CRM GROUP

ANNUAL REPORT 2017

CLOSING THE VALUE CHAIN OF METALS

D/2017/0124/1

Contents

Foreword

The CRM non-for-profit organisation, part of CRM Group, provides solutions in the field of R&D, technology and innovation in the scope of metal and steel production, it remains entrusted with the mission of developing new processes, products and applications.

It is supported by more than 45 industrial members: international steel groups (ArcelorMittal and Tata Steel), metal producers and industries with a metal-related activity. During 2017, more than 70% of CRM activities were directly focused on steel, the other 30% on other metals and developments of new processes in transversal fields like energy, recycling and valorisation of by-products.

Despite its close connections with heavy industry CRM is also supporting small- and medium-sized companies in the processing and application of metallic materials.

At CRM Group, health and safety issues remain the first priority. All the actions implemented at the level of the management, as well as all the CRM staff led to a strong improvement of the results for the year 2017. If, for CRM Group staff, no accident with lost time was registered, 1 accident with lost time was reported involving a subcontracting company during an intervention on a pilot line. Training and audits combined with the daily presence of the management on the floor will continue to be a priority in 2018.

To fulfil its mission, the CRM Group is organised around 6 domains:

1 | Metal production, energy and recycling (Raw material processing, melting & refining, by-products treatment & valorisation)

2 | Metal processing & Metallurgy (casting & solidification, rolling & thermal treatment, product metallurgy)

3 | Smart surfaces and surface functionalization (Functional coatings, lighting, energy & photovoltaic)

4 | Construction products and solutions (organic coatings, building & structure, metal working)

5 | Innovative designs and assembly solutions (Civil engineering, assembly & testing, hybrid/additive manufacturing)

6 | Industrial solutions (Engineering, finishing & metallic coating, process control & measurement, continuous coating pilot lines)

As an independent collective research centre, CRM has continued to benefit from financial support from the Belgian and Regional authorities, as well as from the European Commission.
At a European or regional level, CRM has continued to invest in partnerships with others research organisations. Numerous research projects, financed by the European Commission, have led to many opportunities of co-operation with specialised European partners. CRM is today active in more than 15 European projects.

In Wallonia, CRM has initiated a strong partnership with another accredited R&D centre (Sirris) in the field of additive manufacturing and has reinforced its partnership with Liege University on recycling and circular economy. In Flanders, CRM has similar partnerships (circular economy and additive manufacturing) with R&D centres (Sirris, Clusta and BIL).

The integration during the year 2017 of the R&D centre named "CEWAC", specialized in welding and assembling, aims to consolidate the expertise of the Group in the new manufacturing techniques and the production of innovative metallic products.

The present annual report highlights the main achievements of the year 2017.

Paul PERDANG
President CRM

Jean-Claude HERMAN
General Manager CRM

Company members

On April 18, 2018

Active Members of CRM

ARCELORMITTAL S.A. ..... G.D. Luxembourg
TATA STEEL EUROPE LIMITED ..... United Kingdom

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 BELVAL & DIFFERDANGE S.A. ..... G.D. Luxembourg
ARCELORMITTAL DUDELANGE S.A. ..... G.D. Luxembourg
ARCELORMITTAL FRANCE S.A. ..... France
ARCELORMITTAL LUXEMBOURG S.A. ..... G.D. Luxembourg
ARCELORMITTAL RODANGE et SCHIFFLANGE S.A. ..... G.D. Luxembourg
INDUSTEEL BELGIUM S.A. ..... Belgium

TATA STEEL Group :

SEGAL S.A. ..... Belgium
TATA STEEL IJMUIDEN BV ..... The Netherlands
TATA STEEL NEDERLAND TECHNOLOGY BV ..... The Netherlands
TATA STEEL UK LIMITED ..... United Kingdom

Associated Members of CRM

AIR LIQUIDE INDUSTRIES BELGIUM S.A. ..... Belgium
AMEPA GmbH ..... Germany
APERAM Stainless France S.A.S. ..... France
ARCEO Engineering ..... Belgium
AURUBIS BELGIUM N.V. ..... Belgium
BEKAERT S.A. ..... Belgium
BIOCARBON INDUSTRIES Sàrl ..... G.D. Luxembourg
CARMEUSE S.A. ..... Belgium
CBR S.A. ..... Belgium
CMI S.A. ..... Belgium

COMET TRAITEMENTS S.A.	Belgium
DE LEUZE S.A.	Belgium
DELEUZE GROUP-EMUREF S.A.	Belgium
DREVER INTERNATIONAL S.A.	Belgium
EMG Automation GmbH	Germany
ENSIVAL-MORET BELGIUM S.A. (SULZER)	Belgium
EVERZINC	Belgium
FONDERIES MARICHAL, KETIN & Cie S.A.	Belgium
GONTERMANN-PEIPERS GmbH	Germany
HARSCO BELGIUM bvba	Belgium
HERAEUS ELECTRO-NITE INTERNATIONAL N.V.	Belgium
HERSTAL S.A.	Belgium
INDUCTOTHERM S.A.	Belgium
INSTITUT BELGE DE LA SOUDURE asbl	Belgium
INTERNATIONAL MANGANESE INSTITUTE	France
LASERCO DT S.A.	Belgium
LHOIST Recherche & Développement S.A.	Belgium
MAGOTTEAUX INTERNATIONAL S.A.	Belgium
NDC TECHNOLOGIES S.A.	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
R-TECH S.A.	Belgium
SAFRAN AERO BOOSTERS S.A.	Belgium
SARCLAD Ltd	United Kingdom
THY-MARCINELLE S.A.	Belgium
TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT sarl	G.D. Luxembourg
VM BUILDING SOLUTIONS S.A.S.	France
WESTINGHOUSE ELECTRIC BELGIUM S.A.	Belgium

Organisation

On April 18, 2018

Board of Directors of CRM

President

Paul PERDANG, Member of the leadership team of Global R&D, ARCELORMITTAL

Vice-Presidents

Pinakin CHAUBAL, Head of Process R&D and Americas labs, ARCELORMITTAL
Ernst HOOGENES, Director R&D Europe and Director Business Excellence, TATA STEEL

Directors

Ivan AERTS, Adviseur, Centrale der Metaalbewerkers van België
Vincent CHOLET, CTO, ARCELORMITTAL Europe – Long Products
Philippe COIGNE, Directeur Général, Groupement de la Sidérurgie (GSV)
Renaud COLLETTE, Conseiller, SPF Economie, PME, Classes moyennes et Energie
Mark DENYS, Director Technical Strip Products, TATA STEEL Mainland Europe
Joao FELIX DA SILVA, Directeur Général, CMI Industry
Marc FISETTE, Head of Performance Optimisation, ArcelorMittal Europe Flat Products
Leo KESTENS, Professor, Universiteit Gent
Greg LUDKOVSKY, Vice-President of Global R&D, ARCELORMITTAL
Stéphane PIRON, Secrétaire Fédéral – SETCa Fédéral
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.
Manfred VAN VLIERBERGHE, CEO ArcelorMittal Belgium
Wim VAN DER MEER, Director R&D Programmes, TATA STEEL RD&T
Olivier VASSART, Long Products Portfolio and Research Centres Leader, ARCELORMITTAL
Pierre VILLERS, Inspecteur Général, Direction Générale des Technologies, de la Recherche et de l'Energie de la Région Wallonne
Simone VOOIJS, Director Technical Tata Steel Downstream Operations, TATA STEEL
Pierre WOLPER, Professeur, Doyen de la Faculté des Sciences Appliquées, ULg

Observers

Jean-Claude HERMAN, Directeur Général, CRM
Yvon MASYN, Adviseur, Agentschap Innoveren en Ondernemen

Auditor

Dominique JACQUET-HERMANS

Iron and Steel Committee of CRM

Members

ARCELORMITTAL
Jean-Paul ALLEMAND
Michel BABBIT
Pinakin CHAUBAL
Marc DI FANT
Maïte RODRIGUEZ
Sven VANDEPUTTE
Olivier VASSART

TATA STEEL
Mark DENYS
Loes JANSEN
Wim VAN DER MEER

CRM
Jean-Claude HERMAN
Christian MARIQUE
Griet LANNOO

Quality Management

The CRM Group is certified ISO9001 for all its activities whilst several measurement, calibration and analytical techniques are certified ISO17025.

CERTIFICAT DU SYSTEME DE MANAGEMENT DE LA QUALITE

ISO 9001 : 2008

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

CRM GROUP

dont les sièges des sociétés sont établis

Avenue du Bois Saint-Jean, 21 – 4000 Liège et Technologiepark 903c – 9052 Zwijnaarde – Belgique pour

CRM asbl – *Centre for Research in Metallurgy asbl*

et Allée de l'Innovation, 1 – 4000 Liège et Rue Sompré, 1 – 4400 Ivoz-Ramet – Belgique pour

ACeCS sprl – *Advanced Coatings and Construction Solutions sprl*

a été examiné le 02-11-2015 et a été jugé conforme à la norme ISO 9001, édition 2008 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 le BQA na conformément à son manuel de qualité relatif à la certification de système et après conclusion du contrat de certification N° CER_AJ_QMS_02-11-2015_336_F aux termes duquel la firme accepte un contrôle régulier de son système de management.

Certificat N° BQA_QMS019_C_2006336

Valable jusqu'au 14-09-2018

BELAC

BQA N° 019-QMS

D. SIMOENS

Directeur

BQA

Toute personne ayant connaissance de l'emploi abusif de ce certificat doit en avertir le BQA na. Ce certificat ne peut être divulgué que dans son intégralité.

BQA na – rue Montoyer 24-bte – 1000 Bruxelles

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

BELAC

Signatory to EA, ILAC and IAF Multilateral Agreements

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, that the calibration laboratory

CRM
CENTRE DE RECHERCHES METALLURGIQUES ASBL
Domaine Universitaire du Sart Tilman (p59) Avenue du Bois Saint-Jean, 21
4000 LIEGE - Belgium

has the competence to perform the calibrations as described in the annex which is an integral part of the present certificate, in accordance with the requirements of the standard EN ISO/IEC 17025:2005. The present accreditation is the subject of regular surveillance in order to confirm the compliance with the accreditation conditions.

The Chair of the Accreditation Board BELAC,

Issue date : **2017-12-07**

Validity date : **2022-10-27**

Nicole MEURÉE-VANLAETHEM

Original version of this certificate is in French.

.be

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

BELAC

Signatory to EA, ILAC and IAF Multilateral Agreements

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, that the test laboratory

CRM
CENTRE DE RECHERCHES METALLURGIQUES ASBL
Domaine Universitaire du Sart Tilman (p59) Avenue du Bois Saint-Jean, 21
4000 LIEGE - Belgium

has the competence to perform the tests as described in the annex which is an integral part of the present certificate, in accordance with the requirements of the standard EN ISO/IEC 17025:2005. The present accreditation is the subject of regular surveillance in order to confirm the compliance with the accreditation conditions.

The Chair of the Accreditation Board BELAC,

Issue date : **2017-12-07**

Validity date : **2022-10-27**

Nicole MEURÉE-VANLAETHEM

Original version of this certificate is in French.

