR

PILOT FURNACE FOR PERMANENT MAGNETS DEMAGNETISATION

Permanent magnet demagnetisation

- One of the subjects addressed for the aeronautic sector in the WINGS project (Walloon Innovations for Clean Skies) supported by the Walloon region, is the recycling of the residual powder from the plasma spraying of the abradable layer of the inner shroud of low pressure compressor stators. These powders are a mixture of NiAl and AlSi/polyester. The first step consisted in characterising these powders using the numerous techniques available in the CRM Group: XRF, ICP, CHONS, TGA-FTIR, electronic microscopy, etc. Thanks to a better knowledge of these residual powders, two promising valorisation routes have been identified and are being validated on a pilot scale.
- At the crossroad of our Circular Economy and Advanced Manufacturing platforms, the European Varetit project aims to transform titanium machining chips into powder that can be used in Additive Manufacturing processes. An improved blade crusher will be used to reduce the turnings into intermediate flakes (< 1 mm) and a jet milling machine to reduce the flakes into powders (<150 µm). All the produced powders will be sieved to align their particle size with the specifications for various Additive Manufacturing processes: powder bed applications, DED applications or either thermal spraying. The particles out of range for any Additive Manufacturing technique will be

used to produce "briquettes" to feed foundries, so that 100% of the chips get valorised.

In the frame of the Walloon funded project PureZinc, we have designed a **new zinc purification device in order to recover a high grade zinc in liquid form from zinc scrap** such as for example from old zinc roofs. The principle is to vaporise zinc under vacuum and selectively liquefy its vapor to produce an ingot with a purity between 99.95 % and 99.999%. There are numerous targeted applications for the obtained zinc in mature markets like galvanisation and zinc powders or developing markets like cosmetics, pharma or renewable energy storage systems.



Transforming Ti-machining chips (left) into powder for additive manufacturing via intermediate flakes (right) obtained by improved blade crusher



Design of new zinc purification test rig



3D drawing of new pilot facility in Engis – left: plasma furnace and control room; right: materials pre-processing zone and filtering units for process gas and air extraction system.

The erection of the unique designed **pilot plasma furnace dedicated to metals recovery** has started on the industrial site of Hydrométal in Engis. Melting and fuming trials in various configurations (Electric Arc Furnace, Submerged Arc Furnace, Plasma) will be performed, first of all for the development of new processes in collaboration with Hydrométal, for the **recovery of critical raw metals related to the energy and digital transitions** (from industrial by-products or from end-of-life permanent magnets, batteries, photovoltaic panels, ...). The Plasma Furnace will also be very useful to **study new EAF steelmaking conditions while melting low quality scrap or** **DRI**. Furthermore a **dry slag granulator** will allow to test and optimise various **slag valorisation routes**. A dedicated versatile preconditioning unit (combining mixing, drying and agglomeration through briquetting, extrusion or pelletising) will allow us to treat and prepare a wide range of fine input materials (including hazardous ones) under well controlled and safe conditions.

ENERGY SHIFT

THE PATHWAY TO A CO2-NEUTRAL INDUSTRY AND RENEWABLE ENERGY

An urgent and fundamental shift is necessary in the way our societies capture, transform and use energy. More and more technological developments and projects are thus led at CRM Group in this field.

Four main topics are covered at CRM Group to support the economy and society efforts to meet climate ambitions: **Hydrogen** (production, transport and storage), **Renewables** (harvesting, storage and grid balancing), **Industrial shift** (heat recovery in industrial processes, alternative fuels and process modifications to reduce environmental impact) and **CCUS** (CO₂ Capture, Utilisation and Storage). Transversal actions on environmental balances, on digitalisation and on circularity are also carried out to support these developments. **Hydrogen** is set to play a major role in the energy transition, particularly in industry.

 Among the solutions for green hydrogen, water electrolysis and in particular alkaline electrolysis is one of the first to be considered since it is one of the most mature technologies. The major challenge is to further improve its performances in particular current density while reducing the costs. In partnership with John Cockerill, CRM Group develops a novel cell design and new advanced materials for the alkaline electrolysis, such as catalysts, membranes and functional layers to improve electrochemical behaviour, cell durability and efficiency.



Alkaline electrolysers: test benches for the technological maturation

The transport, storage and use of hydrogen also brings challenges related to materials compatibility with regard to hydrogen embrittlement. Our complete set of characterisation tools, most of them unique and designed at CRM Group, allows assessing the impact of hydrogen under several working conditions such as punched hole test, stress corrosion cracking or 4 points bending test. Together with the high pressure mechanical tests under H₂ up to 1245 bar, the H₂ cryogenic and tightness tests and our competence in welding, corrosion and hydrogen embrittlement we can propose the best material, coating or welding technique for resisting to hydrogen depending on the application or process requirements.

We are notably collaborating with industrial partners such as RESA to study the possibility to partly replace natural gas with hydrogen in the existing gas distribution network. CRM experts assess the impact of various contents of H_2 on the metallic materials present in the different parts of the gas grid.

