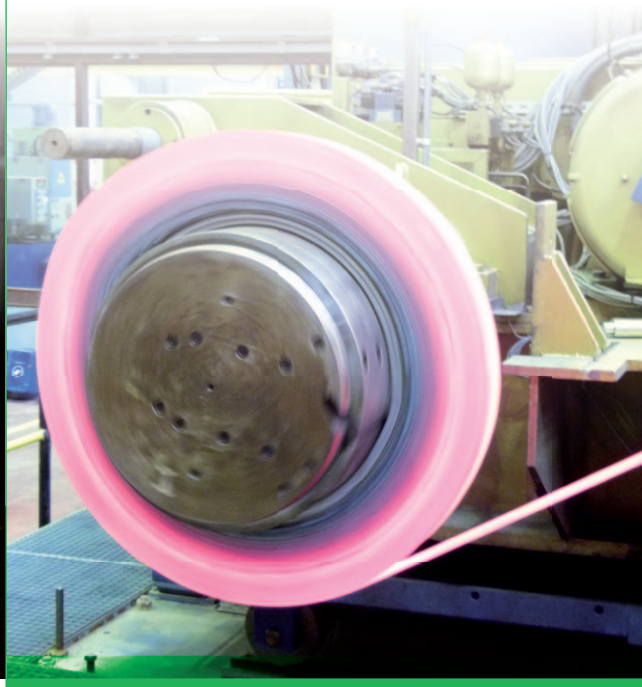
CRM
Annual Report

Production

Recycling Applications

CLOSING THE VALUE CHAIN
OF METALS

2012



CRM GROUP

Contents

CRM GROUP

Foreword

The CRM non-for-profit organisation 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 40 large industrial members: international steel groups (ArcelorMittal and Tata Steel), metal producers and industries with a metal-related activity, ranging from material or equipment supply to metal product production or transformation. Closing the gap between science and market, turning inventions into products and value creation are the main missions of CRM Group.

More than 80% of the CRM activities are focused on steel combining shared and contractual R&D projects. The other activities cover other metals (Cu, Zn, ...). CRM is also developing new processes in transversal fields like energy, recycling and valorisation of by-products. Despite its close heavy industry connections, the CRM is equally listening to small- and medium-sized companies finding themselves faced with problems in the processing and application of metallic materials.

Since 2011, all CRM research activities and general services have been combined with AC&CS into CRM Group. Within this group, the CRM non-for-profit organisation (asbl/vzw) keeps its statutes, such as independant collective centre (equivalent to a so-called De Groote Centre), accredited research centre (Centre "agréé" as recognized by the Walloon Region) and therefore is benefiting from subsidy mechanisms from the European Commission as well as from the Federal and the Regional Authorities. In 2012, this world class R&D organization, managed by one leadership team, had a budget of 30 Mio. EUR for 225 researchers and employees.

At CRM Group, health and safety issues remain the first priority. Training, internal and external audits combined with the daily presence of the management in the shops allow to improve how people behave in any situation especially when performing high risk trials on the pilot lines. Despite the development of good practices throughout the CRM Group, three accidents with lost time occurred in 2012. This recalls to the management the absolute necessity to maintain a top priority on all health and safety issues.

To fulfil its mission, the CRM Group is organised around 4 domains:

- the production of metal, conducting research activities in energy, iron making, electric arc furnace, recycling, valorisation of by-products and environmental issues;
- the transformation of metal with activities in casting and solidification, hot and cold rolling, thermomechanical treatment and cooling, physical metallurgy and the development of new (generic) steels;
- the metal coating and surface functionalization technology with activities in pickling, metallic and organic coatings, surface conversion and the development of new advanced surface properties;

- the application of metal in various fields looking for application and new designs in construction and covering the development of new materials for a large field of applications.

The R&D domains are supported by three expert groups:

- the material characterisation laboratory specialised in chemical analysis, metallography, surface analysis with large competencies in surface reactivity and mechanical properties;
- operational engineering in charge of design, dimensioning, construction, automatisation and implementation of advanced technical solutions on CRM pilot lines and in plants;
- measuring techniques and sensors looking for the development and industrial applications of advanced sensors.