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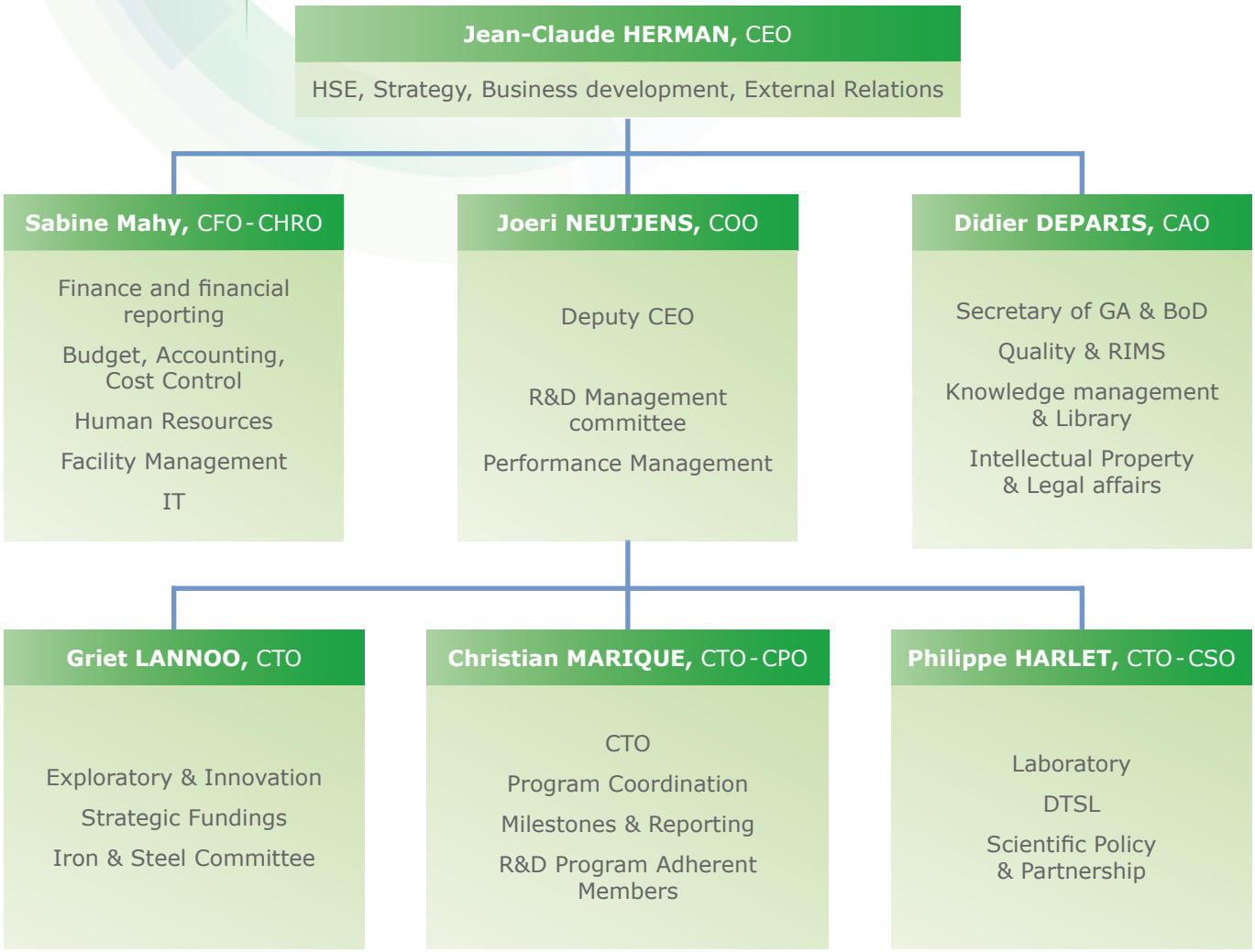
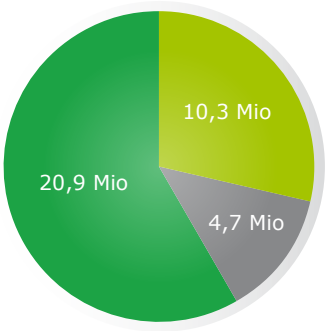
Leadership Team



CEO: Chief Executive Officer
COO: Chief Operational Officer
CFO: Chief Financial Officer
CHRO: Chief Human Resources Officer
CPO: Chef Program Officer
CTO: Chief Technical Officer
CSO: Chief Scientific Officer
CAO: Chief Administration Officer

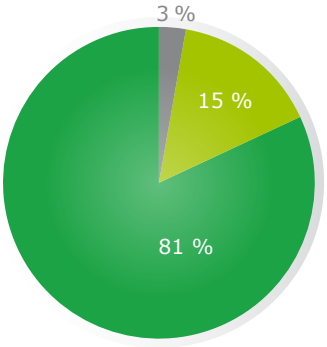
Key figures

Income by program



- Steel Collective
- Steel Private
- Other

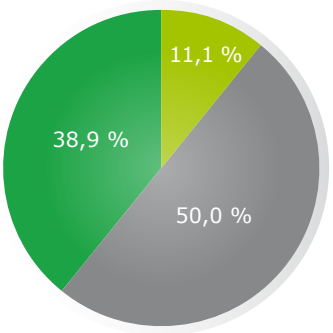
Income by financing



- Private
- National & Regional Grants
- European Grants

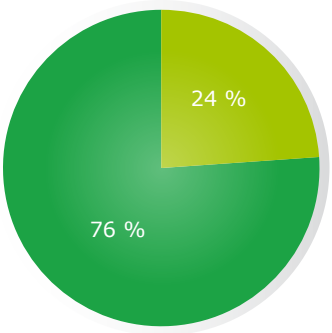
Total Income (CRM asbl): 35.9 Mio. Euros

CRM Group: 262 people



- Researchers
- Technicians
- Administrative staff

Gender balance



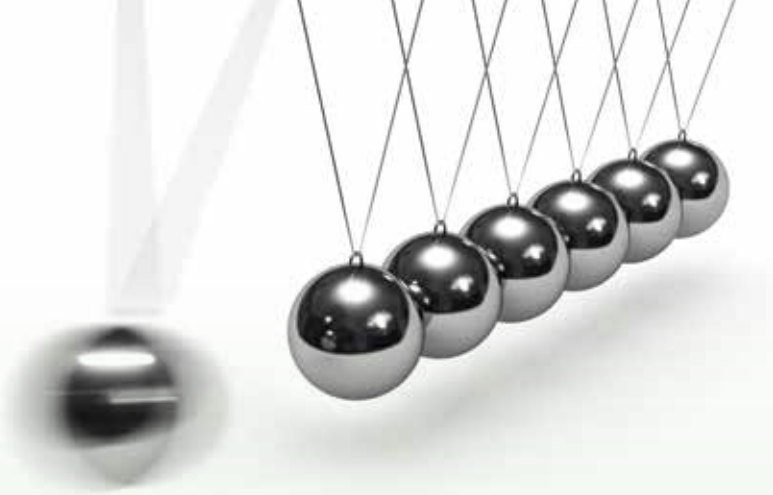
- Female
- Male

Report on R&D activities

After almost 70 years of existence devoted to innovation and promotion of new technologies and solutions in metallurgy and metallic products, CRM has gained a significant competence and expertise to anticipate and meet the needs of its industrial partners (45 members in 2018).

The present move of the modern industry towards a larger integration of the circular economy concept in its production scheme, the more intense application of digital and smart solutions for the processing operations and/or the products delivered to the market, the progressive implementation of new manufacturing technologies such as the so-called "3D or additive/hybrid techniques" is driving the activities of the CRM Group, besides its more traditional actions linked to the core business of its affiliated steel companies and associated members.

The integration during the year 2017 of the R&D centre named "CEWAC", specialized in welding and assembling, aims to consolidate the expertise of the Group in the new manufacturing techniques and the production of innovative metallic products.



Due to this evolution, the CRM Group organisation has been reshaped around six operational units:

- Metal production, energy and recycling (Raw material processing, melting & refining, by-products treatment & valorisation)
- Metal processing and Metallurgy (casting & solidification, rolling & thermal treatment, product metallurgy)
- Smart surfaces and surface functionalization (Functional coatings, lighting, energy & photovoltaic)
- Construction products and solutions (organic coatings, building & structure, metal working)
- Innovative designs and assembly solutions (Civil engineering, assembly & testing, hybrid/additive manufacturing)
- Industrial solutions (Engineering, finishing & metallic coating, process control & measurement, continuous coating pilot lines)

These 6 units are supported by a transversal laboratory (materials characterization and in-use properties) and a business development team.

To be pointed out that the certification ISO9001 covering all the CRM activities has been renewed in 2017 as well as the ISO17025 certification for several measurement, calibration and analytical techniques.

This annual report presents a selection of relevant activities and results open for communication. It also highlights pilot and testing facilities available in the CRM laboratories and located at Liège and Gent.

They are illustrated through 4 main thematic sections:

- Resources and Energy Preservation: how to turn end-of-life products and metallic waste into new valuables raw materials and energy sources
- Innovative processing technologies: from raw materials to final shaped products
- New advanced metallic materials and solutions with tailor-made properties
- Technical support, valorisation & dissemination to industry and regional economy

Resources & Energy Preservation:

How to turn end-of-life products and metallic wastes into new valuable raw materials & energy sources

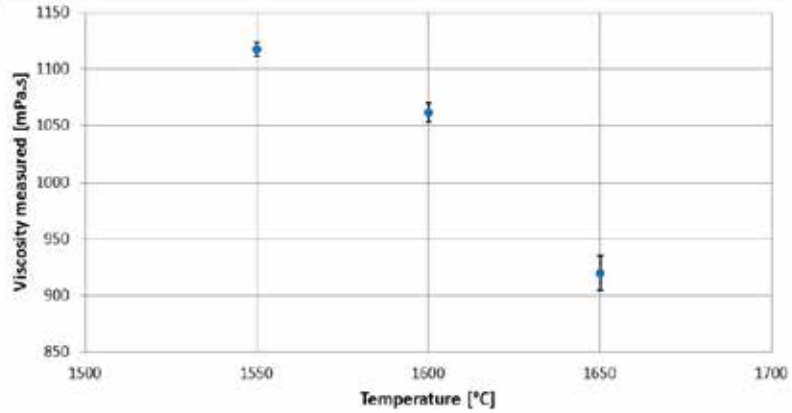
Manufacturing new added-value products through the recycling, processing or re-use of end-of-life goods and by-products is one of the ambitious but necessary objectives of the modern industrial economy, a target of particular importance for Europe.

The steel and metal industries are natural key players of this "Circular Economy" approach as they supply a large part of the products used in many applications and markets all around the world and already recycle a large part of this production. Despite this positive position, it appears mandatory to pursue the effort for further improving the situation and promoting better adapted recycling solutions as the modern goods and products are becoming more and more hybrid and complex notably for what concern the amount and number of metals and materials entering in their design.

