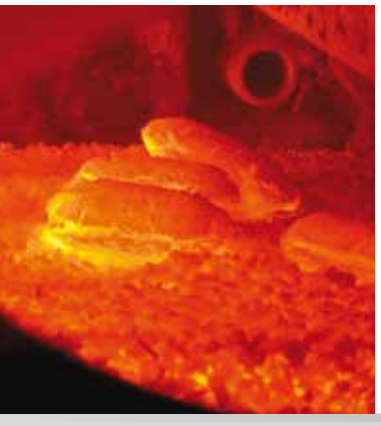
CRM GROUP

Annual Report 2014




Production

Recycling Applications

CLOSING THE VALUE CHAIN OF METALS

D/2014/0124/1

Contents

Foreword

The CRM Group provides solutions in the field of R&D, technology and innovation in the scope of metal production, transformation, coatings, applications and process engineering solutions. It is supported by more than 45 large industrial members: international steel groups (ArcelorMittal and TataSteel), metal producers and industries with a metal-related activity. Within this group, the CRM non-for-profit organization (asbl/vzw) keeps its statutes, such as collective centre (equivalent to a so-called "De Groote" Centre), accredited research centre ("Centre agréé" as recognized by the Walloon Region) and therefore is eligible to subsidy mechanisms from the European Commission as well as from the Federal and the Regional authorities.

Health and safety remains the top priority at CRM Group. Internal and external audits, systematic risk analysis, training and management presence in the laboratories and pilot facilities are examples of the practices being deployed to foster and further reinforce the safety culture within the Group.

In February 2014, the take-over of the activities of "Eco Techno Pôle de Wallonie" (ETP-W) by CRM was finalised. ETP-W operates several pilot facilities: thermo-conversion pilot plant, fluidised bed boiler, fluidisation bench test and circulating fluidised bed pilot plant. The integration of these tools is a unique opportunity for CRM Group to increase synergies with the existing pilot facilities, and to develop new activities in line with the strategy of the Group for the benefit of the CRM industrial members. The running R&D activities are focused on the conversion of waste into energy, the energy production from biomass and the recovery of metals including the treatment of sludges.

In April 2014, the Walloon Government launched officially a platform aiming at the development of activities in the field of metal recovery from urban and industrial wastes and from all types of end of life products. This approach linked to the concept of local "circular economy" has led to a project nicknamed "Reverse Metallurgy", associating several industrial and research partners that is financially supported by the Walloon Region for a period of 5 years. In this frame, a partnership has been initiated with Liege University and its department ULg-GeMMe active in Mineral Processing and Environment. This partnership will be named CReSus - Centre for Resource Efficiency and Sustainability. CReSus will host and share between the partners all existing and new pilot facilities in strategic areas, like sorting, hydrometallurgy, pyrometallurgy and plasma melting.

The present annual report highlights the main achievements of the year 2014 obtained in the steel collective programme shared between ArcelorMittal and Tata Steel and in the regional R&D programme with our partners.

Four thematic sections are covered:

- Innovative manufacturing and processing technologies;
- New advanced metallic materials and their applications;
- Sustainability of natural resources, energy, recycling and valorisation of by-products;
- Valorisation, dissemination, international and regional collaboration.

All significant achievements are the results of trust and open relation between the CRM Group organisation and its industrial members. The CRM Group management warmly thanks them for their continuous and strong support.

Paul PERDANG
President CRM

Jean-Claude HERMAN
General Manager CRM

Company members

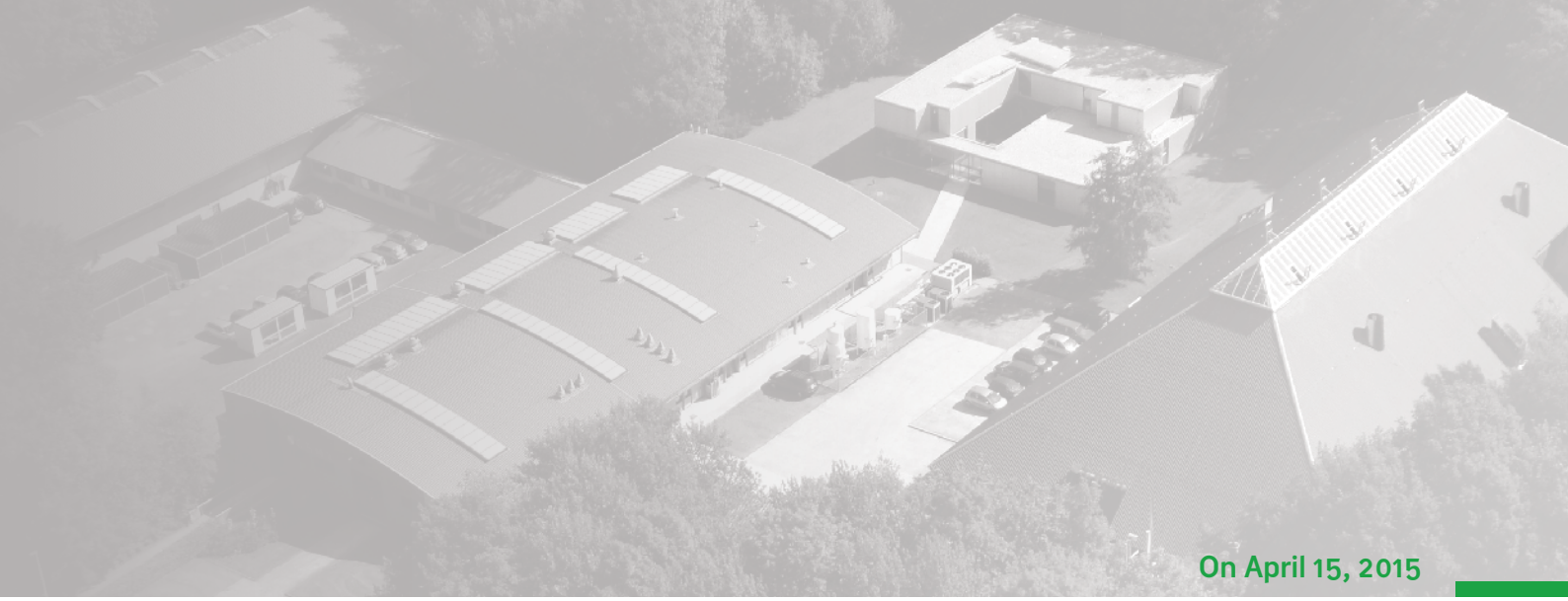
Active Members of CRM

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

And each of their subsidiary companies in the iron and steel industry.

The affiliated companies in the Benelux countries are:

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
ARCELORMITTAL STEEL BELGIUM N.V.	Belgium
INDUSTEEL BELGIUM S.A., ARCELORMITTAL Group	Belgium
SEGAL S.A., TATA STEEL EUROPE Ltd	Belgium
TATA STEEL IJMUIDEN B.V., TATA STEEL EUROPE Ltd	The Netherlands



On April 15, 2015

Associated Members of CRM

AIR LIQUIDE INDUSTRIES BELGIUM S.A.	Belgium
ÅKERS BELGIUM S.A.	Belgium
ALUMINIUM CENTER BELGIUM asbl*	Belgium
AMEPA GmbH	Germany
APERAM Stainless France S.A.S.	France
AURUBIS BELGIUM N.V.	Belgium
CARMEUSE S.A.	Belgium
CBMM Technology Suisse S.A.	Switzerland
CMI S.A.	Belgium
COMET TRAITEMENTS S.A.	Belgium
DE LEUZE S.A.	Belgium
DREVER INTERNATIONAL S.A.	Belgium
EMG Automation GmbH	Germany
EURAGGLO S.A.S*	France
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
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
PAUL WURTH S.A. G.D.	Luxembourg
PRAYON S.A.	Belgium
PRIMETAL TECHNOLOGIES AUSTRIA GmbH	Austria
PRINCE BELGIUM bvba	Belgium
PRÜFTECHNIK DIETER BUSCH A.G.	Germany
RECOVAL BELGIUM SPRL	Belgium
R-TECH S.A.*	Belgium
SLB	Luxembourg
TECHSPACE AERO S.A.	Belgium
THY-MARCINELLE S.A.	Belgium
TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT sarl	Luxembourg
UMICORE S.A.	Belgium
WINOA S.A.	France
WOW TECHNOLOGY S.A.*	Belgium
ZincOx Resources plc	United Kingdom

* Approved by the General Meeting of April 15, 2015

Organization

Board of Directors of CRM

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Debashish BHATTACHARJEE, Group Director R&D, TATA STEEL GROUP