At the European or regional level, the CRM has continued to invest in partnerships with other 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 20 European RFCS projects.

The four independant European steel research institutes CRM, CSM, Swerea MEFOS and VDEh-BFI joined forces in 2011 to found RIES (Research Initiative for European Steel), a network pooling 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. In cross-institute working groups, topics for future research are identified and a common approach discussed for obtaining strong industrial supports and public funding for such research projects. In 2012, several meetings have been held on topics such as “recycling and energy recovery”.

Since 2004, CRM actively contributes to ESTEP “The European Steel Technology Platform”. Since the end of 2012, SPIRE brings together industry partners active in cement, ceramics, chemicals, engineering, minerals, non-ferrous metals, steel and water, that have an urgent interest and can play an essential role in driving the EU resource efficiency agenda due to their high dependence on resources (energy, utilities and raw materials) in their production. These industries also share the potential high impact they may have on the environment through their daily operations as well as the contribution they have on the European economy.

In Wallonia, CRM has initiated a partnership with two accredited R&D centres: Sirris (technology sector - multimaterial) and Cenaero (aeronautic industry) ready to share several technical aspects. The partnerships will effectively start in 2013. This strong association will become the interface with the authorities in Wallonia.

Another partnership has been initiated with Liege University and its department ULg-GeMMe, active in Mineral and Environment. This partnership will be named

CReSus - Centre for Resource Efficiency and Sustainability. It will focus on several societal aspects like securing supply for innovative materials in tomorrow's Europe and recycling. CRM and ULg – GeMMe have already been involved jointly to promote valorisation channels for metal bearing solid residues in melting furnaces (RECYMELT project sponsorised by DG06).

Thanks to regional funds, CRM develops activities with industrial partners. In Walloon Region, CRM has been actively participating to the plan Marshall with different major and challenging contributions that are developed in the present report.
The present annual report highlights the main achievements of the year 2012, obtained in the steel collective programme shared between ArcelorMittal and TataSteel and in the regional R&D programme in partnership with our partners.
The R&D and support activities conducted by CRM in 2012 are illustrated in four thematic sections:

- Design, monitoring and control of innovative manufacturing and processing technologies
- Study and development of new advanced metallic materials and applications
- Sustainability of natural resources, recycling and valorisation of by-products
- Valorisation, dissemination, international and regional collaboration

In 2012, due to the fast changing world economy, CRM has been very attentive to the strategy of its industrial members. Thanks to a flexible and reactive R&D organisation, the CRM has remained focused to new opportunities in its core competences, while creating more and more value for the members investing in CRM. Despite the difficult economic environment, the worldwide implementation of processes developed by the CRM is a clear indication that the research projects undertaken continue to meet the needs of its members.