For all these reasons, CRM is actively engaged since more than 3 years in the development and implementation of new recycling approaches, with a strong support of the Walloon Government ("Reverse Metallurgy" project) and the European Community ("KIC Raw Materials" program). New initiatives have been prepared in the Flemish region.

- With around 560 Mt/y of steel slag generated worldwide, the valorisation and re-use of slag is a key issue for the sustainability of the steel sector. The precise knowledge of the rheological characterisation of the slag is one of the important aspects impacting the slag properties and conditioning the development of new slag processing. In the frame of the "Reverse Metallurgy" project, a high temperature rheometer has been acquired by CRM, allowing to measure the viscosity and other properties of metal and slag at different temperatures between 600°C and 1650°C.

High temperature rheometer

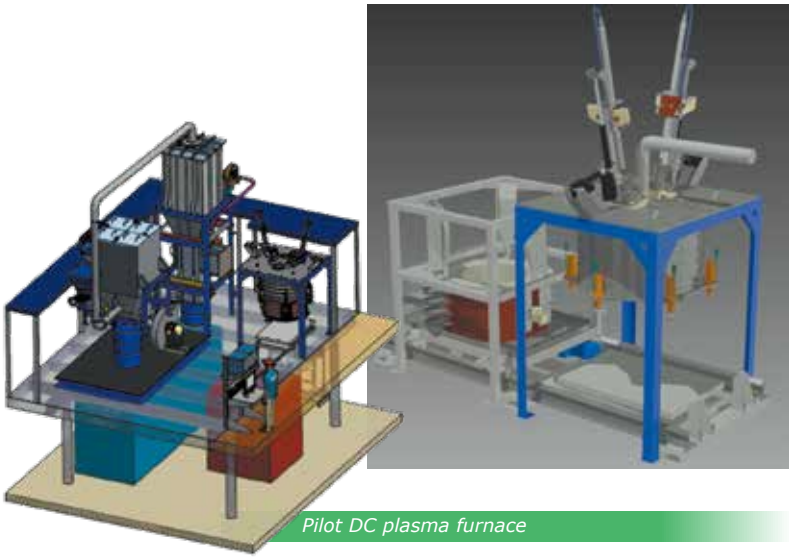


Evolution of the viscosity of a blast furnace slag with the temperature

AET furnace with sample weighing system

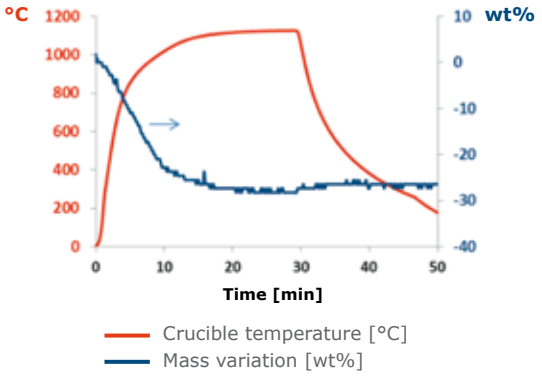
An example of viscosity measurements realized on a blast furnace slag is illustrated herewith.

• Another key equipment under final design and selection is a pilot DC plasma furnace. With a power of 300 kW and a volume capacity of 125 litres, this versatile furnace will allow the processing of slag and various other by-products coming from different industrial sectors. The furnace will be implemented on an industrial site adapted to the treatment of hazardous wastes.

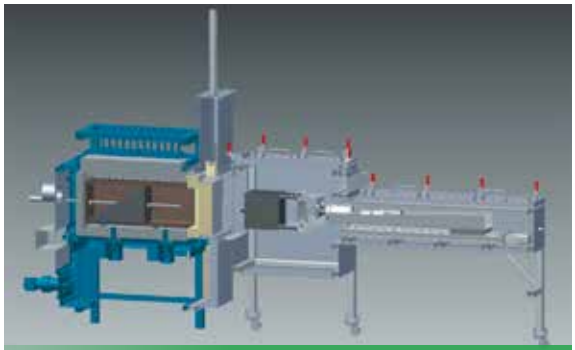


Pilot DC plasma furnace

• The appropriate treatment of Zn bearing dust and sludge remains another important issue for the steel industry. A first type of action is their pre-conditioning by hydro-cyclone to separate the coarse particles from the fines and to concentrate the fraction rich in zinc. Several cyclones are available with a cut size ranging from 3 to 100µm. A second action deals with their thermal processing to remove volatile elements and/or reduce oxidized elements. Dedicated furnaces are operational to study the behaviour of these by-products. On one of these furnaces, a continuous weighing of the sample allows to fully monitor the kinetics of the mass variations and the removal of the volatile



Weight evolution with temperature of Zn-bearing briquettes



Thermal furnace equipped with a mixture stirring system

elements. A second furnace is designed for realizing the same type of treatment but with a bigger weight of material mix (~20kg) that can be stirred during the high temperature processing.

• The treatment of oily by-products is a third critical aspect that is investigated using the "Huge" reactor (high pressure and temperature vessel). After a pre-conditioning and compaction on the material into briquettes, pilot tests of around 50 kg of products are conducted under oxidizing conditions by injecting a mixture of O_2 and CO_2 at a 15 bar pressure and 900 to 1000°C. This treatment eliminates the oil content (very low residual carbon level) and improves the mechanical resistance of the briquettes (the amount of fines generated during a drop test is divided by 5) favouring then their post-charging in a melting or reduction unit.

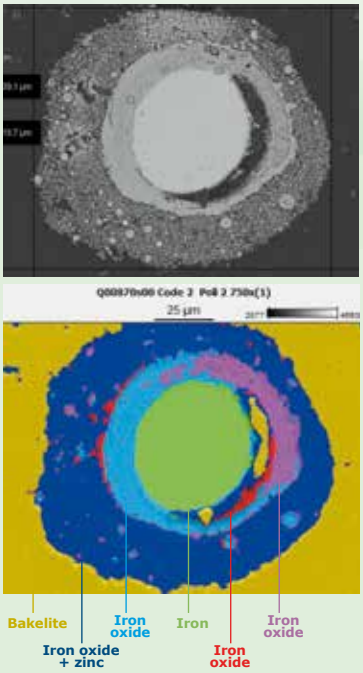
The HUGE reactor

Sludge briquettes after deoiling treatment

• The selection of the most adapted recycling method of by-products and wastes implies a deep knowledge of their morphology, structure and composition, a task becoming more complicated when involving very fine nano-sized particles and dust. A new methodology has been developed in the CRM laboratories by coupling SEM/EDX and Raman spectroscopy.

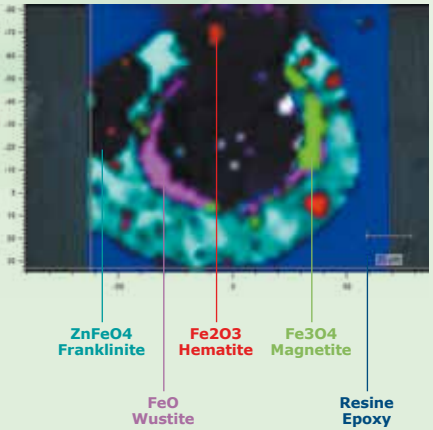
Besides the visual aspect given by the scanning electronic microscope of a particle cross-section, the EDX technique helps to determine the local chemical composition and gives a mapping of the phases present in the particle. In the considered example, one observes iron metal, iron oxide, iron oxide + zinc, iron oxide + calcium. The Raman imaging technique, more sensitive than EDX, allows to clearly identify the different oxide phases and their exact position in the particle. This powerful method is also of great help to understand the formation mechanisms of such particles.

SEM analysis



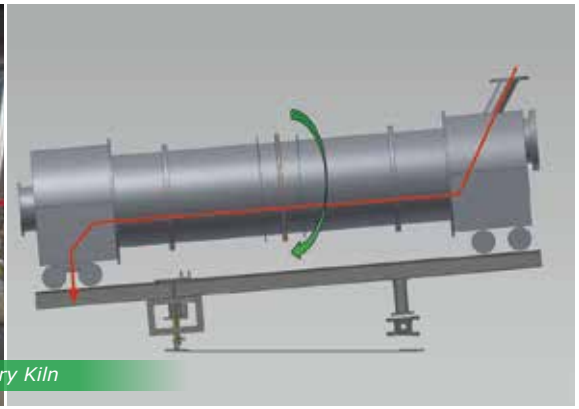
Raman mapping analysis

(fast streaming module)



Detailed analysis of fine dust particles

Briquettes produced with Fe-Mn residues



Rotary Kiln

At the European level, CRM is involved in 3 up-scaling projects within the "EIT Raw Materials" initiative:

• The mixing of by-products coming from different industrial sectors (ferro-manganese production, steel industry and car recycling) to valorize their metallic and organic content and deliver new added-value ferro-manganese alloys. In this project named "GO-4.0" and associating Eramet, Arcelormittal, Comet Traitements and Eurotab, CRM is more particularly charged with the cold preparation of briquettes and their further processing at high temperature in the pilot facilities such as the Rotary hearth furnace, the Multiple hearth furnace or the Rotary kiln in order to select the most profitable and efficient recycling technology. To be outlined is the recent revamping of the Rotary Kiln able to process granular solids, sludge or compacted dust at a temperature ranging between 800°C to 1300°C. The furnace inclination and the rotating speed can be adapted to treat 50 to 100 kg of solid material during up to 2 hours of processing time.

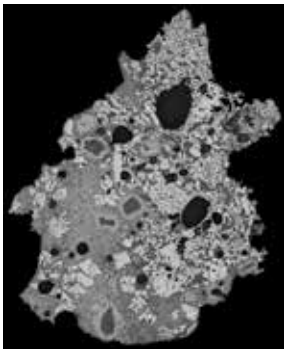
• The valorisation of bauxite residues and copper slag for transforming them into porous construction elements and fire-resistant materials is the scope of a second European project called "Recover". In this project, CRM is offering its competence in sintering of iron ores to treat a mix of these by-products and to obtain a semi-vitreous material applicable for inorganic polymer mortar such as shown through successful preliminary tests.

• The treatment with the "Hisarna" process of zinc-bearing by-products aiming to produce an enriched zinc dust suitable for direct use in Zn smelting furnace is the subject of the third project "Reclamet" coordinated by Tata Steel Europe.

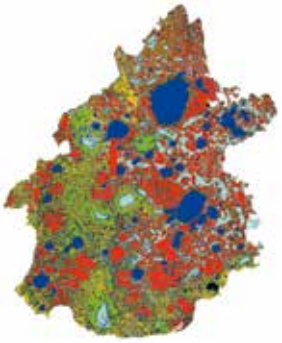
Transformation of bauxite residues into binder material

Innovative processing technologies:
From raw materials to final shaped products

With the aim to support the industrial members in the continuous improvement of the performances of their production routes and to allow substantial gains in terms of productivity, energy dependence, material yield and quality aspects, new processes, manufacturing technologies and control systems are proposed integrating the most recent progress of the digital evolution. The mastering of big pilot facilities located in the laboratories at Liège and Gent contributes to a faster development and up-scaling of the new technology solutions.