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Robert CHARLIER, Professeur, Université de Liège
Vincent CHOLET*, CTO, ARCELORMITTAL Europe – Long Products
Renaud COLLETTE, Conseiller, SPF Economie, PME, Classes moyennes et Energie
Nico CUE*, Secrétaire Général, MWB
Bernard DEHUT, CEO ARCELORMITTAL LIEGE
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Bruno GAY, Senior Project Leader Building Products, UMICORE
Robert JOOS, Directeur Général, Groupement de la Sidérurgie (GSV)
Herwig JORISSEN, Voorzitter, Centrale der Metaalbewerkers van België
Leo KESTENS*, Professor, Universiteit Gent
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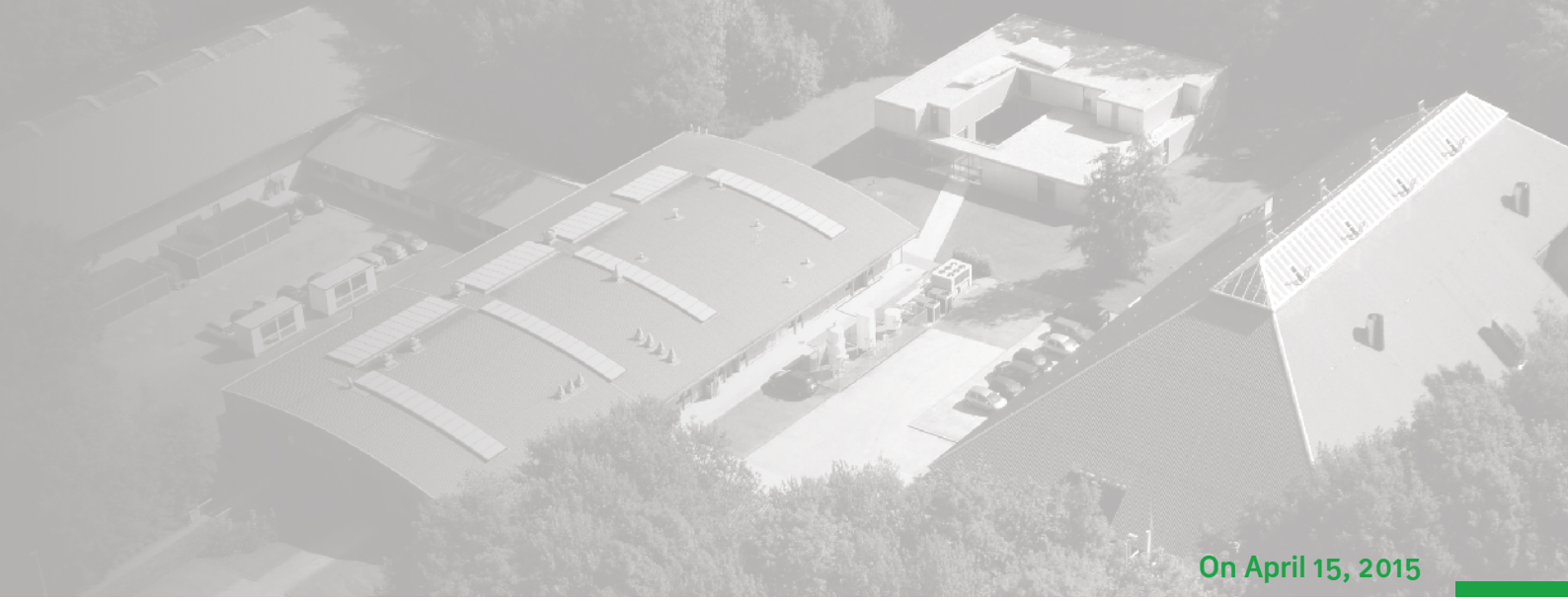
Greg LUDKOVSKY, Vice-President of Global R&D, ARCELORMITTAL
Gabriel SMAL, Secrétaire Général, ACV-CSC METEA
Sven VANDEPUTTE, Managing Director, OCAS N.V.
Wim VAN DER MEER, Director R&D Programmes, TATA STEEL RD&T
Olivier VASSART*, Long Products Portfolio and Research Centres Leader, ARCELORMITTAL
Pierre VILLERS, Inspecteur Général, Direction Générale des Technologies, de la Recherche et de l'Energie de la Région Wallonne

Observers
Jean-Claude HERMAN, Directeur Général, CRM
Yvon MASYN, Adviseur, Innovatie door Wetenschap en Technologie in Vlaanderen (IWT)

Auditor
Dominique JACQUET-HERMANS

* Approved by the General Meeting of April 15, 2015



On April 15, 2015

Iron and Steel Committee of CRM

Members

ARCELORMITTAL
J.P. ALLEMAND
M. BABBIT
P. CHAUBAL
M. DI FANT
S. VANDEPUTTE
O. VASSART

TATA STEEL
M. DENYS
A. DUNSMORE
L. JANSEN
W. VAN DER MEER

CRM
J.C. HERMAN
Ch. MARIQUE
G. LANNOO

CERTIFICAT DU SYSTEME DE MANAGEMENT DE LA QUALITE

ISO 9001 : 2008

Par la présente, le BQA sa déclare que le système de management du ***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 Boulevard de Colonster B57 – 4000 Liège et Rue Sompré, 1 – 4400 Ivoz-Ramet – Belgique pour
AC&CS scrl *– Advanced Coatings and Construction Solutions scrl*
a été examiné le 19-11-2012 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 sa conformément à son manuel de qualité relatif à la certification de système et après conclusion du contrat de certification N° CER_AJ_QMS_22-11-2012_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 18-11-2015

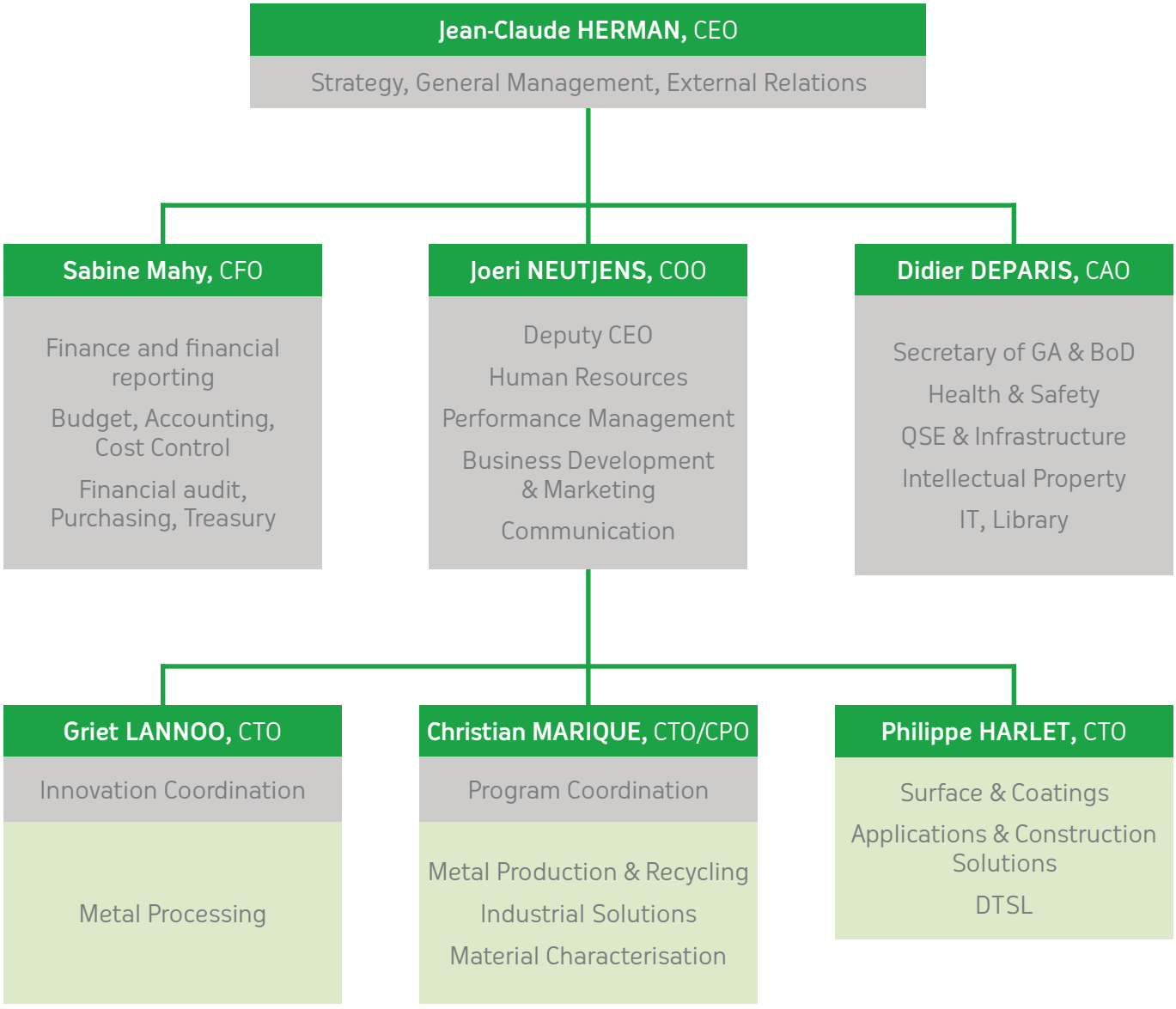
BELAC
BQA N° 019-QMS

D. SIMOENS
Directeur

BQA

Toute personne ayant connaissance de l'emploi abusif de ce certificat doit en avertir le BQA sa. Ce certificat ne peut être divulgué que dans son intégralité.
BQA sa - rue Montoyer 24 (b9) - 1000 Bruxelles.

DS/AJ/C/19-11-2012



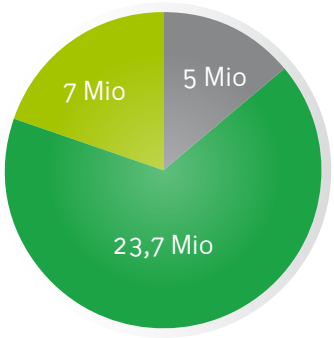
CEO : Chief Executive Officer
COO : Chief Operational Officer
CTO : Chief Technical Officer
CFO : Chief Financial Officer
CPO : Chief Programme Officer
CAO : Chief Administration Officer

CRM Group management functions
R&D operational functions

Key figures

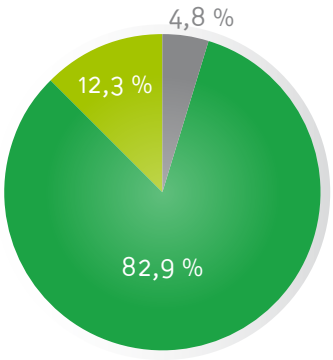
Total Income: 35.7 Mio. Euros

Income by program



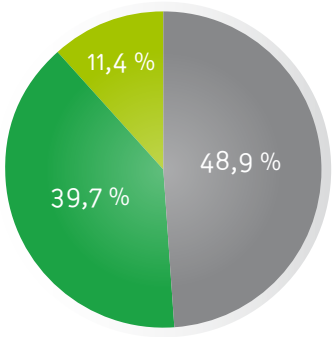
- Steel Collective
- Steel Private
- Other

Income by financing



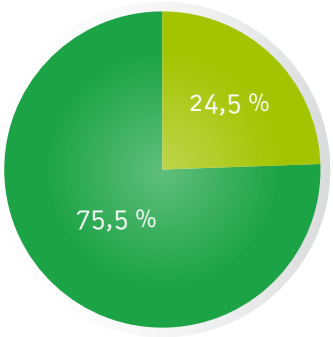
- Private
- National & Regional Grants
- European Grants

CRM Group: 237 people



- Researchers
- Technicians
- Administrative staff

Gender balance



- Female
- Male

Report on R&D activities

Founded in 1948 to become the reference collective research centre for the Steel and Non-Ferrous Metal industries located in Belgium, CRM has progressively enlarged its scope to acquire within the years a worldwide reputation.

Today, the affiliated industrial members represent more than 40 companies active in a broad range of market segments and commercial applications in Europe and in the World.