Furthermore, in collaboration with ArcelorMittal we are working on solutions to control and reduce the hydrogen embrittlement risk in automotive high strength steels. In 2021 investigations have been carried out in the RFCS project Crystal on the sensitivity to hydrogen embrittlement of two



CONSTANT LOAD TESTING

4 POINT BENDING TEST

CRYOGENIC TESTS

Tests to assess the impact of Hydrogen under several working conditions

types of steels: press-hardened and cold rolled steels. For this purpose, the hydrogen uptake was first assessed with adapted hydrogen charging procedure according to the type of materials: cathodic charging for the cold rolled steels and austenitisation heat treatments in controlled atmosphere for the press hardened steels. Hydrogen diffusivity and solubility has been studied and the hydrogen traps in the steels were characterised using Kissinger's methodology consisting of exposing a hydrogen charged sample to Thermal Desorption Analyses exhibiting various heating rates.

With its extensive knowledge on material selection and behaviour and its state-of-the-

art characterisation possibilities, CRM Group is the preferred partner for the selection and development of new materials & designs for **renewable energy solutions**.

We are pursuing the development of innovative BIPV (Building Integrated PhotoVoltaic) solutions in collaboration with ArcelorMittal Construction. The performance of the solutions is tested during accelerated ageing tests but also by installing and monitoring field tests in real life situations. For this purpose a large PV installation has been placed on top of a CRM storage building in 2019, including 5 kWp of experimental modules and is monitored since May 2020. To date, regarding energy



Field testing of developed Building Integrated PV cells

output, no major deviation is observed for the experimental modules compared to commercial modules.

For the realisation of fuel cell bipolar plate stamping for PEM (proton exchange membrane) by hydroforming, a new very high pressure equipment is implemented on our 5000kN press thanks to the support of the European Fund for Regional Development. The setup allows to deform blanks up to 4000 bars with tap water. Besides the forming of thin sheets to obtain deep and narrow channels such as needed for the application, the high

pressure could also be used to generate a roughness which will increase the exchanges (thermal, gas,...) in-service. This prototyping tool completes the platform for the implementation and testing in real conditions of this type of material. In parallel, new wet coatings were developed as a stainless steel protection solution for bipolar plate. These offer excellent performance in terms of corrosion, interfacial contact resistance and forming resistance.

 In the field of **batteries**, an ambitious project has been set up and selected for European funding: the Horizon Europe project Seatbelt, which focuses on solid-state lithium metal battery with in-situ hybrid electrolyte. This project will allow us to combine our knowhow and equipment in coating technologies on metal sheets with our competencies in pyrometallurgical processes to ensure a high recyclability of spent batteries. We are also preparing the update of our pilot lines in a clean room environment to increase our capability to fabricate metal foil battery electrodes with various technologies. **Electrical steels** are key in advancing the energy transition. CRM Group participates in the European H2020 ESSIAL project that intends to improve electrical steel performances for the fabrication of more efficient and eco-friendly electrical machines. The project has now reached the prototyping stage in which our electrostatic spraying system is used to produce thin insulating layers able to improve corrosion resistance and electrical insulating properties that are damaged during the laser scribing strep. The coated steel sheets will be assembled together by industrial partners in order to test the electrical performances in real conditions. Industrial Shift: In its transition to carbon neutrality, the steel industry is planning to progressively shift from the conventional Blast Furnace (BF) route to the Direct Reduction (DR) route using hydrogen as reducing gas. CRM Group is quickly adapting its facilities and testing options to support that shift. We are already well equipped in terms of tools which can be used for the characterisation of input and output materials of the new process route (DR pellets, DRI, scrap). Process pilots are also already available for simulating both the direct reduction and the downstream melting processes (EAF or alternative melting units), and the EAF dynamic model can be used for upscaling the pilot results. Beyond that, the wide range of available pre-



View of the insulating coating step by electrostatic spray on laser scribed electrical steel sheets

processing tools (mixer, pelletiser, briquetting machines, etc) can also be used to support the transition of steel plants, by tailoring more input materials to the new processes and by developing recycling solutions for the new by-products, as there will be less and less sinter plants available for such recycling.

The remaining steel production carried out through the BF route will have to be optimised regarding CO_2 and other pollutants emissions. One main option is the switch to alternative fuels produced from biomass and/or waste materials to substitute fossil fuels, either solid (coal, coke) or gaseous (natural gas). Other options include the direct use of electricity or hydrogen in the BF and other iron and steelmaking reactors.

In the production of alternative fuels or reductants for steelmaking, our calcination/ pyrolysis station including a batch furnace, a pilot rotary kiln, a MHF pilot furnace and facilities for gas processing and dust collection is under continuous upgrade. In 2021, the rotary kiln was upgraded with a 100 kW electrical heater which can now substitute the gas burner to better simulate the torrefaction/ pyrolysis processes currently under industrial implementation. Moreover, our laboratory dedicated to fuels and pyrolysis was involved in the selection of non-recyclable waste to partly substitute coal in coke plants.