Raw image obtained by reflected light microscopy

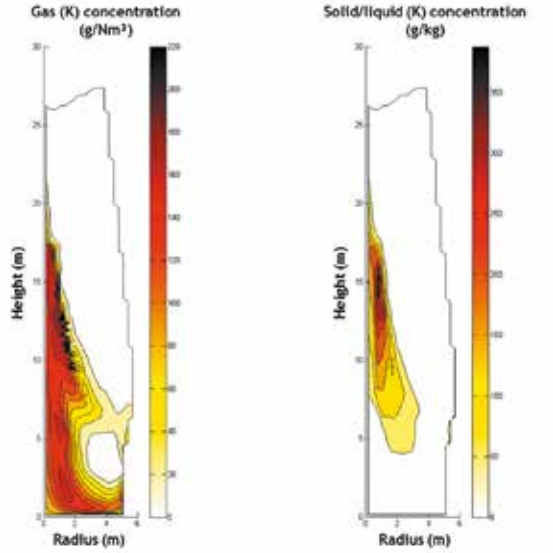


Mineralogical classification of phases: hematite (red), magnetite (green), porosity (blue), glass (cyan), SFCA (yellow)

Image processing for sinter mix characterisation

An illustration of significant results gained during the year 2017 is summarized hereunder for different technical fields.

- The sintering and blast furnace processes have been improved during the last years by a progressive adaptation of the quality of the iron ores and by the implementation of new technologies (hot air/waste gas recirculation in sintering, high rate of carbon injection at BF) for boosting their productivity and to comply with more and more stringent environmental regulations. This evolution needed the redefinition of the key performances indices (KPIs) associated to the raw materials for a better compliance of their quality with the new operating conditions. For supporting this evolution, enhanced characterization techniques have been developed inside the CRM laboratories notably for reaching a more precise assessment of the mineralogical phases present in the sinter mix.



Gaseous and solid/liquid Potassium concentrations profiles in BF

- In the blast furnace area, the MOGADOR model has been adapted to better predict the behaviour of the alkali components and their zones of concentration all along the blast furnace height and periphery. The next step of this upgrading will include the carbonates, silicates, zinc and cyanides components.

- The installation of two new pilot equipment, complementing the existing facilities for the preparation of the sinter mix and the pre-processing of by-products has to be pointed out: largely financed by the "Reverse metallurgy" project, they comprise a pelletizing disk (1.5 m of diameter) and a horizontal mixer (Ploughshare type), both located on a new platform.

Horizontal mixer

Pelletizing disk

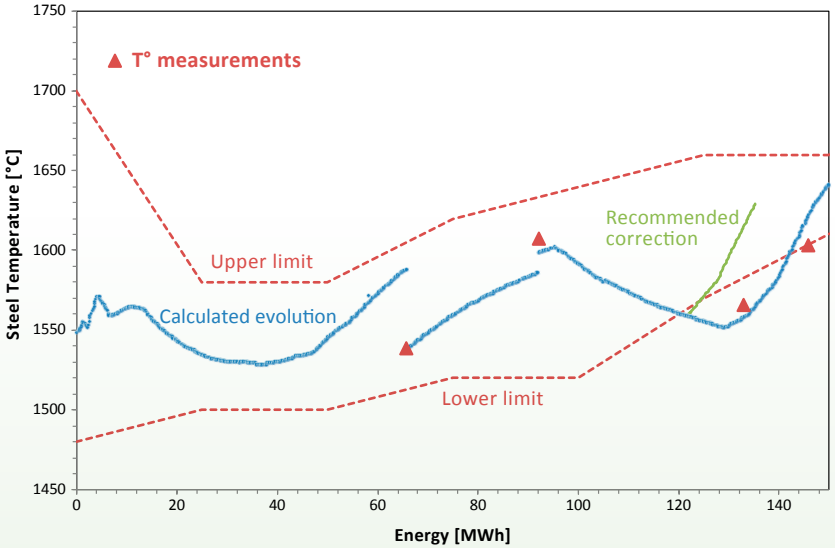
- The sintering pilot installation has been adapted to simulate the injection of high temperature fumes in the sintering process, through the introduction of a combustion chamber able to operate with different alternative combustibles.

The by-products and raw material pre-processing platform

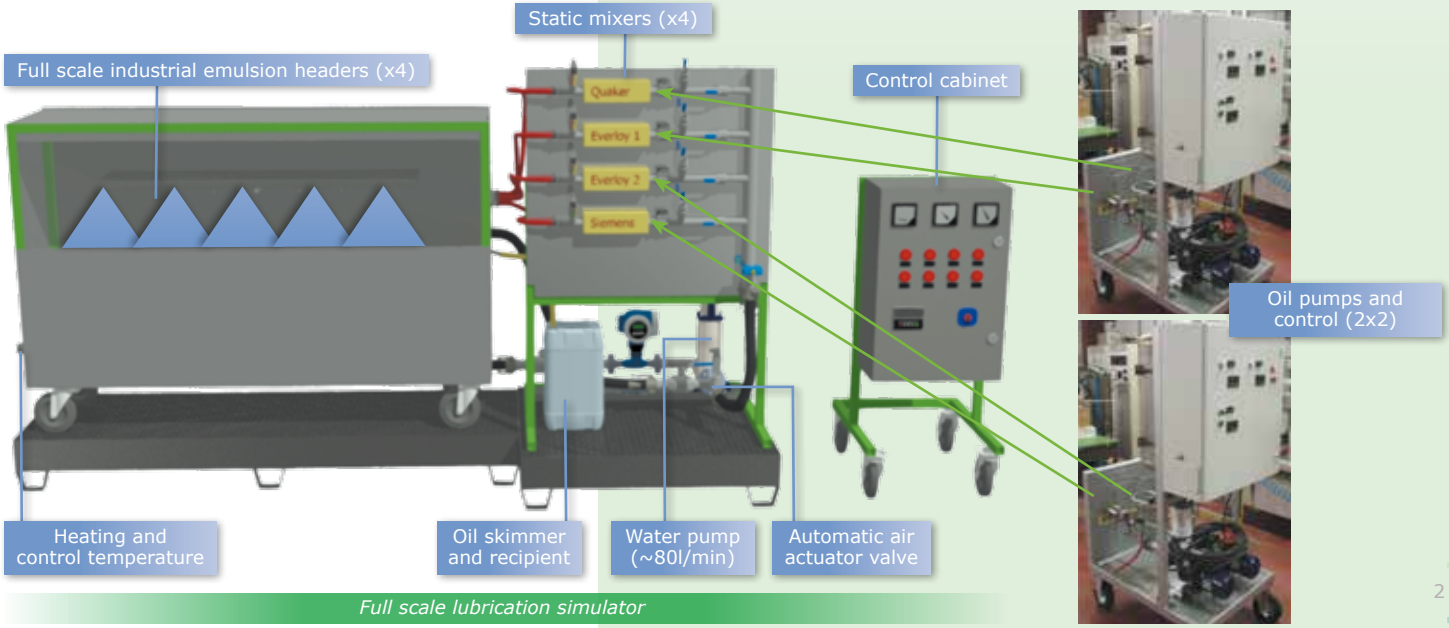
Sintering pilot station in hot gas injection configuration

- The EAF model developed by CRM is currently used as a guidance tool by the operators of the ArcelorMittal Lazaro Cardenas plant. The model is helpful to detect drifts from normal melt behaviour and to propose corrective actions. One of the main goals is to enhance the regularity of the melt temperature at tapping for assuring an optimal dephosphorisation of the steel.

- During the hot and cold rolling, the application of a lubricant is a key element to reduce the friction between the roll and the strip and consequently decrease the rolling forces with a very positive impact on the length of the rolling campaigns and the reduction of the strip surface defects. The processing of more and more hard steel grades requires to further enhance the performances and reliability of the lubrication system. In order to better support its industrial members and to cover the different types of existing installations, a new full scale versatile simulator has been built. It can operate with different nozzles and emulsions and is particularly useful to evaluate the mixing conditions and the clogging behaviour after long term trials. This will help the mill operators to define more precise guidelines on how to restrict the clogging issues and to improve the maintenance and rinsing instructions.



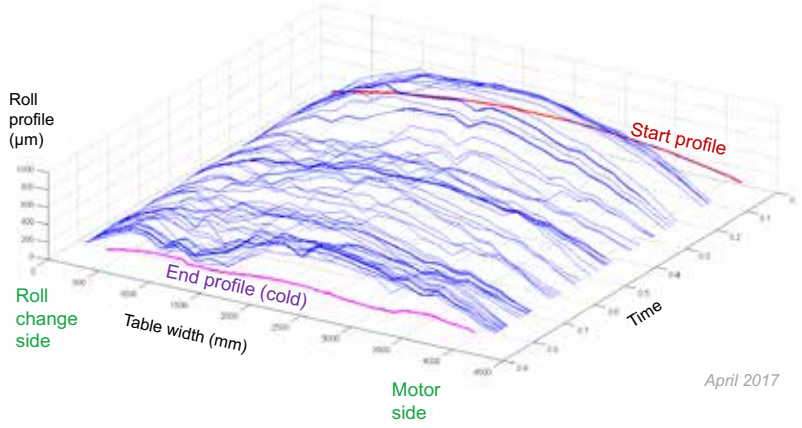
Dynamic follow-up of the EAF process



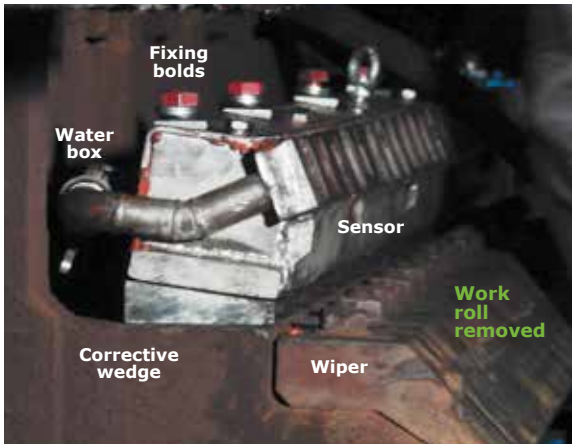
Full scale lubrication simulator

- In line with the more and more intensive application of digital solutions in metal processing and more precisely in the hot rolling operations, the development of the so-called "tablet" technology for assessing the work roll degradation has been pursued at the hot strip mill of ArcelorMittal Gent and initiated at Tata Steel IJmuiden. Using a robust "tablet" adapted to the harsh environment of the hot strip mill, a dedicated software prepared by CRM guides the operator for evaluating the roll state at the end of each campaign. The information is instantaneously transmitted to the mill network via a specific communication protocol.

- An accurate flatness control is a mandatory aspect when processing hot rolled products that are directly commercialized such as thin, medium or heavy plate. A key point is to master the crown of the work roll submitted to wear and thermal phenomena during hot rolling. CRM has developed an original device to continuously measure the roll profile during the rolling operations. It has been applied during long industrial campaign (6 weeks of continuous operation) at the ArcelorMittal Industeel plate mill (roll width of 4.2 m). Among the positive gained results, it has to be pointed out that the thermal crown observed when starting the rolling campaign is higher than anticipated. The measurement has been successfully used to adapt the rolling model applied by the plant.