With laboratories and major pilot facilities located at Liège and Gent, the present activities of the CRM Group remain focused on metallic materials, their manufacturing and applications, largely based on own technological and product development, deployed and valorised for the benefit of its affiliated members.

The offered technical expertise covers the complete loop of the value creation chain extending from the raw materials, their processing up to finished products and their recycling and valorisation at the end of life.

The CRM organisation (more than 230 people in 2014) is structured into five operational units supported by a common characterisation laboratory:

- Metal Production & Recycling (Raw material processing, melting & refining, recycling & valorisation);
- Metal Processing (Casting & solidification, process technology, product metallurgy);
- Metal Surface and Coatings (metallic & organic coating, surface functionalization);
- Metal Applications & Construction Solutions (Building & structure, civil engineering, metal working & assembly, solutions & in-use properties);
- Industrial Solutions (Engineering & thermal technologies, industrial measurement & process control, pilot facilities).

The CRM Group is fully certified ISO 9001 whilst several characterisation and analytical techniques are also certified ISO 17025.

A selection of relevant activities conducted by CRM during the year 2014 is illustrated in four thematic sections:

- Innovative manufacturing and processing technologies;
- New advanced metallic materials and their applications;
- Sustainability of natural resources, energy, recycling and valorisation of by-products;
- Valorisation, dissemination, international and regional collaboration.

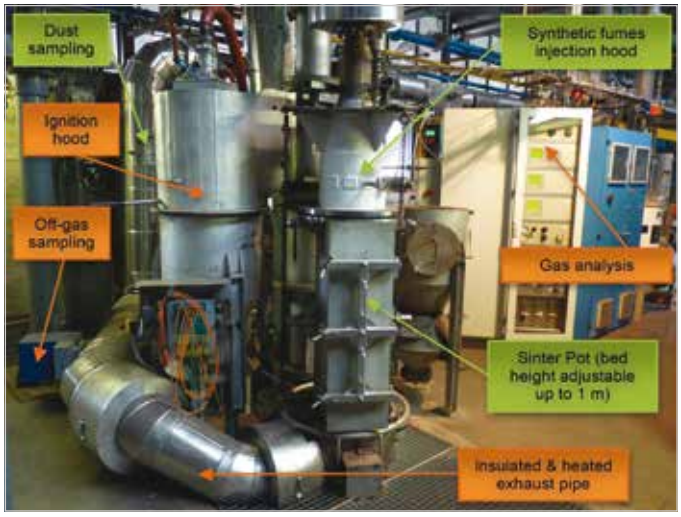
Innovative manufacturing and processing technologies

Major objectives when developing new technological approaches are the reduction of the processing cost, the promotion of a more efficient use of energy and raw materials, a lower impact on the environment and the access to new or improved high quality finished products. These objectives can be separately met but are more often combined.

The activities of CRM in the **Upstream field** start with the conditioning and pre-treatment of raw materials, especially the iron ores, and their sintering before further processing through the blast furnace in order to produce high quality hot metal.

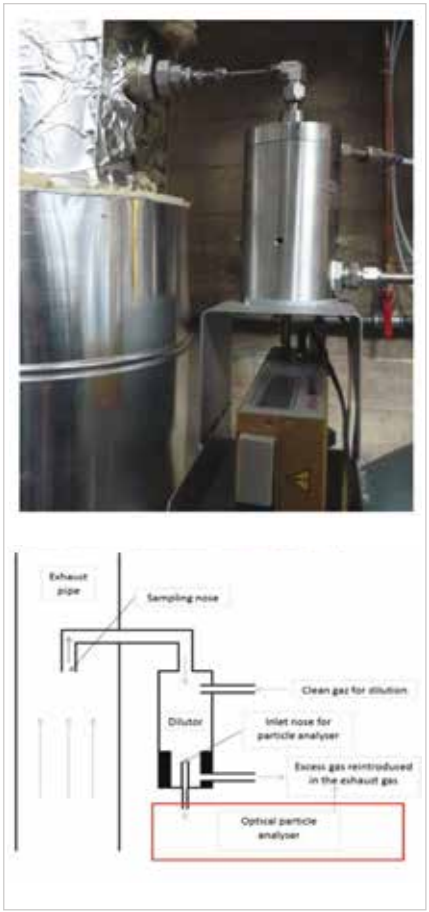
The recognised expertise of CRM in the **sintering of iron ores** is based on a large and unique panel of equipment, tools and competences.

The sintering pilot station, continuously under improvement, is able to simulate industrial situation with a strand height up to one meter and is also equipped with a versatile synthetic fume generator able to simulate any waste gas recycling layouts.



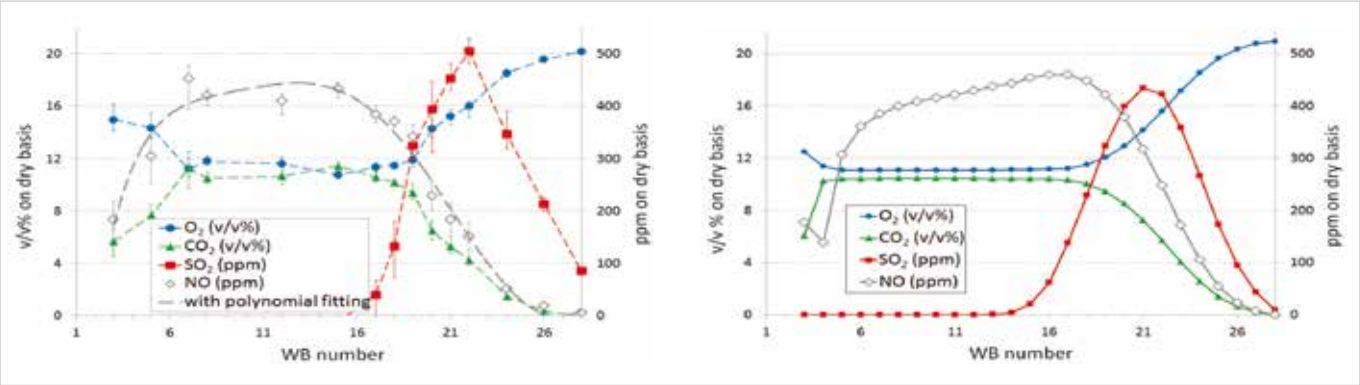
CRM Sintering pilot unit

Coupled with a complete mathematical model, it allows to assess the sintering performances (productivity, quality, energy efficiency) and the emissions impact (gas and dust). The on-line dust measurement placed in the exhaust gas circuit can detect in real time the different dusts emitted during the process with a particule size extending from 0.25 to 35 µm.



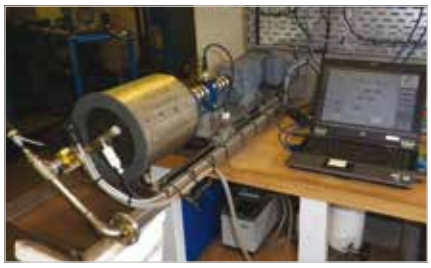
On-line dust measurement

As an example of practical result, it is worthwhile to mention the characterisation of the gas emission profiles in the wind boxes of a sinter strand. A perfect correspondence is obseved between the simulation results and the measurements realised on-site with the mobile analysis unit available at CRM.



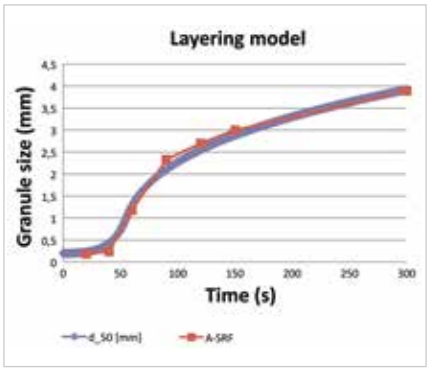
Emission profiles in the wind boxes of a sinter strand – measured (left) vs calculated (right)

As the pre-conditioning and notably the granulation of fine iron ores before sintering shows a direct impact on the sinter plant performances, a more fundamental study has been conducted in the frame of a 1st Doca (PhD) thesis financially supported by the Walloon Region (DGO6) to develop dedicated tools, knowledge and a specific model.



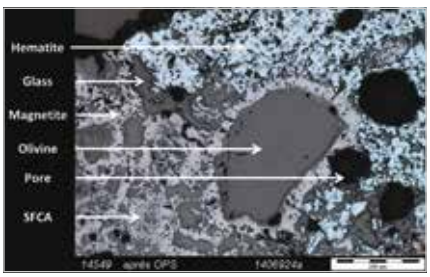
Laboratory equipment to simulate rotative granulation

An instrumented laboratory equipment aiming to simulate granulation in a rotative drum has been built with particularly a high speed camera able to analyse online the particule flow and to predict the granule growth. It allows to determine the material size and characteristics after granulation.



Prediction of the granule size growth with time

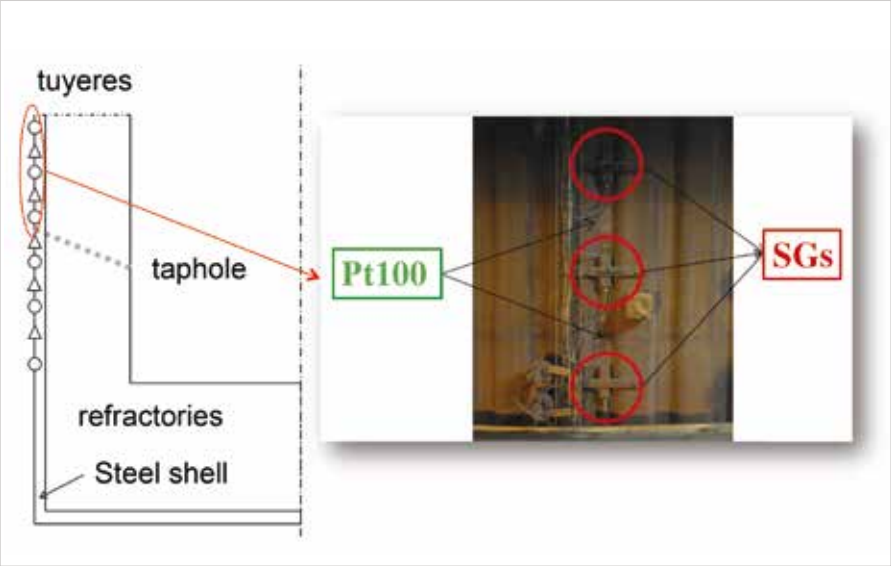
To be also outlined is the ability to realise detailed mineralogy analysis with identification of the different phases present in sintered product.