Inner view of the rotary kiln under cold operation (left) and batch furnace (right)

- Sintering plants are already tackling CO₂ emissions reduction by partial switch to alternative solid fuels and to alternative heat inputs through gases recirculation. CRM Group sintering team can support the plants by industrial measuring campaigns combined with numerical simulations and pilot sinter pot trials for an in-depth understanding of the process and testing new innovative concept.
- For what concerns the blast furnace process, current CRM Group activities deal with increasing the H₂-share in the reducing gases in combination with the charging

of Direct Reduced Iron. Pilot facilities are used in combination with modelling. Our MOGADOR model is a key reference for the simulation of blast furnaces, including the main physical phenomena, reaction kinetics and calculations of the inner state of the blast furnace in a 2D domain of finite elements. In 2021, the MOGADOR model was upgraded to be compatible with up-to-date IT standards. In addition, the algorithm was improved to better fit the results of multi-point vertical probing measurements performed in industrial plants and to take into account the flow of dusts inside the blast furnace (carry-over and pilling up).



Mogador modelling: progress of reduction and flow of dust inside the blast furnace

These improvements positively impact the modelling of the blast furnace permeability which is especially relevant to anticipate the potential effect of the novel burden (HBI/cold-bonded agglomerates and alternative reductants) and of the increased H_2 content in the gas. Several improvements were also achieved on the versatile



View of the insulating coating step by electrostatic spray on laser scribed electrical steel sheets



Surface oxidation during reheating under NG and H₂ firing conditions for 3 carbon steel grades

thermo-conversion pilot facility "HUGE" to increase its functionality, operability and to tackle new R&D challenges, among which a specific powder injection system designed to appraise the evolution of semi-coke particles inside the Blast Furnace.

Also downstream in the steel process the CO₂-emissions will have to be reduced to reach the climate neutrality goal. Since in the downstream process the main CO₂-emission is due to the **reheating furnaces of hot strip mills**, the shift from natural gas to hydrogen

combustion burners is under investigation. We are in particular investigating the impact of this change on the strip surface aspect, namely the impact on the surface decarburisation, the scale formation and its adherence. Test material, sampled from continuous cast slabs at ArcelorMittal Gent and Tata Steel IJmuiden, has been reheated under controlled atmosphere, simulating natural gas or H_2 burning gases, descaled and hot rolled in our test facilities. The first tests show an increase of the surface oxidation in hydrogen firing conditions.



CO, absorption column: top view (left) and inner view (right) : amine distributor and metallic packing

CCUS: The **capture of CO**₂ **on industrial fumes** followed by purification and finally utilisation and/or storage of the pure CO_2 is often regarded as the last resort solution in the industry because it implies large investments and high operating costs. It is however expected that it eventually plays a significant role in most industries, especially for the emissions directly linked with the chemistry of

the process ("hard-to-abate" industrial emissions). CRM Group is currently revamping a 1-2 t/day pilot capture plant based on amine scrubbing technology that will complement dedicated tools existing in Mons and Liège universities (models, corrosion tests, small rig tests) to support future industrial tests.

ADVANCED & HYBRID MANUFACTURING

DRIVEN BY **INDUSTRY** AND **ACTIVE** ON ALL THE VALUE CHAIN

In close collaboration with our industrial partners active in various sectors such as aero & spatial, steel industry, energy, automotive, construction, defence, equipment manufacturers, ... our activities span the complete value chain from the design & development of new alloys, over the metal deposition, the surface finishing and assembly to the reuse, remanufacturing and recycling.



Advanced manufacturing at CRM Group: covering the complete value chain



Development and optimisation of Al-alloys for additive manufacturing



Fine Cu-alloy microstructure achieved by Laser Cladding to improve resistance of electrical contacts

In the domain of the **development of new alloys** specially designed for additive manufacturing CRM Group's activities include Fe-based alloys as well as Al, Ti and Ni-based alloys. More and more we see the multi-material aspects becoming very important.

Supported by the European Space Agency, we are developing new aluminium and titanium alloys specific for additive manufacturing targeting high end-structural applications. A very innovative method has been put it place at CRM Group to develop and test new alloys with high mechanical properties avoiding the classical development route via the expensive powder production. The compatibility of the alloys for the 3D-printing process is assessed with Electron Beam Melting and the selected powders are afterwards tested on Laser Powder Fusion and Laser Metal Deposition machines.

Another illustration is the development of new materials for electrical contacts, resistant to arc-erosion in high power electrical switches. By joining forces with LaserCo (Belgium) and Italian partners, Metal Matrix Composites have been deposited by Laser Cladding and by Cold Gas Spray on the Cu substrate. Results have

shown that both technologies can provide not only cost effective and performant solutions but also open the way for more complex manufacturing designs & repair procedures.