Flatness measurements in plate mill



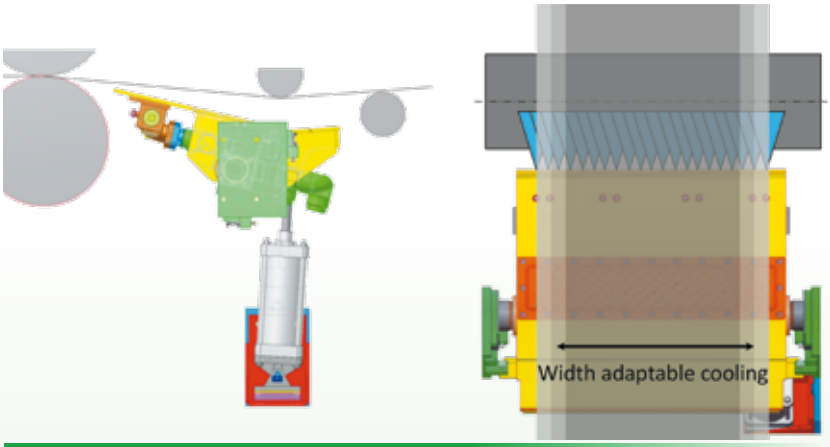
Flatness sensor at the Industeel plate mill

- With the objective to better appraise and simulate the oxidation phenomena occurring on metallic products when processed at high temperature, a new furnace has been acquired in 2017 in the frame of the MPC partnership between OCAS & CRM at Gent. Especially designed for loading/unloading large samples at high temperature, the equipment comprises an electrically heated chamber with a pneumatic lift door and a gas injection unit involving a humidifier. The furnace can operate at a temperature up to 1350°C with the possibility to inject N2 & O2 in a strictly controlled way and to vary the dew point between -7°C and +60°C.

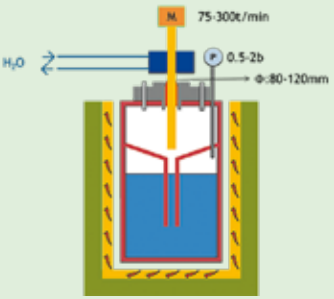
New oxidizing furnace

- After the successful implementation of a new strip cooling header nicknamed "WPC (Water Pillow Cushion)" in one of the cold strip mills of Tata Steel Europe at IJmuiden, an improved design equipped with a width regulation is under installation. Let us recall that with this system, the cooling is performed only on the bottom of the strip avoiding interference with the lubrication applied on the top side. It results in a much better surface quality whilst significantly reducing the rolling forces. The new design will better comply with the rolling of narrow to wide strip.

- Concerning the galvanization process, a major industrial target is to run the lines at higher speed. In this prospect, a key aspect is the improvement of the hardware and more especially the bearings in order to reach a smoother rotation of the immersed rolls whilst keeping a good strip surface quality and a low maintenance cost. A new concept of bearings is tested by CRM, based on the separation of the bearing and tightening functions. A dedicated simulator has been built to test this concept. A conventional high temperature bearing is placed on the top of a tight chamber containing liquid zinc. By increasing the pressure inside this chamber, the liquid zinc can rise until it makes contact with the upper part where the bearing is fixed. This upper part is drilled for letting the rotating roll shaft penetrating in the sealed chamber. The cooling of the shaft with water leads to solidification of zinc inside the bearing opening and assures in this way the sealing of the chamber simulating the zinc pot.



WPC strip cooling unit



Simulation of a new bearing concept in galvanizing

New strip stabilization in hot dip galvanizing

- The development of the patented stabilisation system aiming to reduce the vibration of the moving strip as it emerges from the galvanising bath has been pursued through pilot line campaigns. Thanks to several improvements introduced during the last year such as a more constant behaviour during the transitory phases (start-up phase, slow-down and weld passage more open-space let to the operators for the top bath skimming, finer tuning of the pass-line), a better damping effect is obtained leading to a more homogeneous control of the strip vibrations.

- In the field of the new emerging "hybrid & additive manufacturing", CRM has chosen to focus its effort on the production of large metallic parts as offering attractive opportunities for various industrial applications. A first action deals with the selection of the most appropriate technologies having to meet the following main criteria:

  - the necessity to be highly flexible and to adapt the treatment according to the part size or the area to be treated,
  - the manufacturing of different part size,
  - the implementation of a post-treatment to meet severe requirements in terms of bulk or surface properties,
  - the need to repair complex and expensive parts.

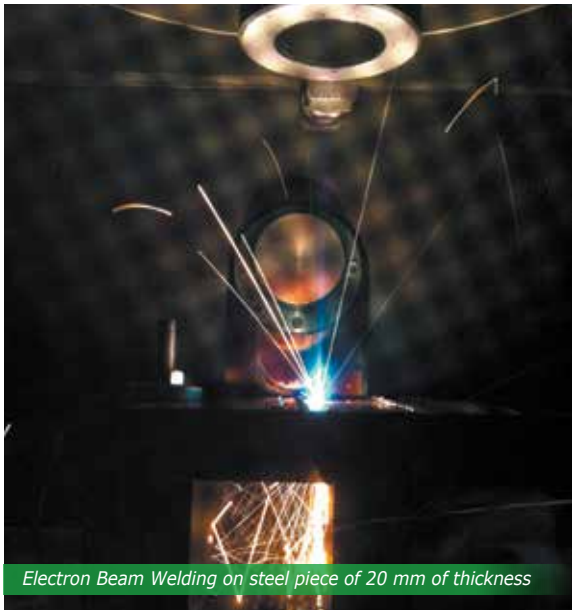
Robotized additive manufacturing

With the support of the European Fund for Regional Development (EFRD) and the Walloon Region, CRM Group will acquire a flexible multi-technique equipment for the direct metal deposition. Two techniques will be available : the wire arc additive manufacturing and laser additive manufacturing with powder and wire.

With the support of the Walloon Region, CRM is also actively involved in the validation and characterization of the metallic additive manufactured parts with the aim to transfer the acquired know-how to the Regional Economy.

Thanks to the integration of CEWAC, additional welding, joining and assembling technologies complement the panel of equipment useful for the manufacturing of complex and/or multi-metal pieces.

Welding processes such as arc, friction, friction & stir, resistance (spot & seam), laser beam or electron beam are available not only to support more conventional applications but also to contribute to the design and development of new manufacturing routes and associated products.



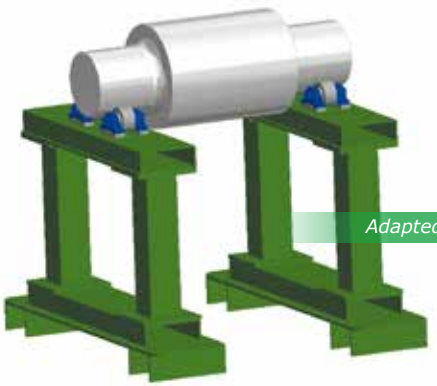
Electron Beam Welding on steel piece of 20 mm of thickness

New advanced metallic materials and solutions with tailor-made properties

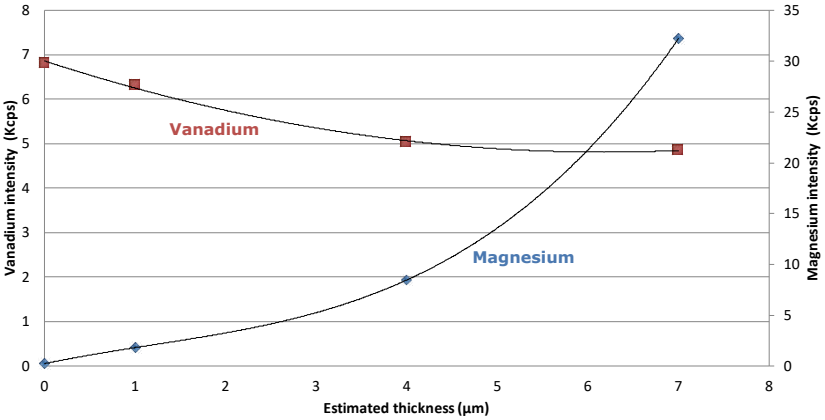
The search for innovative metallurgical routes and new processing or manufacturing approaches, leading to supply the market with more attractive and efficient products notably in term of improved properties or lower production cost, is a permanent preoccupation of the steel and metal industry to which CRM is actively contributing, based on its long-term expertise in the field and the management of unique experimental processing and testing equipment.

Laser cladding with powder refiller

• A dedicated project is for applying the laser cladding process to the manufacturing of work rolls for the hot strip mill showing enhanced properties. A pilot equipment has been installed in that prospect in an industrial hall of Marichal Ketin. The powder feeder of this laser-cladding pilot equipment has been adapted with a refilling system for enabling long duration continuous laser-cladding campaign (10-15h). In order to produce small diameter rolls (from 100 to 450 mm in diameter and 1 m in length) to be tested in the CRM pilot hot rolling line, an adapted supporting system has been designed to fit with the existing laser cladding unit.



Adapted roll support

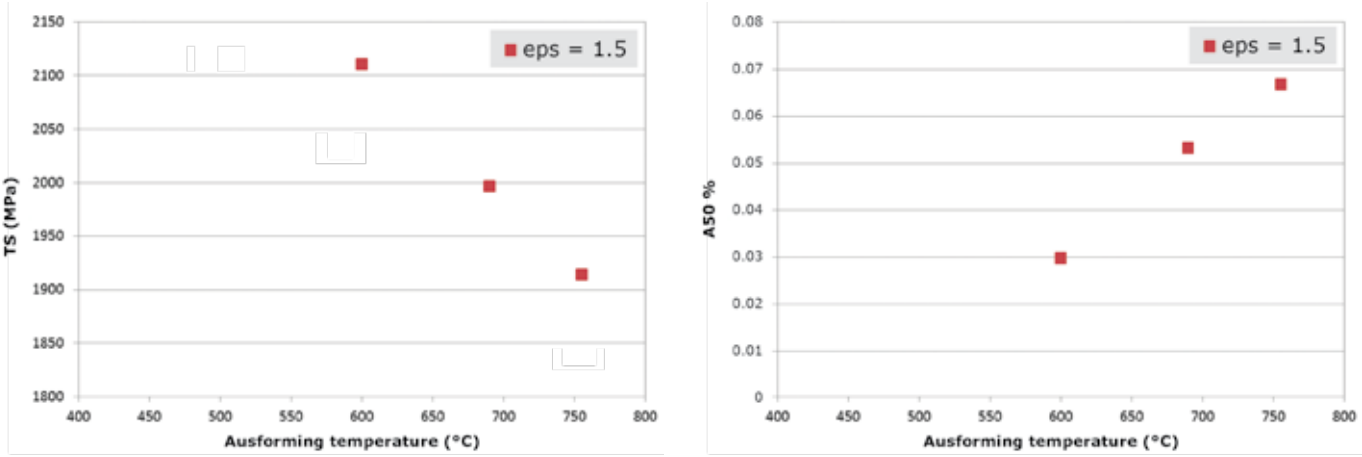


Work roll oxide thickness measurement by XRF

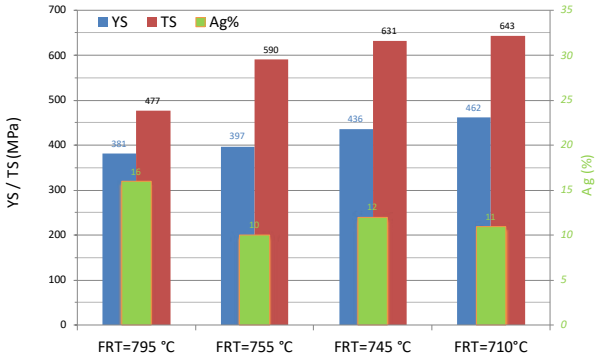
Associated to the development of new HSS work rolls and the characterization of their behaviour under oxidizing conditions, a non-destructive method using a XRF device is proposed by CRM to measure the oxide thickness formed on the work roll during the rolling operations. Determining the level of an element normally not present in the roll material but well in the cooling water (such as Magnesium) allows to evaluate the thickness of the oxide layer considering that the more the oxide layer is growing, the more the Mg level increases. The comparison with the evolution of an element present in the roll material (such as Vanadium in this case) shows a certain dilution due to the progressive oxidation of the roll but confirms indeed that the measurement concerns the base material. This method will be further extended for application to a wider range of roll materials by establishing such type of pre-set calibration curve.