Polished section of a sinter product

In the field of the **blast furnace** operation, a major input of CRM deals with the control of the process and especially the optimisation of liquid flows inside the reactor and the tapping. The original development proposed by CRM and using strain gauges placed along the shell of the blast furnace has been licensed to TMT and continues to be deployed in several plants. During the year 2014, two new installations have been completed for Tata Steel Scunthorpe, complementing the industrial implementation existing at ArcelorMittal Fos.

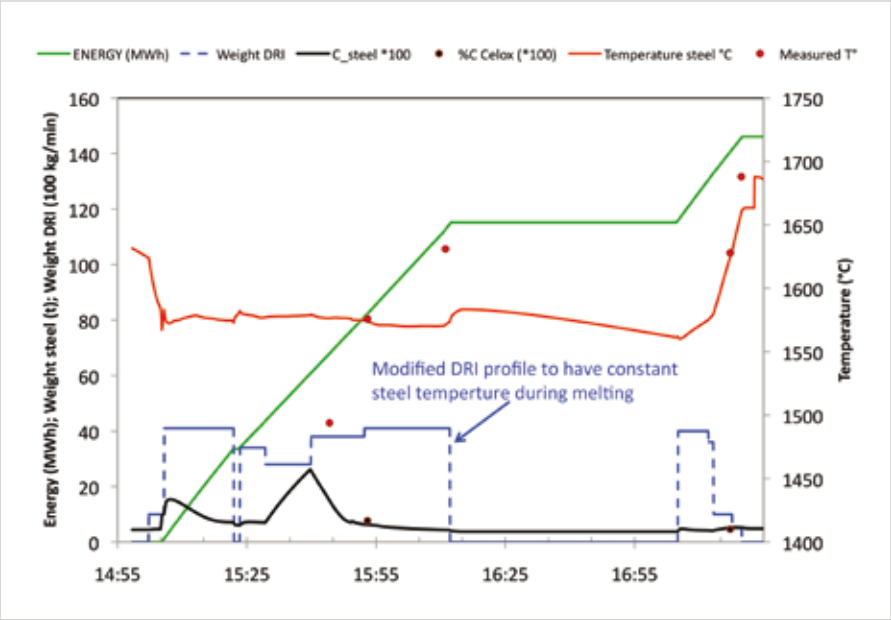
Installation of strain gauges onto the BF shell



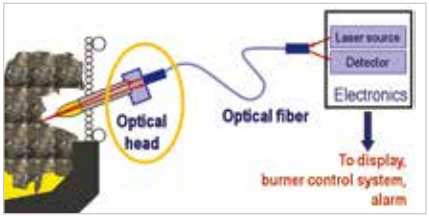
Implementation of strain gauges along the BF shell

In the field of the **Electric Arc Furnace** (EAF) steelmaking, let us recall the dynamic metallurgical model built by CRM. It continuously solves mass and thermal balances for scrap, molten steel, slag, gas and refractories. It calculates in-line the scrap melting evolution, the melt composition and the end-point of the heat. The model can be applied to any type of furnace. The last implementation realised in 2014 concerns the plant of ArcelorMittal Lazaro Cardenas (Mexico) working with 100% DRI addition. The model is used to regulate the addition of DRI in order to reach the final aimed temperature.

An innovative sensor (called SERaFin) has been developed for monitoring the scrap melting and the oxygen blowing in EAF. The principle is to measure the distance from the injector tip to the scrap. The burner power regulation and the start of oxygen blowing can be managed accordingly to this information. This development has been done by CRM with the support and collaboration of ArcelorMittal Belval, Dommeldange and AMEPA.

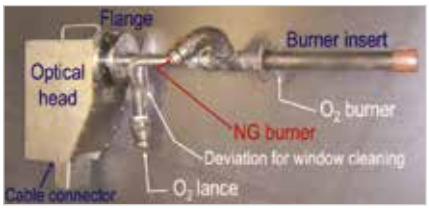


Temperature prediction in a EAF operating with 100% DRI

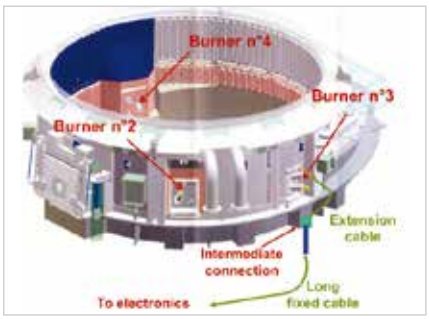


Monitoring the scrap melting in EAF

It allows to control the requested power input during the starting phase, to switch off the burner when its efficiency decreases (no more scrap in front), to move from burner to lancing mode, to alarm the operator in case of blow-back risks.

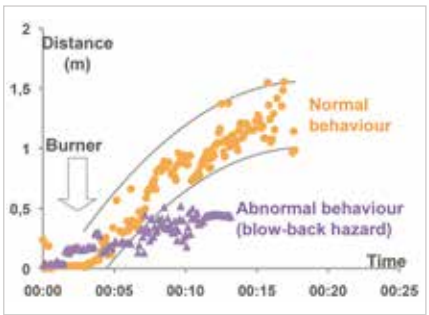


Burner equipped with the SERaFin sensor



Implementation of SERaFin in EAF

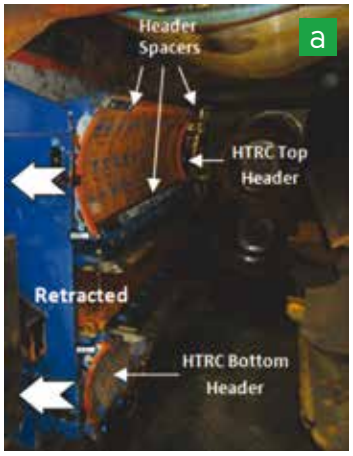
The last industrial campaign with the sensor operating during 6 weeks (more than 600 heats) has confirmed its robustness and the ability to accurately detect and avoid the hazardous blow-black situation leading to damage the cooled furnace panel when not prevented. Control rules have been defined for integration in the on-line close-loop procedure of the plant. This sensor is now ready for roll-out and commercialisation.



Control of the scrap melting in EAF

The **metal processing** is a second technical field where the CRM competences are highly recognised, mainly for what concern the hot and cold rolling operations. The development of adequate **cooling technologies** is to be highlighted with as a relevant example, the efficient cooling of the work rolls in flat and long product mills thanks to the application of a breakthrough technology called "High Turbulence Roll Cooling" (HTRC). In this concept, a turbulent water cushion is formed around the work roll surface with a controlled and forced water circulation.

This technology has continuously been improved over the last years, in close partnership with the plants where it is implemented, ArcelorMittal Gent (Belgium) and more recently ArcelorMittal Dofasco (Canada).

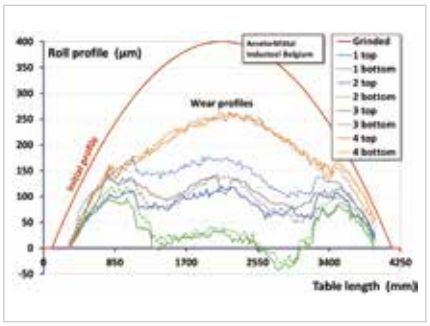


HTRC cooling at the hot strip mill of ArcelorMittal Dofasco:
***a :** retracted position*
***b:** extended header position*

Besides the possibility to control the distance between the cooling header and the work roll surface (retractable system), the turbulence of the water is created combining the water pillow cushion technology and the high turbulent low pressure cooling principle. For a similar flow rate, the heat transfer coefficient is increased by 25% compared to the first generation of HTRC and by more than the double compared to a traditional roll cooling system with flat jet nozzles operating at 14 bar. As the enhanced HTRC unit operates at a low pressure (2 to 3 bar), the energy saving reaches values close to 85 to 90% compared to a conventional cooling system.

A second example of development in **hot rolling** is the application of an on-line work roll profile measurement in a roughing mill stand at ArcelorMittal Industeel (Belgium). This mill is producing plate with a thickness range from 5 mm up to 150 mm.

The roughing mill stand at Industeel



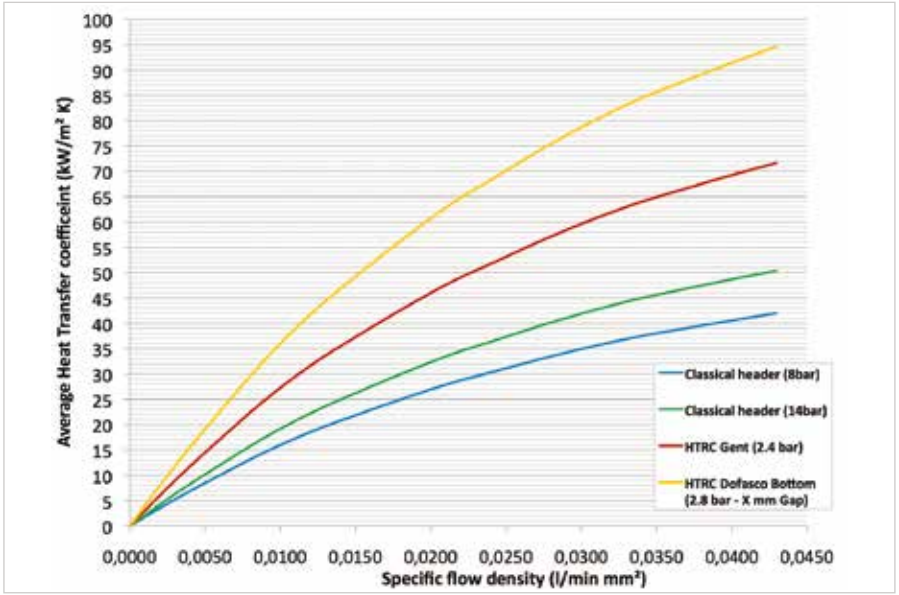
Work roll profile measurement

An original technique based on the use of multiple inductive sensors placed along the rolling table aims to continuously monitor the wear roll profile.

The objective of this development is an enhanced control of the product flatness by applying selective work roll cooling and by adapting it based on the geometry and profile of the roll from the early stage of a campaign to its end.