Paul PERDANG
President CRM

Debashish BHATTACHARJEE
Vice-President CRM

Jacques PELERIN
Vice-President CRM

Jean-Claude HERMAN
General Manager CRM

Company members

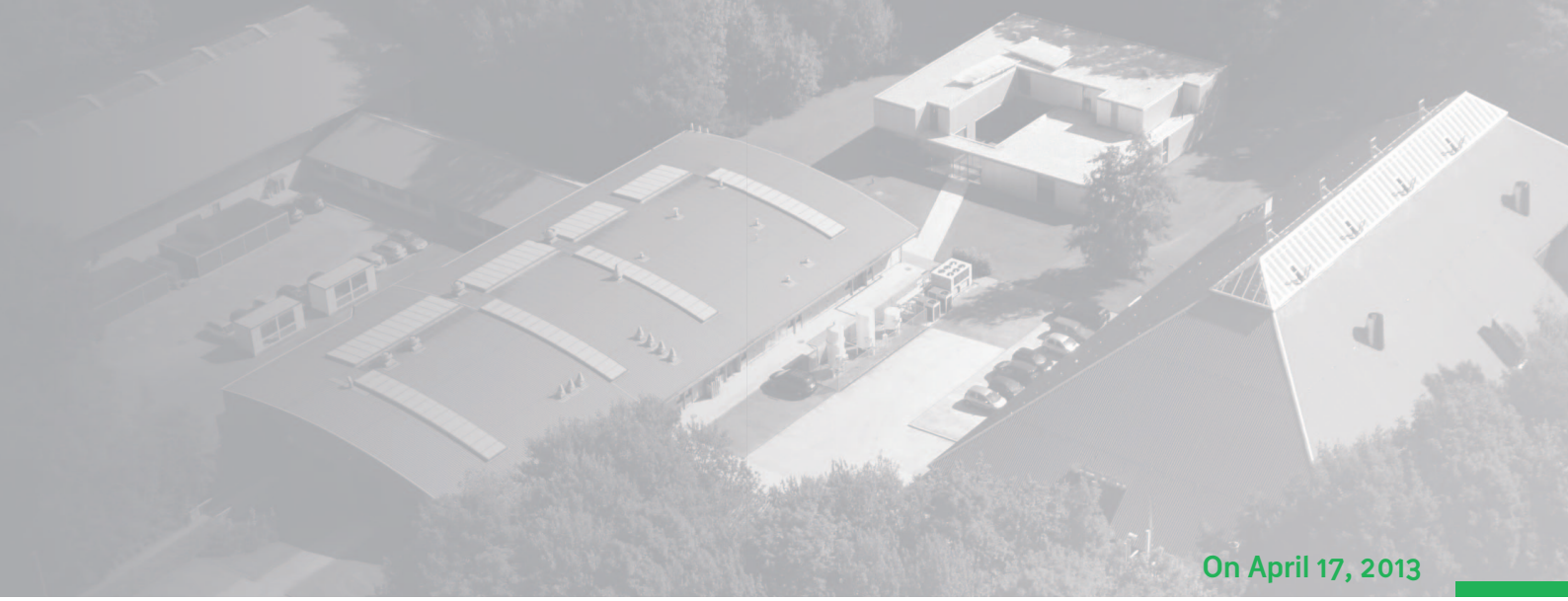
Active Members of CRM

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 WIRE INTERNATIONAL 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
COCKERILL SAMBRE S.A., ARCELORMITTAL Group	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 17, 2013

Associated Members of CRM

AIR LIQUIDE INDUSTRIES BELGIUM S.A.	Belgium
ÅKERS BELGIUM S.A.	Belgium
AMEPA GmbH	Germany
APERAM Stainless France S.A.S.	France
AURUBIS N.V.	Belgium
CARMEUSE S.A.	Belgium
CARRIERES ET FOURS A CHAUX DUMONT-WAUTIER S.A.	Belgium
CBMM Technology Suisse S.A.	Switzerland
CMI S.A.	Belgium
COMET TRAITEMENTS S.A.	Belgium
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DUFERCO BELGIUM S.A.	Belgium
EMG Automation GmbH	Germany
FONDERIES MARICHAL, KETIN & Cie S.A.	Belgium
GONTERMANN-PEIPERS GmbH	Germany
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INSTITUT BELGE DE LA SOUDURE asbl	Belgium
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NLMK CLABECQ S.A. – Plates	Belgium
NLMK LA LOUVIÈRE S.A. – Strips	Belgium
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SIEMENS VAI METALS TECHNOLOGIES GmbH	Austria
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TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT	Luxembourg
UMICORE S.A.	Belgium
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José VERDIN, Représentant, Centrale de l'industrie du Métal en Belgique (CMB)