Further development of the capabilities and control of our unique advanced manufacturing tools is also of crucial importance.

In the Wire Laser Additive Manufacturing Process, the evolution of the temperature during the deposition is monitored thanks to a specific thermal camera. The recorded data allows a better control of the process and feeding models that are developed by the partners in the Interreg project FAFIL.



Wire Laser Additive Manufacturing with temperature recording during deposition allowing to distinguish area with and without oxidation.

HyMax with protective chamber for Ti-printing. Illustration of control of oxygen level by the surface aspect of deposited stainless steel

The deposition of Ti-alloys by direct metal deposition for additive manufacturing or repairing requires working conditions under very low oxygen levels. The HYMAX machine has therefore been equipped with a home designed protective chamber to be fully in line with the requirements needed for the printing of parts for the aeronautic industry in the frame of the WINGS (Walloon INnovation for Green Skies). The control of the oxygen level is illustrated by the deposition of stainless steel: by decreasing the oxygen level the surface aspect becomes brighter.



Surface preparation is a crucial step for **the finishing and coating of 3D parts**. CRM Group has therefore extended its surface preparation capabilities with new tools to treat industrial complex parts in an automatic cleaning and



New surface preparation tools : Top cleaning & degreasing by spray, Bottom sand blasting for improving coating adhesion

degreasing installation and a sand blasting cabinet to improve the coating adhesion. Both have operating chambers close to 1m³ which can treat parts up to a weight of 500-750kg.

CRM Group is already for many years active in **the surface finishing of 3D printed parts**. Chemical polishing, electro-polishing, tribofinishing or a combination are selected and optimised according to the alloy and the parts' geometry. Recently the finishing process has been optimised for Aluminium-Magnesium-Scandium alloys (ScalmalloyTM), specifically developed for the additive manufacturing with growing attractiveness from the aeronautics and space industry. The developed process allows surface cleaning, brightening and smoothening and will be exploited by the Walloon company Chimiderouil. New projects have recently been launched supported by the Walloon Region and the ESA, respectively on the **selective finishing of additive manufactured** components and on the definition of **finishing protocols for components for space applications**.

In order to study the different **coating solutions** and to identify the best solution and its processing parameters depending on its application for both 2D or 3D complex parts, CRM Group has integrated a hybrid 2D/3D sample holder in the



industrial pilot vacuum chamber. Both **2D and 3D parts** can be **homogeneously coated with different vacuum coating processes** such as magnetron sputtering, plasma assisted CVD, evaporation as well as the HiPIMS (High Power Impulse Magnetron Sputtering). The latter is known and reported in previous reports for its capabilities to deposit thin and dense coatings.



Vacuum coating chamber with hybrid 2D/3D sample holder

Let us also recall that in complement to the vacuum coating technologies, CRM Group also has **thermal spray and electrolytic spray technologies** for the coating of 2D and 3D complex parts. The feasibility of hard **thermal spray coating deposition** on carbon fibre reinforced polymer **composites** is investigated with SONACA within the WINGS project for anti-erosion coatings.



Thermal spray coating on composite samples exposed to sand-blasting and showing the good adhesion of thermal sprayed layers

DIGITALISATION

INDUSTRY 4.0 AND SMART PRODUCTS

Digitalisation empowers the energy transition, the circular economy and the advanced manufacturing in transforming the industry towards competitive and sustainable industries.

Smart production

With the support of the Walloon region and in collaboration with Tata Steel Segal a complete Industry4.0 Proof of Concept of has been deployed in an industrial galvanising line.

For further improving the predictive maintenance abilities, reliable Industrial Internet of Things (IIOT) elements in combination with communication protocols, both suitable for industrial environments, are required. In the context of an Industry 4.0 Proof of Concept project for the galvanising line of Tata Steel Segal, CRM Group developed temperature and vibration sensors able to monitor bearings life cycle. Amplification system and radio frequency protection shield have been



IIOT temperature & vibration measurements with adapted communication protocol for industrial environments such as a galvanising line

integrated to the transceiver allowing to communicate in a range of about 100 meters in industrial conditions. Future Machine Learning based studies will be developed for an automatic failure detection system.

IIOT is also applied to improve operator safety in potential dangerous locations thanks to an indoor positioning system for operators. The system includes two key elements: Tags & Anchors. The tags are the mobile elements the operator must take to be localised. The anchors are the fixed satellites strategically placed in the working area and must be at least four if the idea is to localize the tags in the **XYZ space**. To ensure a wide range and as most precise as possible localisation in industrial and metallic environments, the chosen technology is the Ultra-Wide Band (UWB). The tags can be localised thanks to the Time Of Flight (TOF) measurement: the tags and the anchors will communicate in a well-defined protocol and the time its respective communication will take is an image of the distance between them.