The **lubrication** during hot rolling is also a parameter to be controlled in order to reduce the rolling force, to master the roll life time and to improve the strip surface quality.

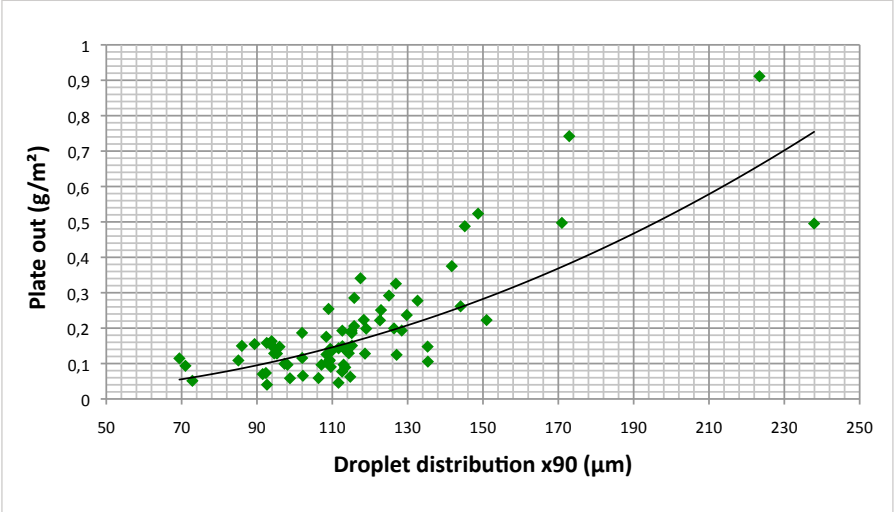
To achieve a low cost and effective lubrication, a quantification methodology allowing to identify the most important parameters to be controlled under industrial conditions has been designed by CRM.



Cooling performances of the HTRC concept

Preheating the sheet before lubrication

Application of the lubricant



Oil droplet size and plate out index

The lubrication performances are assessed in a plate-out simulator built by CRM. The plate-out of a lubricant (emulsion, oil,...) is the main mechanism acting on the homogeneity, distribution and adhesion of the lubricant on the strip roll surface. Using a dedicated measurement technique, the oil droplet size distribution at the surface of a sample can be quantified as well as the plate-out index. A high plate-out index is to be searched, what can be obtained by increasing the oil droplet size in the emulsion, resulting in a more efficient application complemented with a saving of the oil consumption.

During the **cold rolling**, the surface of steel strip is inevitably contaminated with a certain amount of iron fines and residual rolling oil components. Excessive strip surface contamination compromises the product quality in downstream processes. Today most of the cold rolling mills still apply hard Cr-plated work rolls to control the surface cleanliness of cold rolled strip. However chrome plating becomes an environmentally undesirable process, the Cr(VI) material being likely banned in the EU in 2017. A possible alternative way to assure the strip cleanliness when alternative roll material will be implemented industrially is being studied at CRM with advanced cleaning methods. A potential cleaning method is to use a high pressurised water spray to remove the contaminants from the strip. In 2014, a successful pilot line test has been performed with such a high pressure cleaning system. Directly after the rolling process, the strip cleaning system was positioned to remove as much as possible the contaminants from the strip. A very good performance can directly be observed.

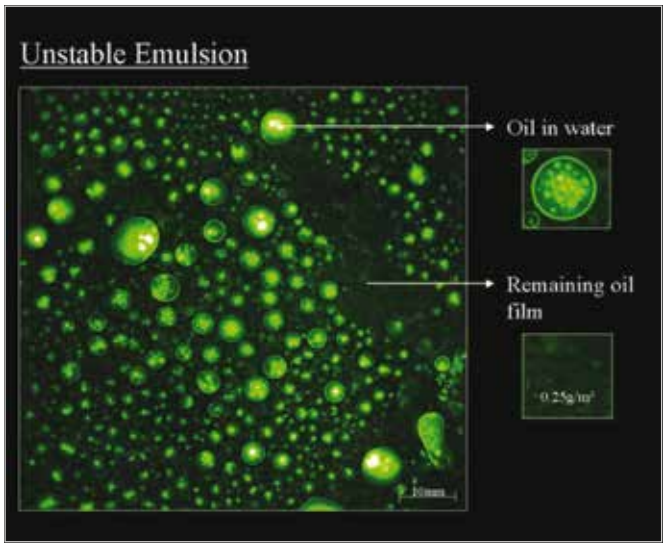
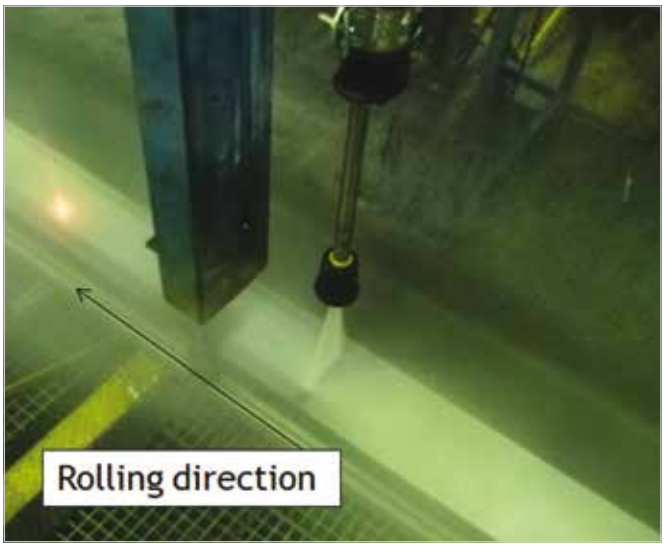
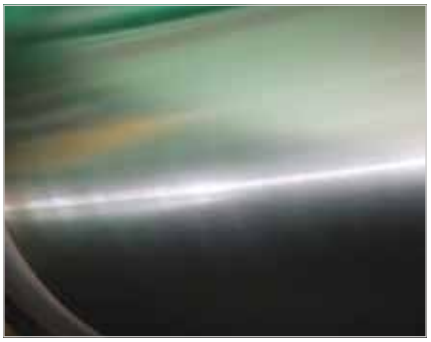


Plate-out measurement by camera



High pressure strip cleaning for cold rolling

Water pillow cushion header for cold rolling



High strip surface quality after WPC unit

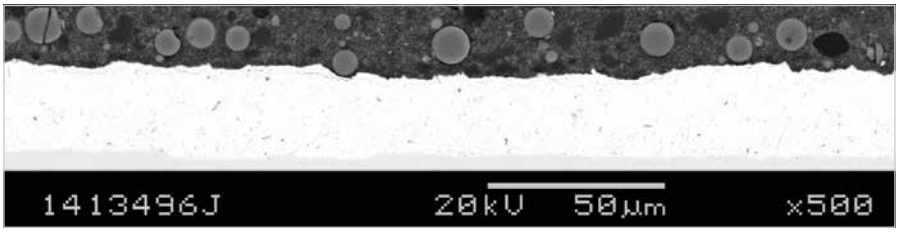
The application of original cooling technologies is also pursued in the cold rolling field. With the industrial objectives to suppress strip defects related to excessive temperature in the rolling gap, to improve the lubrication efficiency and to boost the line rolling speed, an intense "water pillow cushion" (WPC) strip cooling header has been added to the stand 3 of a tin plate mill of Tata Steel IJmuiden complementing hence the unit already installed two years ago after stand 2. Long term campaigns have confirmed significant benefits on strip quality, line speed (increase by 5%) and force reduction. The second installation would allow an increase of the line speed by 10%. It will be fully operational for the end of the first quarter of 2015.

The coating treatment of metallic products also remains one of the key competences of CRM including metallic, non-organic or organic (paint) deposits.

Besides the activities dedicated to continuous lines, a specific effort is devoted to "batch" galvanising processing such as met in the manufacturing sector. In that context, it is worthwhile to recall the innovative galvanizing concept proposed by UMICORE to deliver Duplex products at a low cost.

This concept called "EVAPLEX" has now reached the industrial demonstration phase. Associating UMICORE, DREVER, GALVA 45 and CRM, and thanks to the financial support of the Walloon Region (DG06), an Eureka project is running with the objective to build a large industrial equipment able to process pieces up to 3 meters in length in a 10 m^3 vacuum vessel. Intensive tests have been conducted during the year 2014 and the commissioning of the industrial unit is planned for the first semester of 2015.

Another example of new "coating" process under development concerns the introduction of micro-size particles in paints in order to deliver additional properties and surface functionalities to the final products. This development is conducted in collaboration with SOVITEC, in the frame of a "CWality" project financially supported by the Walloon Region (DG06). Large scale tests have been conducted in the pilot painting line available at CRM with very attractive results on products..



Paint layer with micro-glass beads

EVAPLEX : Industrial pilot equipment

Pilot painting line

New advanced metallic materials and their applications

Whilst a substantial part of the CRM activities remains focused on the development of new generic concepts for high performance steel grades, it is worthwhile to mention that progressively a larger effort is attributed to the development of other metallic products where the competences in physical metallurgy, technologies and process-product interactions can be industrially valorised.

The development and promotion of **new advanced steel grades** combining a light weight, a high mechanical resistance and a high ductility remain important and priority items mainly when aiming at applications in challenging markets like the automotive industry or the construction and building sector.

In the frame of a RFCS project shared with European partners, a dedicated study is conducted by CRM with a focus on dual phase steel (DP grade).

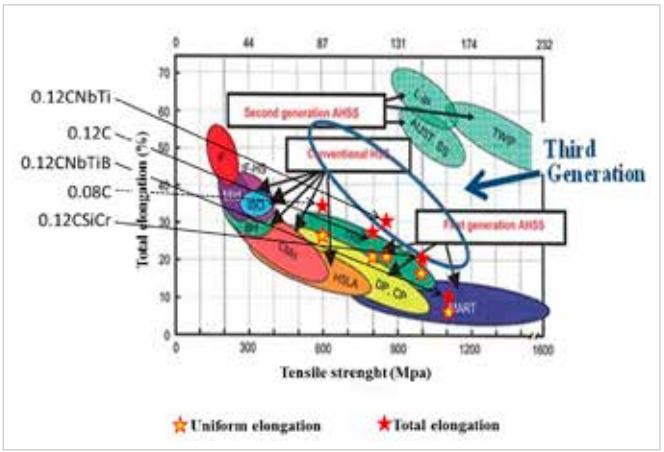
The user properties of DP steels such as strength, ductility, formability and weldability are notably influenced by the chemical composition but also by other processing parameters, pertaining to continuous casting, hot and cold rolling, and finally thermal treatment during continuous annealing/galvanising. Due to the complex interaction of all these parameters, the required balance of strip properties can be achieved by properly adjusting the most influencing process parameters.