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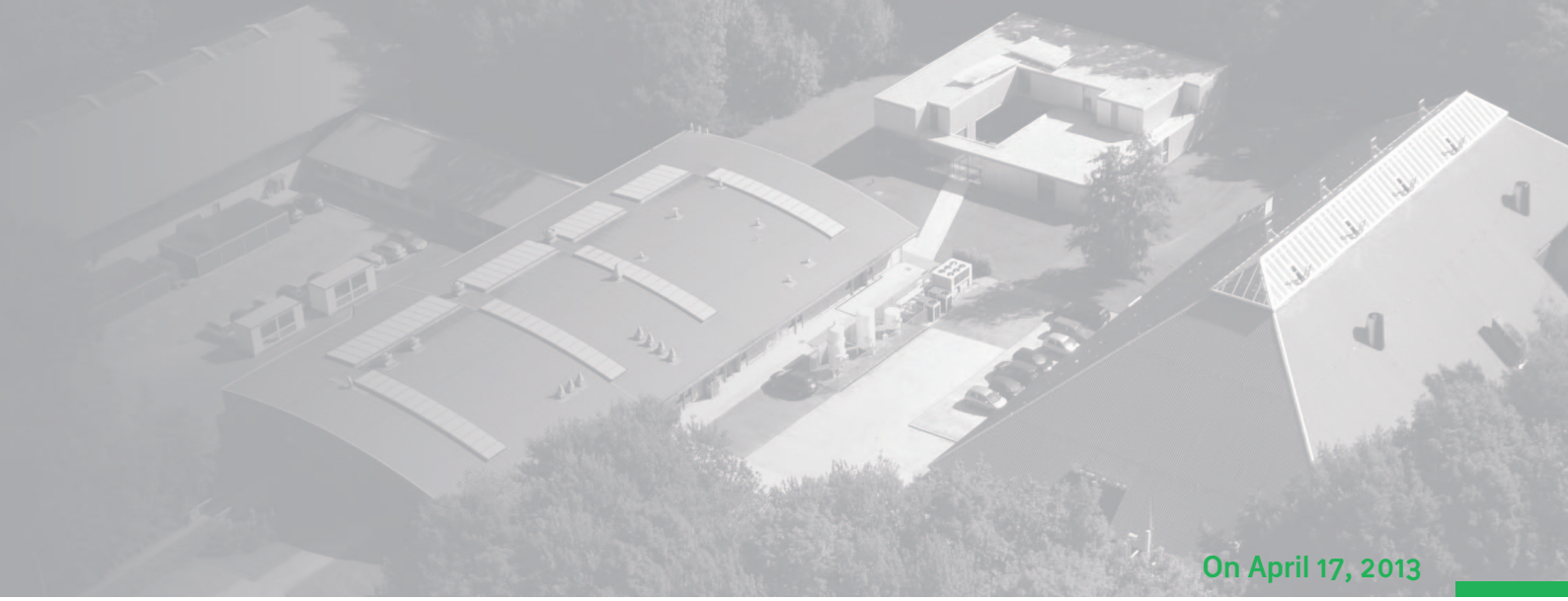
Yvon MASYN, Adviseur, Innovatie door Wetenschap en Technologie in Vlaanderen (IWT)
Pierre VILLERS, Inspecteur Général, Direction Générale des Technologies, de la Recherche et de l'Energie de la Région Wallonne