- The expertise of CRM in physical metallurgy and process-products interactions is applied for developing or improving new generic concepts of advanced steel grades and their associated applications.

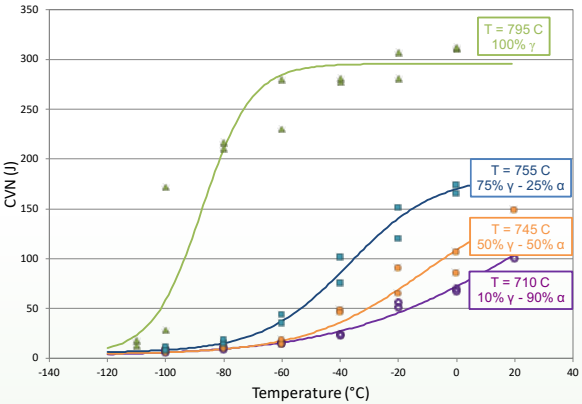
Based on the "ausforming" approach where a high deformation of the metastable austenite is applied during the hot rolling at relatively low temperature, ultra high strength steel can be produced. When rolling such type of steel grades below 700°C under several deformation passes cumulating a sufficient deformation rate, a tensile strength of more than 2000 MPa can be obtained whilst keeping a very satisfactory elongation rate of 2 to 5% without showing brittle fracture aspects. The strengthening results from a combination of the grain size refinement of the formed martensite and the inheritance of the dislocations accumulated in austenite before its transformation in martensite.



Evolution of the Tensile Strength and Elongation with the Ausforming temperature



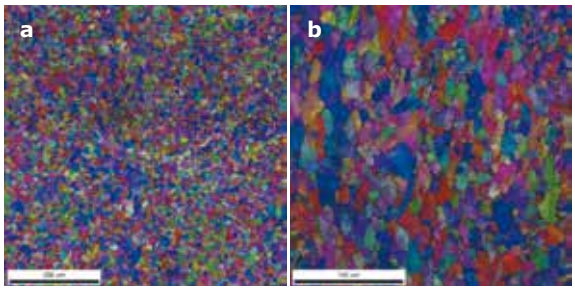
Tensile properties (transverse direction)



Charpy impact toughness of 12 mm-thick plates as function of the finish rolling temperature (FRT) - accelerated cooling strategy

Another example of product-process oriented projects concerns heavy plate and the balance between strength and toughness. Due to their high thickness, the plates are often (at least partially) rolled in the two-phase region (co-existence of austenite and ferrite in the microstructure) since a large temperature gradient exists over both thickness and width. This intercritical rolling is applied during the last rolling step by decreasing the final rolling temperature (FRT) with the aim to increase the product strength. Numerous pilot rolling campaigns conducted at CRM Gent have confirmed that such a type of intercritical rolling (with a 25% reduction rate during the last pass) effectively increases the yield strength (+80MPa for a conventional structural steel grade). However, the toughness properties are adversely reduced due to the presence of deformed ferrite in the microstructure. Compared to the austenitic rolling, leading to a fine ferrite microstructure, the intercritical rolling delivers large and deformed ferrite grains, less prone to high toughness performances. This practice is nevertheless an easy and cheap solution to obtain higher strength when the toughness requirement is not critical.

Aiming to explore the options offered by the use or combination of high melting point metals, a new laboratory arc melter has been installed at Gent within the MPC collaboration. Besides the reaching of very high temperatures, the equipment allows



EBSD mapping of plates rolled and accelerated cooled: (a) FRT=795°C –austenitic rolling; (b) FRT=745°C (intercritical rolling: 50% austenite, 50% ferrite)

New laboratory arc melter

Multipurpose Dynamic Annealing simulator

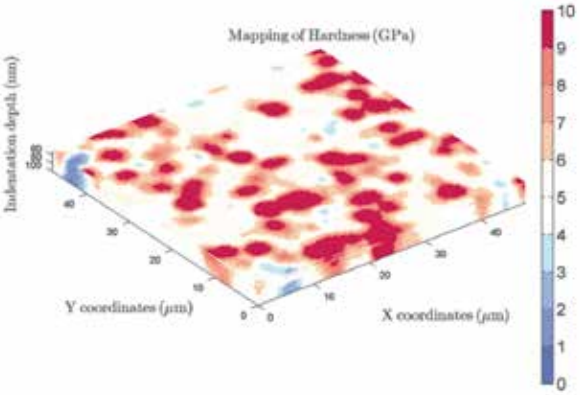
to melt materials very sensitive to oxidation under pure inert atmosphere (N2, Ar). A charge of around 400 gr can be directly molten in the arc in different crucible mould. The melting can be monitored by camera.

To be also mentioned that the Multipurpose Dynamic Annealing simulator (MDA) installed at CRM Gent has been modified to enhance its abilities to simulate complex thermal cycles such as those aimed at for the new steel generations. An upgraded lamp furnace allows to reach heating speed of 20°C/s.mm up to a max. temperature of 950°C. Higher speed and temperature can be reached with a transverse flux induction heater. The cooling section has also been adapted to better control the stop quench temperature at different cooling rates (<50°C/s.mm up to 200°C/s.mm).

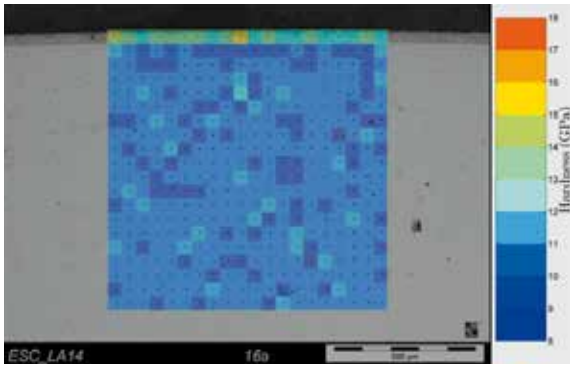
Shaft with ring-shaped samples for lab-scale rolling trials.

The replacement of "Hard Chrome" in many applications continues to be an item of preoccupation for the industry considering the progressive banning of CrVI as coating element. Substitution solutions are searched notably through the use of electroplated "CerMet" coatings. A first example of possible application concerns the rolls used for the cold rolling of steel strip. CRM is developing appropriate techniques to obtain a coating with hardness and wear performances matching as closely as possible those of the hard chrome solution. Large size samples are produced with these techniques in order to be tested in real rolling conditions. A second example based on the same approach concerns the manufacturing of hydraulic components that is managed inside a M-ERANET project supported by DGO6 (Walloon Region) and nicknamed "HEI-Coat".

For supporting the development of very thin coating solutions on metallic substrates and the characterisation of their surface mechanical properties, an innovative approach based on nano-indentation experiments has been developed by CRM in the frame of a post-doctorate project promoted by DGO6 (BEWARE program of the Walloon Region). A dedicated and sophisticated software, implemented in the MatLab environment allows to combine a 3D mapping of mechanical properties (hardness



Representation of 4D nano-hardness map for an electroplated Ni–SiC coating on steel



Nano-indentation map of a steel roll with a CerMet coating

measurements at the nano-scale) and correlation with microstructural images. An example of such a mapping is illustrated for a particle-reinforced metallic matrix composite coating and for a CerMet coating on a steel roll. This method is a new way to analyse nano-indentation measurement by applying an automatic correlation procedure between mechanical properties (hardness) and microstructure maps through a more reliable quantification and identification of the properties of each present phases.

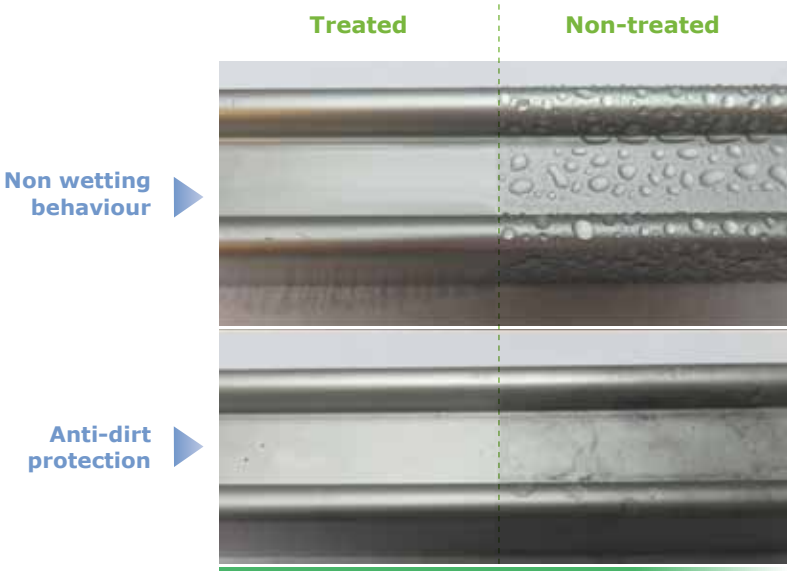
- CRM is actively contributing to the ILZRO (International Lead Zinc Research Organisation) program via two thematic projects:
  - the first one takes an in-depth look at the problem of Hydrogen solubility in high strength steels with the target to extend past examinations of hydrogen effects in high strength steel grades
  - the second project aims to explore the limits of wettability of AHSS grades, primarily focusing on steels that have been prepared using an oxidation-reduction treatment prior hot dipping
- In the frame of the project "Solar Focus", supported by the Walloon Region and managed by CMI and Advanced Coating, CRM is involved in the design of a high temperature solar absorbing coating dedicated to the new generation of Central Towers Receivers. Compared to the solution applied today in the Solar Towers, the new coating obtained by thermal spraying enables a long-term use at a temperature higher than 750°C.