- Product characterisation and process control improvement through machine learning has been applied for the control of the industrial galvanising line. Big plant datasets generated by recovering a lot of production campaign data. have been analysed and used to establish a deep learning prediction model. This model takes as input some real time process key parameters affecting a measurable characteristic of the final product, then use it to estimate this characteristic. At present, the model is about to be tested in real conditions. It has been tested on thousands of testing samples and gave a prediction error range from about -10% to about 10%, while the actual process target could tenfold increase during a production.
- People training and operator assistance through Augmented Reality has first been demonstrated in the CRM Group laboratory. Digital work instructions are provided to the operator through the projection of holograms visible through smart glasses. After the knowledge gained through the laboratory demonstrator, this technology was industrially implemented at Tata Steel Segal to support maintenance operations. Therefore a robust version of the smart glasses was used to withstand the environment and to be compatible with a safety helmet.



People training and operator assistance through Augmented Reality in an industrial galvanising line

During the last years CRM Group has developed a dynamic on/off-line model for the EAF process. Contrary to calculations using statistical inputs, our model uses a fundamental set of calculations based on thermodynamics and kinetics that takes dynamically into account furnace operating data. The purpose of the on-line application is to provide the operator with a better estimation of the melting state of the furnace and liquid steel temperatures to reduce the frequency of temperature measurements and increase the reliability of those taken. This in turn will enable lower tap temperatures and reduce energy consumption. Furthermore it can be used for deciding the best time to load the second basket or regulating the bath temperature during the



EAF model: Example of simulation results – good correlation between calculated (red line) and measured (red dots) temperatures despite disturbed process whole processing time, allowing for example to control the %P of the steel in case of continuous DRI feeding.

The model has been successfully used for off-line simulations of different furnaces and scenarios (e.g. various operating patterns). It is currently also running on-line in 3 plants and the deployment in a fourth one is ongoing. For those applications, it was adapted to continuous feeding of DRI.

Smart products

The Horizon Europe HiperMat project aims at developing longer lasting materials and components to withstand continuous high temperatures or thermal cycling such as in hot stamping furnaces. To monitor the performance of these new materials in the austenisation furnaces for hot stamping CRM Group is **developing and integrating embedded temperature sensors**. For those components embedded in industrial furnaces under **high temperature and corrosive oxidising conditions**, two temperature sensors are under development using plasma spray deposition directly on the SiC 3D ceramic furnace tube : printed thermocouples based on NiCr and NiAl coatings and Resistive Thermal Sensors based on for example NiCr deposition.



Printed sensors

In the frame of the Mecatech VIRGA project, CRM Group collaborates with John Cockerill to develop a smart stealth solution for defence applications. The solution aims to decrease the visibility of armored vehicles turrets in thermal Infrared and Radar range, as well as to avoid being recognised if the vehicle is detected. We are involved in the IR stealth developments for which a first proofof-concept has been proposed. It is based on printed IR elements that can be activated in order to modify the surface appearance in thermal IR wavelengths. Our printed solution allows producing a controllable and an active luminance panel that can be modified to fit with the IR characteristics of the vehicle environment. The system architecture, which is based on independent pixels, furthermore allows drawing a pattern that will increase the similarities with the environment (forest, desert, ...) or that can mimic an artificial object (for example another type of vehicle). The first demo manufactured at CRM Group shows the possibility to activate the desired pixels thanks to a dedicated application controlled from a tablet.

Thermoelectric effect to convert temperature differences into electric voltage is achieved by movement of electrons and holes (N-type and P-type junctions) in 2 dissimilar metals at different temperature. **Thermo-electric converting devices** composed of off-stoichiometric Fe₂VAI alloys present advantages in terms of cost and stability compared to the conventional Bi-Te systems.



View of the active IR demo in the visible and IR range, without (off) or with (on) the activation of selected IR pixels by the application installed on a tablet.

Thanks to the **co-sputtering** technique, CRM Group succeeded in producing off-stochiometric **thin films** of either N-type (by using $Fe_2VAI \& V$ targets) or P-type (by using Fe_2VAI and AI cathodes). Because of the flexibility of the co-sputtering approach the composition can be tuned for optimised thermo-electric properties and without the need tp produce separate N-type and P-type off stochiometric sputtering targets.



Co-sputtering for printing thin film thermo-electric layers and the Seebeck-coefficient obtained depending on the used sputtering second target.

INDUSTRIAL PROCESSES AND SOLUTIONS

INNOVATION THAT CREATES VALUE

Providing industrial solutions for and together with our industrial partner is our main mission. The innovations aim at improving the competitiveness of the industry through improved efficiency, reduced maintenance, new and improved products while progressing on energy & resource-efficiency and environmental impact. The maturation and validation of the solutions on our pilot lines and during industrial trials are key steps in their upscaling.