Simulations on the flexible annealing pilot line (MDA) available at CRM Gent have led to very attractive results.

Multi device annealing (MDA) simulator

Through a proper combination, after full austenisation, of the cooling rate and the finish cooling temperature, a fine microstructure with an excellent ductility/strength balance can be obtained, with a lean chemistry.

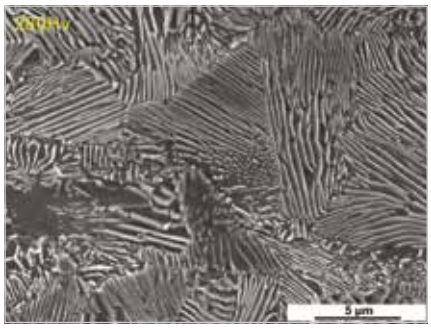
Multi device annealing (MDA) simulator



Elongation versus mechanical resistance of steel grades

The railway transport represents an important market for high quality long products and notably the eutectoid rail steel grades.

To improve the prediction of the final mechanical properties of eutectoid rail steel, a model is being developed by CRM. Mechanical properties are predicted based on metallurgical laws describing the austenite to pearlite transformation. One of the key parameter governing the mechanical properties is the control of the interlamellar spacing of pearlite.



Microstructure of a pearlitic steel

The **"roll material"** is of prime importance for the thermo-mechanical processing of metallic products, the largest volume being consumed by the Steel Industry. The roll behaviour and performances impact as well the mill productivity as the product quality and the production cost.

The rolling operation concerns the flat and the long products sectors.

CRM is active in the study of work roll performances since more than 40 years, thanks to an intense collaboration with its affiliated steel companies and with roll maker members such as Marichal Ketin, Gontermann-Peipers and Åkers. It has developed unique and innovative approaches to assess and characterise the work roll materials.

The most recent activities are illustrated through several examples:

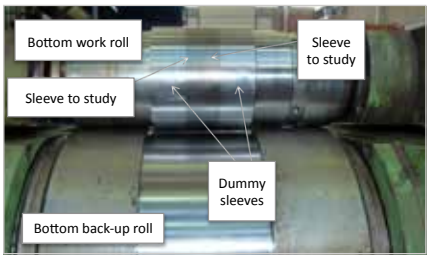
- In the field of the long product (rod and bar), an objective is to find alternative materials to replace the cemented carbide used as sleeve material and to test new ceramic or cermet materials. This study is performed at different levels using the pilot simulators and rolling mill available at CRM in the frame of an RFCS project.

For testing alternative options, and notably assessing the tribological properties and wear resistance, trials are conducted at high temperature on the so-called "twin disk" simulator.

Twin disk simulator

In a second step, continuous hot rolling trials are conducted with a full roll equipped with sleeve or multi-sleeve materials.

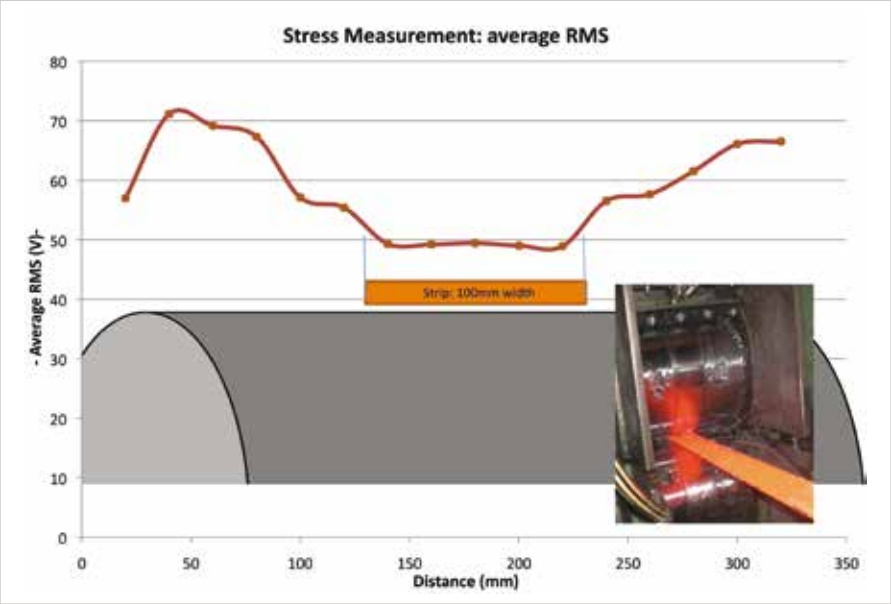
For trials in flat rolling conditions multiple sleeve components are mounted next to each other on a work roll axle to assess different solutions under the same rolling conditions. For testing rod rolling conditions, grooved sleeves are used to reach the aimed product deformation and profile.



Multi sleeves roll

Continuous flat rolling with multiples sleeve

Continuous rod rolling with cermet sleeve material



Internal stress measurement on experimental working roll

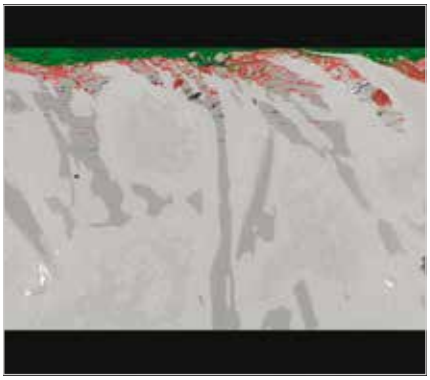
Barkhausen non-destructive stress mesurement

■ As the roll behaviour can be significantly affected by the deformation and stress intensity applied during rolling, a new measurement technique is under testing and development (RFCS project) to evaluate the surface stress evolution in the roll. Based on the Barkhausen noise analysis method, this technique using the application of a magnetic field to the roll appears promising for the off-line control of the roll.

■ The degradation of the work roll and hardware during hot rolling can be influenced by different process parameters and notably the **quality of the water** used for cooling purposes. Surface degradation and internal oxidation generally result from a combination of thermo-mechanical fatigue and roll gap friction. The impact of the water quality has been evaluated through hot trials on a three disk test rig.

A metallographic method has been established to quantify the internal oxidation and crack occurrence on the roll material.

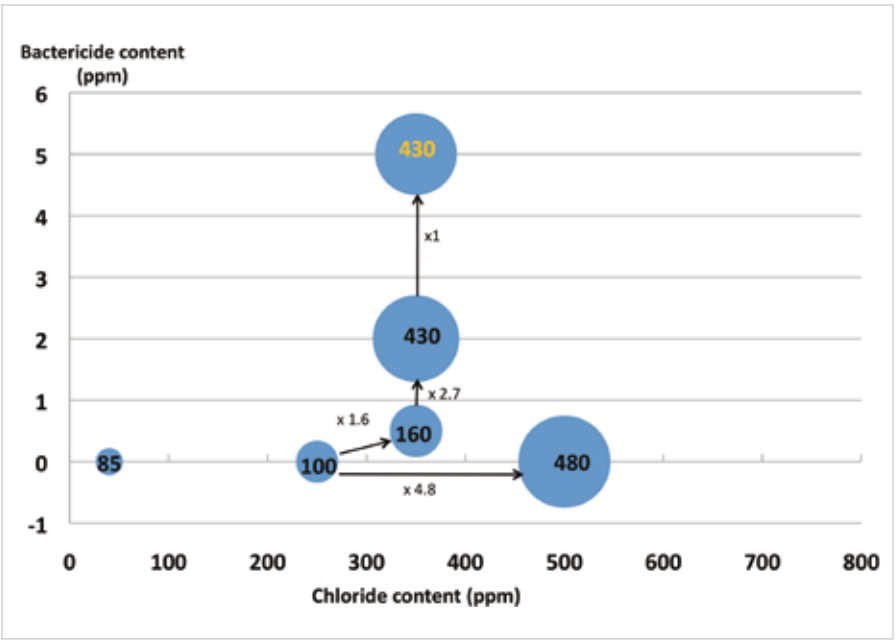
3D test rig



Metallographic quantification of internal oxidation/cracking
Green zone: oxidation
Red zone: cracking appearance

On this basis, the definition and quantification of indicators leading to excessive roll degradation are possible pointing out the negative role of too high chloride or bactericide level in the water composition.

■ New legal imposition such as the banning of specific chemical element (like CrVI components) is modifying the selection of the roll material with the need to develop alternative technical solutions for the cold rolling and temper mills as already mentioned earlier in this report. A large collaborative research has been conducted with the RFCS financial support to identify promising solutions



Water quality and roll degradation impact

Industrial trial with alternative roll material at Tata Steel

to replace the chromium plated rolls. Based on pilot tests, the HVOF-plated and EDC-prepared rolls were selected for industrial test campaigns conducted by both ArcelorMittal and Tata Steel. These industrial tests have confirmed the good behaviour of EDC rolls prepared by SARCLAD in terms of roughness transfer and strip cleanness. However, they do not match the performances of Cr-plated rolls in term of roughness retention which remains an issue for future applications.

■ The substitution of banned elements like cadmium or hard chromium due to the REACH imposition is also a major challenge for other application domains. CRM, in collaboration with European partners, has launched several R&D initiatives, offering its competences and investigation tools in **coating technologies**. These initiatives are largely supported by the Walloon Region (DGO6). Let us mention as relevant examples:

○ The preparation of the second generation of environmentally-compliant **coatings** for steel components in the aeronautic sector (CORNET project: Alti2de). Different coating processes and materials are investigated and combined, using notably the PVD CVD pilot coaters of CRM able to process various 3D shaped pieces.

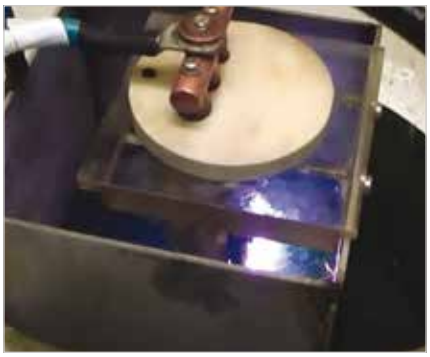
PACVD/PVD vacuum coater

Coating of 3D pieces

○ The deposit of chromium nitride (CrN) coatings on complex tools and components by ionised PVD technology (CORNET project: IonChrome).