Another major development in line with the production of energy concerns the manufacturing of photovoltaic cells deposited on steel substrate for equipping on a large panel the roof of industrial or domestic buildings. Through a strong and close collaboration with ArcelorMittal, this project nicknamed "PHOSTER" has been realized with the financial support of the European Commission (Life + program) and has largely used the pilot coating facilities located at CRM in a "clean room", to manufacture complete steel strip coils.

Prototype of a photovoltaic PHOSTER roof

Pilot line for manufacturing photovoltaic cells on steel strip coil

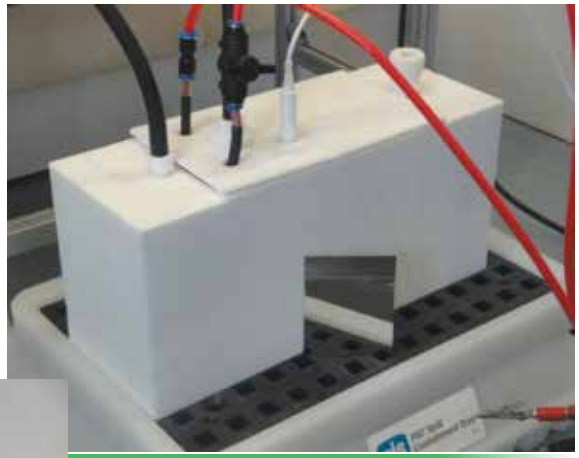
• With the aim to give additional functionalities to coated metallic products, let us mention the application of specific sol-gel solutions on aluminium profiles in order to confer them non-wetting and anti-dirt properties.



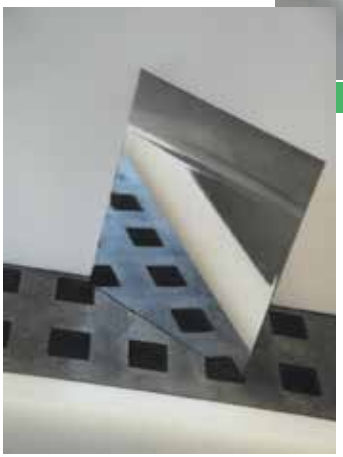
Ultra thin coating on Aluminum profiles

Within the development of the new additive manufacturing approaches, a great care will be required to deliver products with a very high quality of surface finishing. As possible post-treatment options, CRM is looking further into the application of advanced electro-polishing techniques on both 2D (thin metallic films used in micro-electronics) and 3D components (for instance optical tool inserts in injection moulding). A dedicated electro-polishing cell has been erected for that purpose with the support of the DGO6 and the CORNET program.

The competence of CRM in this field is also valorized in the frame of different projects sponsored by ESA (European Space Agency) with, as a relevant example, the chemical polishing of Aluminium and Invar parts produced by additive manufacturing.



Laboratory-scale electropolishing cell

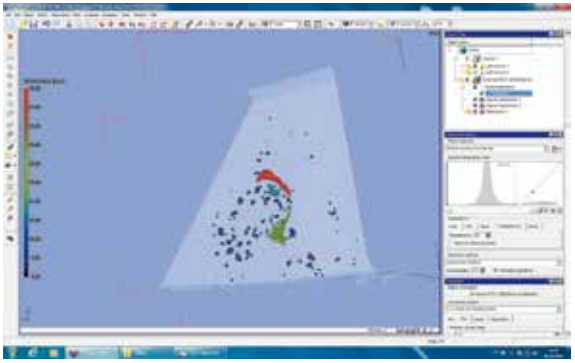


Technical support, valorisation & dissemination
to industry and regional economy

As a collective research centre, certified by the Belgian Public Authorities, CRM offers to the industrial members and non-members and to the regional economy its expertise and the access to unique characterisation/ testing equipment. The dissemination of the acquired knowledge and the promotion/application of its own development are also part of its missions.

With the integration of CEWAC into the CRM organisation, new testing facilities (mostly certified ISO 17025) and linked competences have substantially enlarged the support of the Group towards its members, partners and customers.

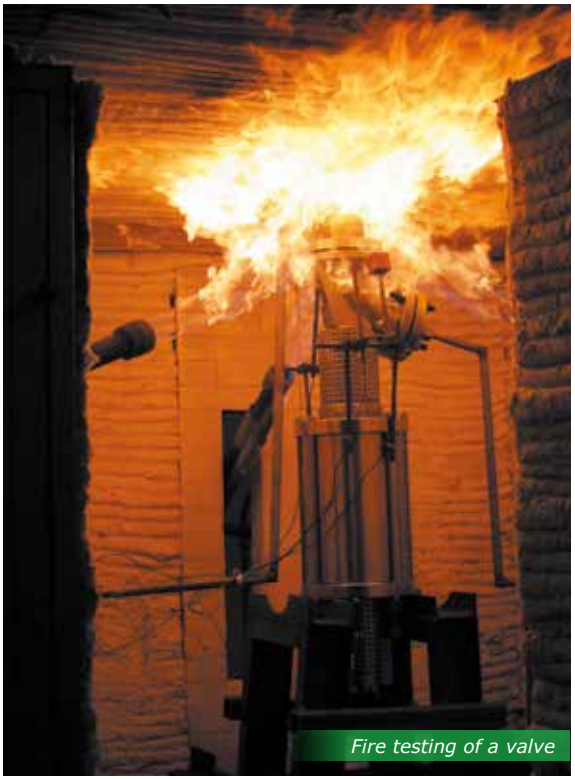
A first example concerns the non-destructive testing laboratory equipped with various techniques that can be applied in-house or on site depending on the request of the customer. To be especially mentioned is the inspection of large parts or specimen by penetrant, magnetic or radiographic measurement. The last one includes digital radiography and tomography, a very helpful technique for complex parts.



Example of a tomography analysis

Are also available : the ultrasonic testing (including Phased Array), the visual and endoscopic inspection as well as the Helium leak testing. All the operators are qualified according to ASNT and EN standards to perform the tests.

A second example is illustrated by the industrial hydraulics laboratory allowing to study and optimize the fluid flow working conditions of valves, pumps, separators, filters and to simulate their behaviour under extreme working conditions: from low to high temperature like in fire conditions, high or low pressure, static or cyclic solicitation.



Fire testing of a valve

For what concerns the simulation in fire conditions, this complements the facilities already available at CRM and recently upgraded in line with the European harmonized classification. It comprises a small flame impingement test (EN 11925-2 standard) now certified ISO 17025, a calorimetric bomb (EN 1716 standard), a small scale fire resistance furnace and a SBI (Single Burning Item). The two last equipment are more particularly devoted to assess, in a quick and cheap way, the fire behaviour of building components such as column or panel.

Strain gage measurement

Small flame impingement test

Single Burning Item (SBI)

In most of the common structural materials like iron, steel or concrete, one can observe the presence of very small internal deformations (strains) also causing **internal stresses** that can affect the properties and behaviour of the structure. For measuring such small strains, electrical resistance strain gages are the most commonly used technique. Strains gages can be placed on various structural components, on critical parts of machineries or even on smaller objects. Special gages and data treatment techniques also enable the measurement of residual stresses resulting from any manufacturing process implying a temperature gradient or a plastic deformation. CRM has developed a high competence in the application of the internal stresses measurements and their interpretation. As an example of recent application, let us mention the measurement campaign realized on the bolts used to fix the door of a large lock.

Strain measurement on a large lock door

Strain measurement on large buiding structure

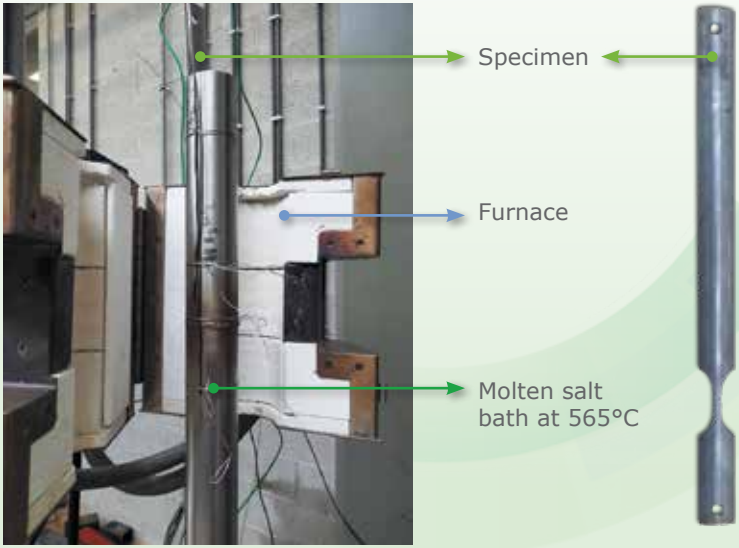
Another example deals with the testing of large panels submitted to a strong deformation.

The assessment of the **fatigue resistance** is largely requested to determine the behaviour of pieces, metal parts or mechanical assemblies under periodic stress solicitations, similar to those prevailing in service and applications.

The equipment available at CRM have been completely revamped and have extended their testing abilities to high temperature (up to 900°C) and to corrosive and aggressive environment such as molten salt bath. It is possible to combine the two options such as shown in the picture where a sample is submitted to controlled stress cycles in a molten salt bath at a temperature of 565°C.

Fatigue testing at high temperature

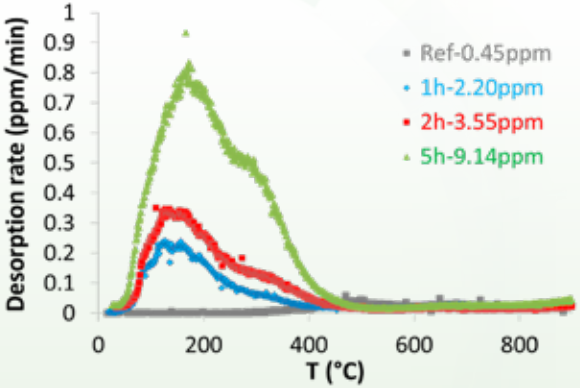
Fatigue testing



Fatigue testing in corrosive medium

The problem induced by the **hydrogen embrittlement** of metallic components and their resulting cracking in service continues to be followed by CRM, notably using the dedicated Thermal Desorption Analyser (TDA). This technique is now certified ISO 17025 for the quantification of diffusible hydrogen in various steel grades including electro-galvanised steels. The diffusible hydrogen is measured by mass spectrometry. To illustrate this competence, developed with the support of the Beware program financed by the Walloon Region (DGO6), let us mention the case of the

high strength "Maraging" steels largely used in the aeronautic sector. The effect of the temperature on the desorption rate of the hydrogen preliminary charged in the material can be specifically determined.



Measurement of diffusible hydrogen in "Maraging" grade

It is also helpful to recall the financial support granted by the Walloon region to SME's for their development studies ordered to a certified research centre like CRM. This initiative called "Chèques entreprises" is now managed by the non-profit organisation "CEQUAL" (Centre Wallon de la Qualité www.cequal.be) such as recently decided by the Walloon Government.

During the year 2017, CRM has participated to different events, seminars, congresses, workshops and fairs.