The continuous development and upgrade of our pilot installations is of prime importance to keep on responding to the need to validate our solutions in conditions mirroring the real industrial situation. De Leuze and CRM Group, with the support of the Walloon Region, successfully designed and built a **pickling and rinsing pilot line** 'Picklean' enabling the simulation of industrial processes on 300x200mm sheets. The pilot allows the testing in conditions close to those of an industrial line while respecting all health & safety aspects, new pickling & rinsing processes and additives as well as

the definition of the right pickling & rinsing parameters for new steel grades. The Picklean simulator enables the simulation of acid cascading of an industrial pickling line, the reproduction of stains formation during rinsing or a line stop. This pilot line strongly helps in the development of solutions for each industrial problem by adequately simulating industrial hydrodynamics.



Pickling & rinsing pilot line 'Picklean' and strip surface before and after pickling



Cold rolling simulator (Top) with integrated emulsion system (Bottom) for testing new roll coating concepts substituting hard Cr-plating

For the development of new coating concepts for the substitution of the hazardous hard Cr-plating of cold rolling rolls, the assessment of the wear resistance of the new coatings in conditions representative to the industrials ones is mandatory. The rolling simulator '3-Disc-machine' initially developed for hot rolling simulations has therefore been adapted for cold rolling simulations. In particular, an emulsion lubrication system has been integrated on the equipment.

Several developments are under way to master the rolling process:

Controlling the wear of the pinch roll in front of the down coiler in a hot strip mill is essential to master strip flatness issues and coiling defects. To monitor this pinch roll wear in realtime, the CRM Group's Roll Profiler System implementation is in progress within the RFCS funded RollProf project. The concept, based on inductive sensors with low response time, has been fully tested in the lab simulating the environment, temperature, presence of dirty coolant and high rotation speed. Furthermore a portable control device has been developed to calibrate in lab and on-site the Roll Profiler System. The industrial installation is in preparation and its start-up in the ArcelorMittal Dunkirk hot strip mill is planned for mid-2022.



Roll Profiler System for real-time monitoring of the pinch roll wear

Characterised by its robustness and low cost, the torque measurement system that was previously tested on our pilot line has now been integrated in the hot strip mill of ArcelorMittal Belgium. Indeed a good torque measurement is essential in hot & cold rolling operations to master the asymmetry in the roll bite and associated steering problems, spindle breaks and flatness issues. Since in an industrial hot strip mill the direct installation of encoders at the work rolls is not feasible, a dedicated software for real-time calculation of the angular twist between top/bottom cardan shaft and motor shaft has been developed.



The mill diagnostic program to calculate in real time the angular twist

The **development and improvement of work roll grades** and the mastering of their performance remain key competences of CRM Group.

CRM Group is well equipped and experienced for the analysis of surface degradation on metal working tools such as work roll, backup roll but also forging dies; not only in the laboratory but also on-site. In 2021, several analyses have been performed in the frame of running projects such as on cold rolling backup rolls in the frame of the RFCS-funded project 'BurWear' as well as in support to our adherent members such as Aperam, ESW, Marichal Ketin for understanding the degradation mechanism and proposing solutions to improve performances.

In collaboration with Marichal Ketin and supported by the Walloon Region in the Eratrapro project, we are **developing a novel** thermal treatment for roughing and finishing mill work rolls to further improve properties and performance. Since an in-depth monitoring of the full heat treatment cycle is crucial for the optimisation of the heat treatment, a technology has been defined to correctly assess the temperature evolution during the full cycle





On-site work roll inspections and the good correspondence between lab and on-site analysis

of the heat treatment (T>1000°C, t>300h). The analysis of the heat treatment enables to validate a Finite Element model that estimates the residual stresses along the heat treatment.



Monitoring of the temperature during the heat treatment of work rolls for optimising the thermal cycle



In the field of annealing & galvanising the control of the product during and after production is of paramount importance to ensure quality.

 Mastering the cleanliness of the strip at the entry of the galvanising line is a key success factor for good coating properties. To properly tune the cleaning section, a high sensitive device for measuring the surface



CleanEx installed in CASTL line and correspondence between lab and on-line surface carbon measurements

pollution is necessary. The LIBS-based CleanEx sensor has been validated on our Continuous Advanced Surface Treatment Line (CASTL). The device can differentiate surface carbon from iron fines pollution without any contact with the product. A good correlation between the on-line measured LIBS spectra and the reference laboratory pollution measurement has been reached. The next step is to integrate the prototype sensor in the Tata Steel Segal galvanising line for industrial measurement campaigns.

In order to control the mechanical properties of high strength steel, the monitoring of the austenite fraction and its transformation is essential. CRM Group is therefore continuing, with the support of the RFCS-fund and in collaboration with Tata Steel and ArcelorMittal, the development of a **low cost sensor allowing the evolution and the homogeneity of this austenite transformation to be measured in**



Correspondence between the secondary tension online measured with the AUSSENS sensor and the steel grade properties

real time on moving strips. The sensor has been installed in a continuous galvanising line for first industrial trials and it has been confirmed that the useful signal measured on-line by the sensor, i.e the secondary tension, follows the mechanical properties of the steel grade. As the secondary tension is slightly and inversely proportional to the temperature variation a correction algorithm has been defined for measurements at high temperature.