○ The development of hard iron-based coatings for mechanical components requiring high corrosion and wear resistance (DGO6 project: NoChrome).

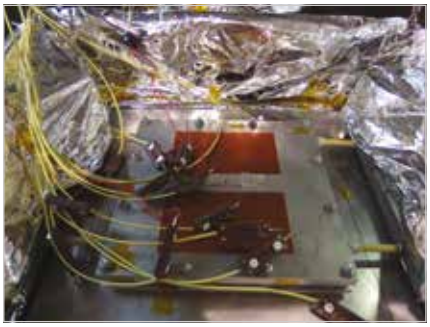
○ The application of new promising coating method like the electrochemical plasma technology (plasma generated within liquid bath at atmospheric pressure) (DGO6 project: PlasmLiq).



Experimental electrochemical plasma unit

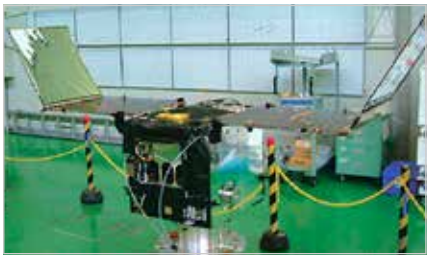
■ Thanks to an active partnership with WALOPT (a SME located at Liège), CRM is progressively enhancing its collaboration with ESA (European Space Agency). Three technical items can be mentioned to illustrate this positive situation:

○ The use of PCM (Phase Change Materials) to develop new heat storage devices for satellite and launcher in which the electronic units must be kept under strictly controlled temperature limits. The prepared prototype is under “earth” condition testing (TRL: Technology Readiness Level of 6), a step just preceeding the test in “space” environment.



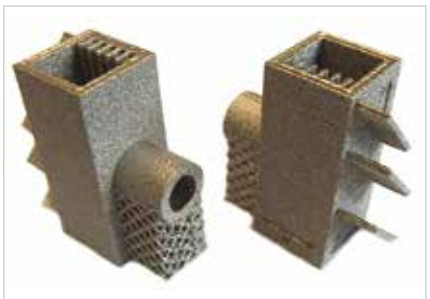
Prototype heat storage unit

○ The development of a low cost concentrator solar array. The task devoted to CRM concerns the design of the solar panel (reflector film and structure, deploying system,...).



Solar array for satellite

○ The coordination of a study about the surface processing of specific parts realised by additive manufacturing and processed from different metallic materials (aluminium, titanium and stainless steel).



3D manufactured parts for space application

Sustainability of natural resources, energy, recycling and valorisation of by-products

The expertise and competence of CRM are largely devoted to the development and implementation of new production routes, minimizing the environmental impact and favouring the recycling and valorisation of by-products turning them into valuable materials for closing the loop of the metals value chain.

Started in 2013 and extended during the year 2014, a multi-year plan aiming to promote the effective recycling and valorisation of metallic residues and other manufacturing and urban wastes has been prepared under the auspices of the Walloon Public Authorities, the Group for the Economic Renewal of Liège (GRE Liège) and the "Mecatech" cluster, driving innovation in mechanical engineering in Wallonia.

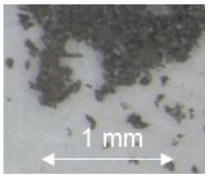
This initiative has been officially launched by the Walloon Ministers of Economy, Mr J.-C. Marcourt, and Technologies/ Innovation, Mr J.-M. Nollet, during a visit of the CRM facilities.

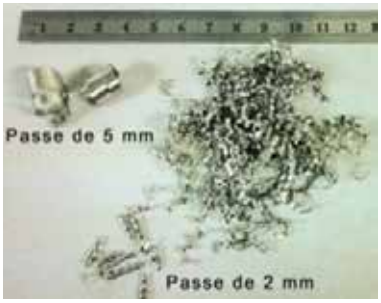
This approach linked to the concept of local "circular economy" has led to a project nicknamed "Reverse Metallurgy", associating several industrial and research partners. It is financially supported by the Walloon Region for a period of 5 years.

Development axes			
Axis 1	Axis 2	Axis 3	Axis 4
Smart sorting	Bio/Hydro-metallurgy	Plasma	Pyro-metallurgy

Amongst the 4 selected axes, CRM is charged to coordinate the axis 4 focused on the development of pyro-metallurgical recycling routes in cooperation with foundries, the manufacturing industry and recycling organisations.

Official lauching of the project "Reverse Metallurgy"





Several priority topics have been identified for this axis 4 “Foundries”, briefly summarised hereunder:

■ The **recovery of high value alloying elements** (Cr, Ni, Mo, V,...) contained in many metallic residues and end-of-life (EOL) products with a special mention to grinding wastes (foundries, rolling mills) and machining chips/turnings (mechanical workshops).

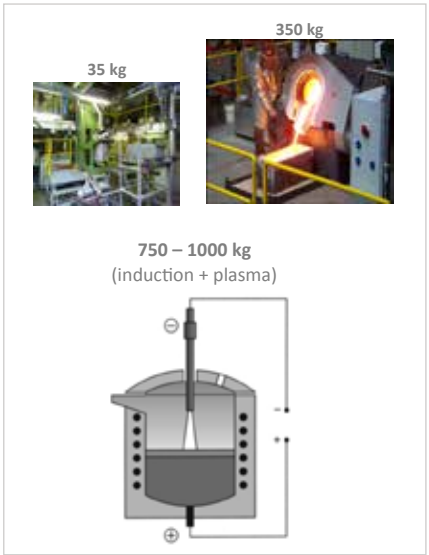
To reach an optimal valorisation of these materials through the melting way and the casting/processing of new products, their pre-conditioning is necessary to remove the machining oil and to densify them before the melting furnace.

New pre-conditioning units will be acquired by CRM like a mobile shredder system or a compaction press to complement those already existing.

Mobile shredder unit

Mobile compaction presses (for sludges and turnings/swarfs)

For the melting operation, a new versatile induction furnace (~1000 kg) coupled with a plasma torch is planned to complete the two existing furnaces (35 and 350 kg).



Melting units at CRM

It has to be pointed out that these furnaces are largely instrumented allowing to establish complete and detailed mass, thermal and energy balances as well as monitoring the fumes and dust emissions.

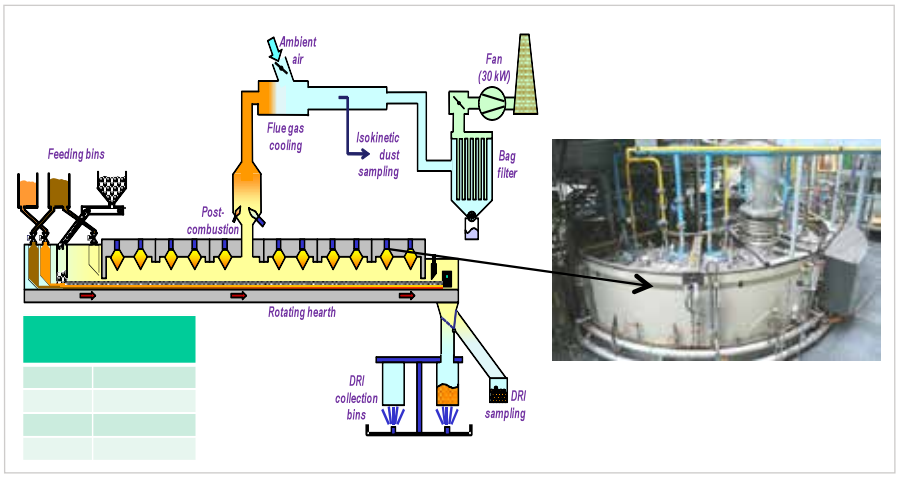
To be also mentioned is the start-up at the early beginning of 2015 of two new air induction furnaces (300 et 80 kg) in the Gent laboratory (a common investment between OCAS and CRM) to cast steel and iron products.

■ The **production of secondary aluminium** collected from various sources (packaging, mechanical workshops, aeronautics,...).

Aluminium melting furnace

A dedicated rotating furnace for the aluminium melting under salts and controlled atmosphere has been acquired by CRM and will be adapted for complying with relatively high organic content in the recycled products.

Fluidisation bench test



Rotary hearth furnace

■ The valorisation of **sludge, dust, scale...** containing Fe, Zn, C or hydrocarbons (old deposits and/or fresh production: biomass residues, urban and industrial waste).

Two main valorisation ways are foreseen depending on the nature and composition of the by-products:

- The valorisation of the organic fraction and its conversion in heat (energy) or synthetic gas (syngas). This work will be conducted with the equipment available at CRM-ETP (pyrolis, oxy- or hydro-gasification or combustion).
- The valorisation of the contained metals through direct reduction and/or smelting reduction process such as the Rotary Hearth Furnace (RHF) available at CRM.

In line with the valorisation of these by-products, it can be helpful to recall the support by CRM to Recyco (an Aperam subsidiary company active in the recycling of austenitic dusts, sludges and refractories) where the combination of pilot tests at CRM and the follow-up of industrial campaigns have allowed to reach significant productivity improvements, a reduction of the production costs and new ways to re-use by-products.

■ The selective sorting and innovative treatment of **complex EoL (End of Life) products** such as the enamelled or zinc-coated products or the stainless and special steels. In that prospect, a first exercise has been realised in partnership with AREBS (Seraing) and Intradel to better assess and characterise the nature and volume of metallic products deposited in the urban recycling parcs.

Sorting metallic products

Valorisation, dissemination, international and regional collaboration

Besides its close connection with large industrial groups, CRM is also supporting small- and medium-sized companies in their development and progress towards innovation in the processing and application of metallic materials. Moreover, a significant part of the activities are devoted to promote and disseminate the acquired knowledge and to support the industrial implementation of developed technologies.

In the frame of the guidance mission supported by the Walloon Region (DGO6), a team of almost four guiders is helping SME's and economic actors to solve practical issues and to innovate in their respective activity field. A very broad range of expertise and technical competences is covered by their mission.