To be particularly pointed out are:

• On February 3, 2017, his Majesty King Philippe of Belgium has officially inaugurated a new production line "the Jet Vapour Deposition (JVD) line" at ArcelorMittal Liège. This event was the culminating step of years of R&D by ArcelorMittal and the CRM Group to create a new, breakthrough technology for the metallic coating of steel.

The official inauguration of the JVD line

• The "Métamorphoses" fair dedicated to new materials and manufacturing approaches was held on March 28 & 29, 2017 in Marche-en-Famenne.

• The information session on the "3D printing" was organized by Flam3D on May 9, 2017 in Sint-Truiden.

• On May 30 & 31 in Liège, there was the seminar "Active Envelopes for Positive and Environmental friendly Buildings".

• The "Materials Market SIM" User Forum took place in Antwerp on June 5th, 2017.

• The workshop on "Surface Engineering" (Material Technology Day) was held in Liège on October 24, 2017.

• The workshop on the "Innovation in Wallonia by the Additive Manufacturing Technologies (IAWATHA)" was organized on November 20, 2017 in Liège.

• Since several decades, CRM Group is actively participating to associations, organisations and networking aiming to exchange and share experience at the National and International level where its expertise and competence in the manufacturing and processing of metallic materials are largely recognised.

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

UCRC (Union of Collective Research Centres): The association representing at the Federal level the Belgian collective research organisations.

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.

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

CReSus (Centre for Resource Efficiency and Sustainability): A common initiative of CRM and ULg/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.

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.

- 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).

Together with ULg 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. More info : 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). More info : www.metnet.eu

The four independent European steel research institutes (CRM, CSM, Swerea MEFOS 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.

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*

Publications & Conferences 2017

METAL PRODUCTION, RECYCLING AND ENERGY

AWARD

AIST 2017 Rolls Technology Best Paper Award
A. Brown, J. Sychterz, P.H. Bolt, M. Krugla, S. Sengo, M. Rijnders, A. Scholes, E. Mathey, G. Walmag, O. Lemaire, J. Malbrancke
Development of Tailored Roll Grade Materials for the Early Stands of Finishing Hot Mills.

PUBLICATIONS

V. Piret, M. Lopes
Enhancement of the EAF dust recycling in self reducing briquettes by controlling their hydration behaviour
Proceedings of the 3rd ESTAD conference, Vienna, 26-29 June 2017

J.C. Pierret, C. Ojeda, P. Nyssen, J.C. Baumert, J.C. Thibaut, M. Lowry, F. Lopez, R. Lule, C. Chacon, J. Mendosa, R. Warmbold
Adaptation of CRM EAF model for 100% DRI charging and implementation at Lazaro-Cardenas plant
Proceedings of the 3rd ESTAD conference, Vienna, 26-29 June 2017

J.F. Stumper, R. Mancini, R. Lin, R. Soulignac
Liquid levels measurement in the blast furnace using strain gauges
Proceedings of the 3rd ESTAD conference, Vienna, 26-29 June 2017

R.J. Contreras, N. Berger, E. Izard, J.F. Douce, A. Koltsov, J.-Y. Delenne, E. Azema, S. Nezamabadi, F. van Loo, R. Pellenq, F. Radjai
Cohesive strength of iron ore granules
Proceedings of the 8th International Conference on Micromechanics on Granular Media, Montpellier, 3-7 July 2017

J. Malbrancke, H. Uijtdebroeks, L. Vanhulle, T. De Vriendt
Introduction of tablets for work roll evaluation
3rd ESTAD «European Steel technology & Applications Days», June 26-29, 2017, Vienna

B. Vervaet, M. Nicholls, C. Pelletier, L. Jacobs, V. Masaguer Torres
Hot strip mill roll gap lubrication with low cost green oils and waste oils
3rd ESTAD «European Steel technology & Applications Days», June 26-29, 2017, Vienna

S. Flament, G. Walmag, O. Lemaire, M. Sinnaeve
Characterizations, modelling and lab trials assisting the development of a graphitic HSS work roll for rear finishing stands
3rd ESTAD «European Steel technology & Applications Days», June 26-29, 2017, Vienna

M. Caruso, B. Pohu
Process parameters for the production of steel roll-bonded multilayer plates and strips
3rd ESTAD «European Steel technology & Applications Days», June 26-29, 2017, Vienna

P. Huyghe, L. Malet, M. Caruso, C. Georges, S. Godet
On the relationship between the multiphase microstructure and the mechanical properties of a 0.2C quenched and partitioned steel
Materials Science & Engineering A 701 (2017) 254–263

F.D. Duminica, R. Belchi, L. Libralesso, D. Mercier
Investigation of Cr(N)/DLC multilayer coatings elaborated by PVD for high wear resistance and low friction applications
Surface and Coatings Technology, Vol. 337, pp. 396-403 2018

J. Mahy, G. Léonard, S. Pirard, D. Wicky, A. Daniel, C. Archambeau, D. Liquet, B. Heinrichs
Aqueous sol- gel synthesis and film deposition methods for the large-scale manufacture of coated steel with self-cleaning properties
Journal of Sol-Gel Science and Technology, 2017, 81 (1), 27-35.

A. Daniel, C. Archambeau
Le secteur des transports : de nouvelles applications pour les films minces fonctionnels
Numéro thématique VOM Info juin 2017.

D. Mercier et al.
Microstructural and mechanical characterization of electroplated Nickel matrix composite coating
Surface Engineering, 2018

D. Mercier et al.
Mechanical characterization of an electroplated nickel matrix composite coating
Matériaux & Techniques, 105(1), 2017

CONFERENCES

D. Espinosa
Innovative shot blasting process to remove scale
Seminar on Oxide scale formation and flexible descaling during steel processing, 23 November 2017, Düsseldorf

S. Flament, G. Walmag, O. Lemaire, M. Sinnaeve
Development of a new grade for rear finishing stands based on modeling and evaluation of specific degradations,
AISTech 2017 The Iron & Steel Technology Conference and Exposition, 8-11 May 2017, Nashville, USA

S. Flament, G. Walmag, O. Lemaire, M. Sinnaeve
Characterizations, Modeling and Lab Trials Assisting The Development of a graphitic, HSS Work Roll for Rear Finishing Stands
Saruc 2017: South African roll users conference, Oct. 2017, Vanderblijkpark Gauteng, South Africa

J.-L. Collet, M. Caruso, I. Tolleneer, C. Georges, S. Cobo, L. Bracke, S. Van Bohemen, L. Morsdorf
New Metallurgical Tools for optimum design of modern Ultra High Strength Low Carbon Martensitic Steels
Journées Annuelles de la SF2M, 23-25 Octobre 2017, Villeurbanne

N. Nutal, G. Walmag, F. Duminica, S. Lecraz, C. Georges
Metal additive manufacturing is not only a question of manufacturing
BIL/NIL Lassymposium, Antwerpen

C. Dessart, B. Nabi, C. Georges, B. Vertruyen
Measurement of hydrogen in titanium alloys by thermal desorption technique
Hydrogen and metals, Royal Society, UK

M. Mandy, C. Georges, P. Drillet, T. Sturel, P. Jacques
Study of the hydrogen introduction in bare and Al-Si coated steels during the hot stamping process,
Hydrogen and metals, Royal Society, UK

O. Hubert, C. Georges, S. Cobo, P.J. Jacques
Interactions between diffusible hydrogen and the microstructure of third generation steels with a bainite-martensite matrix exhibiting a TRIP effect,
Hydrogen and metals, Royal Society, UK

O. Hubert, C. Georges, S. Cobo, P.J. Jacques
Interactions between diffusible hydrogen and martensitic/bainitic model microstructure in low and high carbon steels
Conception d'alliages métalliques , Aussois, 2017

C. Georges, T. Sturel, P. Drillet, J.M. Mataigne, D. Cornette
Identified influencing factors to control to remove any hydrogen-induced delayed fracture risk on Usibor® 1500 parts
CHS2-2017

C. Georges, B. Colinet, T. Sturel, C. Allely, V. Lhoist, D. Cornette
Development of electro galvanized AHSS with tensile strength ranging from 1200 to 1500MPa for automotive application with no risk of delayed fracture
Galvatech 2017

S. Reuter, C. Georges, P.J. Jacques
Optimisation of the corrosion rate of iron-based alloys for bioresorbable stent applications by surface acidification
Eurocorr 2017

S. Reuter, C. Georges, P.J. Jacques
Study of the corrosion rate of iron-based alloys for bioresorbable stent applications by surface acidification
Biomedical materials 2017

J.-F. Vanhumbeeck, D. Mercier
Microstructural and mechanical characterization of an electroplated Nickel matrix composite coating
Oral presentation, XXXI International Conference on Surface Modification Technologies (SMT31) JULY 5-7, 2017, MONS, BELGIUM

J.-F. Vanhumbeeck, D. Mercier
On the influence of pulse parameters on the chemistry and performances of wear-resistant electrodeposited Fe-C coatings
Oral presentation, XXXI International Conference on Surface Modification Technologies (SMT31) JULY 5-7, 2017, MONS, BELGIUM

J.-F. Vanhumbeeck, A. Denoirjean
Elaboration of Cermet coatings by electroplating and spraying techniques
Oral presentation, 6th CeramicNetwork, 2017 June 7-8, Limoges, France

M. Larnicol, N. Nutal, J. Crahay, J.-P. Collette
Phase Change Materials; Investigating new applications emerging from an ESA project
Oral presentation, 2017 June 7, ESA Technology Transfert day, Gembloux, Belgium

R. Clausius, M. Gremling
ArcelorMittal MASH TL5 Steel Median Barrier
International Roadside Safety Conference, June 14th 2017, USA

R. Clausius, M. Gremling
New Zinc-Aluminum-Magnesium (ZM) Metallic Coating for Guardrails
International Roadside Safety Conference, June 12th 2017, USA

C. Cofano
Co-Engineering activities overview
Steel Solutions Day ArcelorMittal CLN, June 2017, Italy

C. Cofano
Développement de nouvelles solutions performantes et compétitives pour la sécurité routière
Congrès Belge de la Route, October 2017, Belgique

P. Lepense, C. Cofano
Sustainability: Environmental Product Declarations for road restraint systems
STA Annual meeting, November 2017, Belgium

F. Delcuve
ArcelorMittal Global R&D capabilities for innovation in steel building envelope - From performance qualification to digitalization
11th European congress on sandwich panels and profiles on 19th and 20th of October 2017 in Hamburg.

J. Matias de Paula Filho
Steel engineering – retour à la simplicité – l'Orange Book et autres
Journée Construction Acier 2017 : en route vers la troisième révolution industrielle, 7 novembre, La Chambre de Commerce à Luxembourg, Présentations orales.

POSTERS

Mechanical properties and decohesion of sol-gel coatings on metallic and glass susbtrates,
SMT31 (Mons, Belgique, 07/2017) 2nd best poster award

Mechanical properties and decohesion of sol-gel coatings on metallic and glass substrates,
Indentation 2014 (Liège, Belgique, 09/2017)

Up-scaling of hydrophilic water-based coatings for easy-to-clean and anti-staining applications,
19th International Sol Gel Conference, Liège

Pilot lines dedicated to the transfer of sol gel products for the development of dielectric barrier on steel for energy and optoelectronic applications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