For the aeronautics industry CRM Group is collaborating with Safran Aero Boosters to develop a manufacturing method for the blades of future engines by high precision forging. This high precision forging is a key step in the manufacturing process as it allows the aerodynamic part of the blade to be shaped without any subsequent remachining, thus allowing a significant saving in cutting tool costs and final machining time. To achieve these objectives, the CRM Group is adapting its capabilities and equipment to the new manufacturing method. The modification of our hydraulic press was studied and a first concept of original tooling allowing the high precision forging has been obtained. Our electrostatic paint booth will be used to apply homogeneously and with a level of control a glass coating on the part before the forging operation. Finally, the CRM pickling line will also be adapted to remove from the surface the altered layer appearing on the titanium blades during forging.



Hydroforming press and special tool developed for the high precision forging of aircraft engine blades

TECHNICAL SUPPORT, VALORISATION & DISSEMINATION

The know-how acquired in the research projects has been disseminated through the organisation of webinars, dissemination events, visits, participation to conferences and the publication of papers.

Dissemination events

CLEANSCRAP webinar on the pre-treatment technologies to improve the 'value-in-use' principle of scrap. Presentation of results of on-site visits and case studies and some general outlines related to scrap pre-treatment, CRM Group, SIRRIS, CLUSTA, SIM, 21/01/2021.

Webinar on 3D printing with steel co-organised by CRM Group, BIL and Sirris to disseminate results of the VLAIO project, Inside Metal Additive Manufacturing, February 22nd, 2021. CRM Group offers access to its innovation knowledge in Flanders through the #industriepartnerschap.

Virtual visits organised by CRM Group, LASEA SA and Multitel to discover the equipments for the special session "company visits" of PLI Conferences, July 8th 2021.

On October 12, the CRM Group welcomed in its buildings Mr. Frédéric Daerden, Vice-President and Minister of Budget and Finance of the FWB. Exchange and visit of some CRM facilities as well as a broad discussion on the role of research centers in the innovation ecosystem and the need to strengthen the partnership between research institutions.

On wednesday 20th of October CRM Group organised together with the other partners of the INTERREG project Pulsatec a technical workshop to share experiences and technologies in the field of plasma coating. On 9-10 November, the final conference of the 'Green Steel for Europe' (GreenSteel) project took place, which aims to help the EU achieve its 2050 climate-neutral targets by proposing effective solutions for low-carbon steel production. The event highlighted the assessment of promising technologies, investment needs and financing opportunities, and discuss policy options and their impact, as well as the way forward for climate neutral steel production in Europe.

A webinar presenting the key results from the subsidised project "MasteringRolls II Project" has been organised with success with over 120 registrations the 16 & 17th November. The MasteringRolls II project objective is to integrate an enhanced mastering of work roll degradation in hot rolling by applying new measurement technologies and innovative actuators developed in previous RFCS and internal research projects.

CRM Group took part in the Belgian Digital Trade Mission on 22 - 26 November 2021. New materials are a strategic sector for Sweden and Norway. The areas that were highlighted were among others technologies related to weight reduction, coatings and eco-design/sustainability.

On-line WORKSHOP on "Additive manufacturing in industrial environments" has been organised on December 9th, 2021 in the frame of the INTEREG project Fafil.

A visit of the Minister David Clarinval and the President of the MR Georges-Louis Bouchez took place at the CRM Group, in the presence of small, medium and large companies.

'The paints of tomorrow: Towards zero CO_2 emissions and Digitalisation 4.0' was a thematic day co-organised at CRM with VOM Promosurf.

Our extensive network of R&D partners, associations and partnerships are at the benefit of our industrial members to identify opportunities, collaborations or funding possibilities. As a collective research centre recognised by the Belgian and Regional Authorities, CRM 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/fr



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/fr

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/



CReSus (Centre for Resource Efficiency and Sustainability):

A common initiative of CRM and ULiège/GeMMe aiming to strengthen collaborations at regional level as well as in the European initiatives such as Horizon 2020 and EIT/KIC on (primary and secondary) raw materials.



MATERIALS RESEARCH CLUSTER GENT

MRC (Material Research Cluster Gent) is an initiative in which seven partners (OCAS, Gent University, Sirris, BIL, Clusta, CRM, SIM and its division Flamac) 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/

At the European level, CRM 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/

METNET

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).

www.metnet.eu



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.