This activity during the year under review can be illustrated through the following example:

- Fixation bolt placed in the door of a large lock and deeply immerged under the water were prematurely broken before the normal lifetime expected for this component. In order to better design and select the needed type of bolt, CRM has instrumented with strain gauges around 10 bolt specimen and realised in-situ measurement to determine the tensile stress supported by the bolt under service.

Instrumented bolts

In line with this guidance mission and its knowledge dissemination role, CRM has also organised information seminar and participated to international conferences.

To be particularly pointed out:

- At the request of the "Mecatech" cluster and the University of Liège, CRM, as coordinator of the guidance "SUREMAT" (Surface of Metallic Materials) has been associated to the

In-situ analysis in a lock door

The "Intermat GR" seminar

WOW-CRM partnership

The "Wavisurf" sensor

organisation of a two-days workshop (September 30th & October 1st, 2014) in Wallonia (Francorchamps and CRM Liège) in line with the inter-regional project "Intermat GR" (Wallonia, Luxembourg, Lorraine and Sarre). The topic of the seminar "New industrial challenges in surface treatments" has attracted more than 100 participants.

■ The thematic day devoted to "Corrosion and Forming of metallic materials" (November 6th, 2014) with the participation of more than 35 representants of SME's and large enterprises. The results of two projects financed by DGO6 (Metalex and Steelpro) were notably illustrated.

■ The presentation by CRM of 11 papers during the 1st European Steel Annual Conference (ESTAD) in April 7th and 8th at Paris. This conference has attracted more than 500 participants representing worldwide organisations and industrial companies.

The **industrial valorisation** and effective application of its own technologies and solutions represent another major objective of the CRM Group. In that prospect, two specific competences have to be highlighted:

■ The **measurement techniques** and the related developed sensors.

- A new partnership and collaboration agreement has been concluded on October 22nd, 2014 between CRM and WOW Technology.

WOW Technology is a SME located in Wallonia active in engineering and delivering of complete solutions for a large range of industrial segments. Under the sponsorship of the "Mecatech" cluster, CRM and WOW Technology will jointly operate to maximise the industrialisation of sensors developed by CRM.

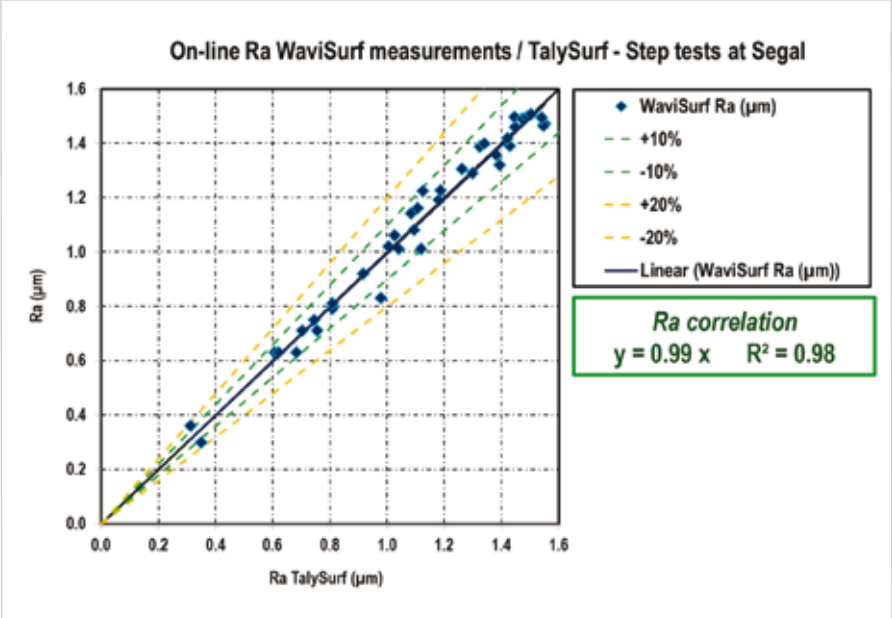
- This new partnership completes the existing license agreements already concluded with adherent members of CRM:

○ AMEPA: On-line roughness measurement (SRM)

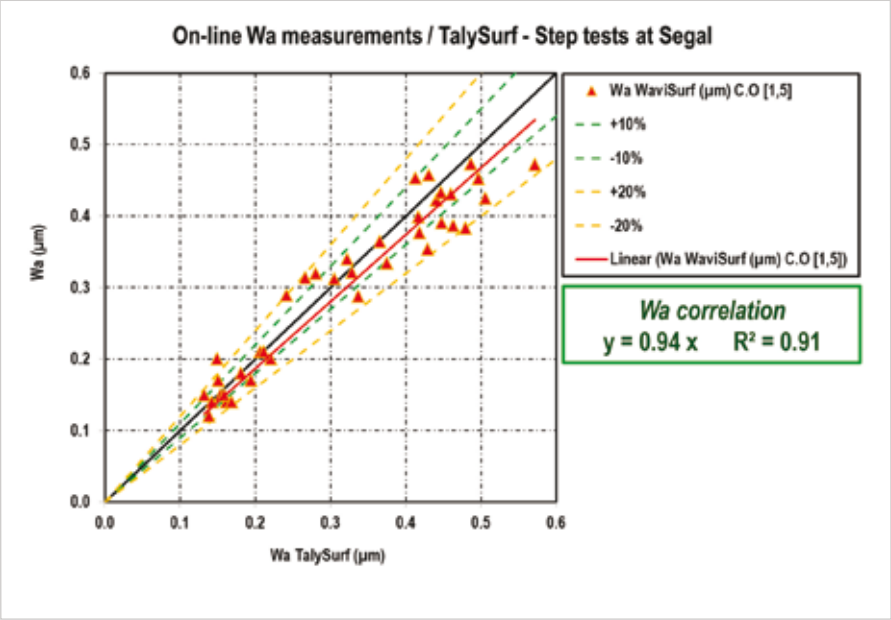
○ TMT: Liquid level detection in the blast furnace

○ Paul Wurth: on-line control of the sinter cake quality (Supermagnag)

- After pilot industrial trials supported by the RFCS program and realised with the active contribution of Tata Steel Segal and ArcelorMittal Spain, a new sensor called "Wavisurf" has proven to be ready for its worldwide implementation and rolled-out. It allows to combine the on-line roughness and waviness characterisation of moving strip (with



In-line roughness measurement



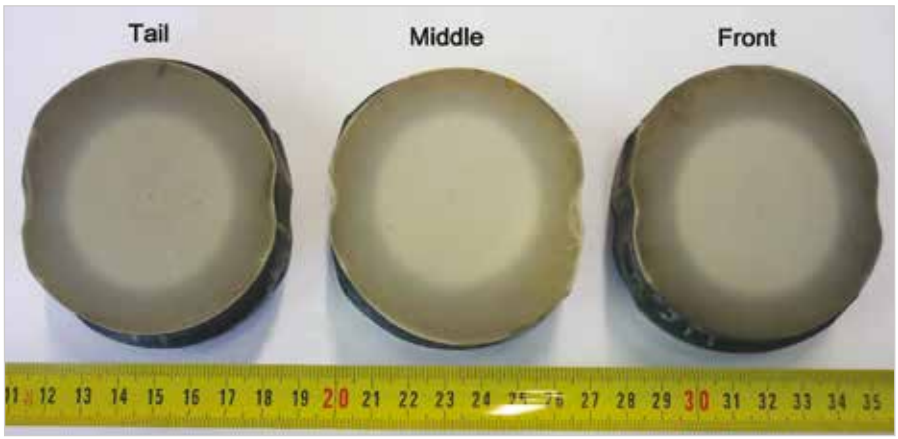
In-line waviness measurement

a range respectively of Ra from 0.1 to 0.6 µm and Wa from 0.1 to 0.6 µm).

■ The **cooling technologies** applied for the thermo-mechanical processing of metallic products.

○ During the year 2014, the longest **"Tempcore"** installation (54 m) ever designed by CRM has been commissioned for the benefit of ArcelorMittal Ostrava. This installation is adaptable to the quenching and self-tempering treatment of threaded rebars of diameter from 35 to 75 mm (the biggest diameter processed until now with this technology). One advantage of the Tempcore process is to request leaner steel composition characterised by a lower cost of production. Three parallel cooling lines have been installed to cover the full range of needed bar diameter with the option to laterally move the cooling boxes. To be noticed that the safety of the workers has been carefully taken into account by the introduction of a remote control unit able to regulate each cooling nozzle valve from the control room. The fine tuning of the Tempcore parameters combined with a strict regulation of the pinch-roll unit located at the exit of the cooling installation and controlling the bar speed lead to very homogeneous products and constant mechanical properties all along the bar.

○ The **"MULPIC®"** technology (MULti Purpose Interruped Cooling), a water-based cooling system for the processing of steel plate continues its worldwide implementation through the collaboration and license agreement with Primetals Technologies Limited (previously SIEMENS-VAI). Two new contracts for the installation of this technology in Japan and in China have been concluded in 2014, completing the number of ≈18 installations already implemented in Europe, India and Asia.



Cross-section of "Tempcore" bar

The longest "Tempcore" installation

Valorisation, dissemination, international and regional collaboration

- Since several decades, CRM is actively participating to associations, organizations 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 recognized.

- As a collective research centre recognized 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 organizations.

- Wal-Tech: An association regrouping the 22 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 : common initiative of CRM and ULg/GeMMe aiming to strengthen collaborations at regional level as well as in the perspective of 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 organizations 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).

The RawMatTERS consortium, of which CRM is core partner with ULg and 120 other European industrial, academic and research partners, has been selected by the European Institute of Technology (EIT) to constitute a «Knowledge and Innovation Community" (KIC) on Raw Materials including several themes as exploration, mining, raw materials use in process & manufacturing industry, recycling and substitution of critical raw materials.

In relation with this initiative, the Minister-President of the Flemish Region, M. K. Peeters, has been welcomed at CRM Liège on May 20th, 2014 for a press conference and a visit of the facilities aiming to announce the support of the Government of Flanders to the KIC Raw Materials.

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. The aim of the network is to strengthen the competitiveness of the European steel industry by conducting joint research and development work.

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. Its main objective is to develop enabling technologies and solutions along the value chain. It associates 8 industrial sectors (steel, chemicals, minerals, water, non-ferrous metals, engineering, cement and ceramics) as well as research organizations among which CRM as one of the funding members.

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

Visit of M. K. Peeters

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