Legally formed in July 2012, **SPIRE (Sustainable Process Industry through Resource and Energy efficiency)** is a European Public Private Partnership (PPP), dedicated to innovation in energy and resource efficiency and created to meet and participate to the Horizon 2020 Framework Programme of the European Community.

https://www.aspire2050.eu/



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/

FLAMED

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

https://www.flam3d.be/



Hybrid 3D network, a network partner of small and mediumsized 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/



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/



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/

LET US MENTION THAT CRM IS ALSO MEMBER OF:

worldsteel

WorldSteel: the International Institute of the Steel Industry,

EUROFER The European Steel Association

EUROFER: the European Federation of the Steel Industry,



UWE: Union of the Walloon Enterprises



VOKA: the Flemish network of Enterprises.

NEW MEMBERSHIP:



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



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/



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Metal production, Recycling & Energy

R. Contreras, F. Blaffart, L. Fraikin, C. Polato, M. Pacheco, O. Havelange Sintering with high By-Products Recycling Rate and Environmental Optimization by Selective Preparation 5th ESTAD (European Steel Technology and Application Days), 30 August – 2 September 2021, Stockholm (Sweden)

J. Rieger, V. Colla, I. Matino, T. Branca, G. Stubbe, A. Panizza, C. Brondi, M. Falsafi, J. Hage, X. Wang, B. Voraberger, T. Fenzl, V. Masaguer, E. Faraci, L. di Sante, F. Cirilli, F. Loose, C. Thaler, A. Soto, P. Frittella, G. Foglio, C. di Cecca, M. Tellaroli, M. Corbella, M. Guzzon, E. Malfa, A. Morillon, D. Algermissen, K. Peters, D. Snaet Residue Valorization in the Iron and Steel industries: Sustainable Solutions for a Cleaner and More Competitive Future Europe Metals 2021, Volume 11, Issue 8

F. Coelho, V. Decottignies, Y. Yang, B. Sprecher, B. Saje, C. Rado, N. Menad, S. Abrahami, Z. Li, K. Bru, T. Marcon

Upscaling of Permanent Magnet Dismantling and Recycling through VALOMAG project

International Conference on Raw Materials and Circular Economy, 5-9 September 2021, Athens (Greece)

METAL PROCESSING & PRODUCT METALLURGY

J. Malbrancke, J. Niemi, E. van den Elzen, T. Fall, L. Vanhulle, K. Schutte, M. Moujib

Mastering Rolls II: fast work roll surface analyses with a tablet application *Rolls 6*; 23 June 2021

C. Childs, Dr J. Schindhelm, J. Malbrancke

Roll surface treatments & Assessments I.M3 Institute of Materials, Minerals & Mining, 23 June 2021

S. Flament. G. Walmag, M. Sinnaeve

Work roll degradation in HSM: mechanisms and new challenges Webinar Steel Times international "long products/rolling webinar"; 25 June 2021

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Development of a FE-model to optimize the roll life in reversing roughing stands Webinar Rolls 6 – session Modelling & Roll Life Optimisation 07 July 2021

J. Malbrancke, S. Flament, J. Niemi, E. van den Elzen, K. Schutte, D. Beentjes, M. Picard, Th. Harmand, Th. Fall Mastering work roll degradation for the Hot Strip Mill MasteringRolls II Webinar 16-17 November 2021

FINISHING & COATING

L. Bordignon, N. Zacchetti, A. Chierichetti, E. Thienpont, J-M Arbiol, M. Blumenau, T. Vilics

Non sticking furnace rolls for steel products to improve service life and product quality in continuous annealing and galvanizing lines: Preliminary study on chemical interactions and pickup mechanism

12th International Conference on Zinc & Zinc Alloy Coated Steel Sheet -GALVATECH 2021

K. Van Den Bergh, C. Allély, P. Tanguy, F. Berger, C. Le Pen, V. Carlier

Study of the influence of the phase repartition of Zn(Al)Mg alloys on the corrosion behaviour of pre-painted steel EuroCorr2020, 07-11 September 2020

M. Hoseinpoor, T. Prosek, L. Babusiaux, J. Mallégol

Simplified approach to assess water uptake in protective organic coatings by parallel plate capacitor method Materials Today Communications 26 (2021) 101858

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Toward more realistic time of wetness measurement by means of surface relative humidity *Corrosion Science 177 (2020) 108999*

M. Mandy, B. Nabi, M. Larnicol, X. Vanden Eynde, C. Georges, F. Goodwin

Influence of Zn-based coating alloys on hydrogen diffusion and corrosion resistance in a DP steel Proceedings Galvatech, journal BHM

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Toward more realistic time of wetness measurement EUROCORR 2021, 20 - 24 September 2021 (virtual event)

A. Daniel, F. Duminica

Augmenter la robustesse des surfaces grâce aux revêtements par projection plasma

VOM-PROMOSURF, Webinar via Zoom, Le plasma pour durcir les surfaces, 18 May 2021

Hybrid & Additive manufacturing

N. Jimenez Mena, N. Nutal, C. Georges, P. Dufour, A. Brandao

Use of direct metal deposition for launcher parts

32nd Advanced Aerospace Materials and Processes (AeroMat) Conference and Exposition, 2021/5/24-26

N. Jimenez Mena

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