Auditor
Dominique JACQUET-HERMANS



On April 17, 2013

Iron and Steel Committee of CRM

Members

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W. MOONEN

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

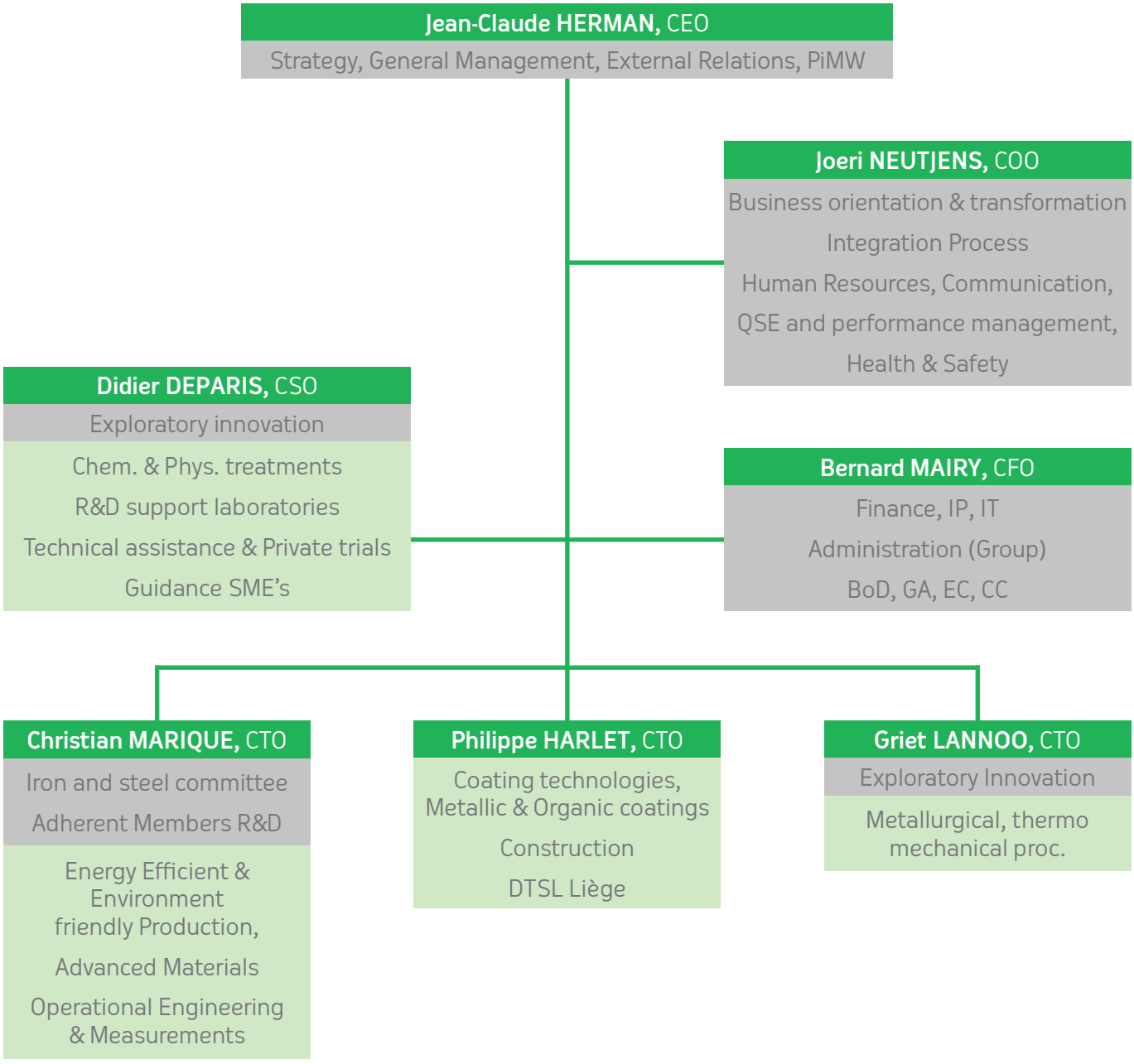
D. SIMOENS
Directeur

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

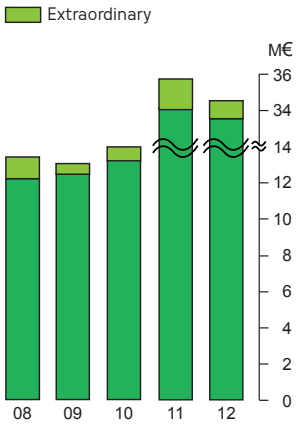


CEO : Chief Executive Officer - COO : Chief Operational Officer
CFO : Chief Financial Officer - CTO : Chief Technical Officer
CSO : Chief Scientific Officer

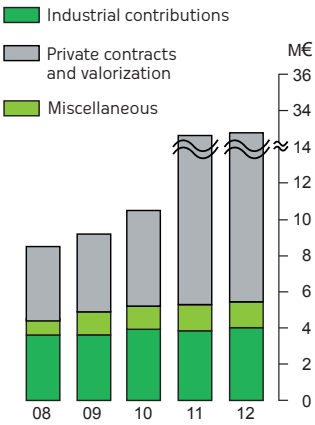
CRM Group management functions
R&D operational functions

Income Data

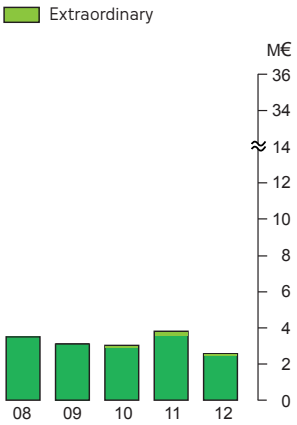
Income



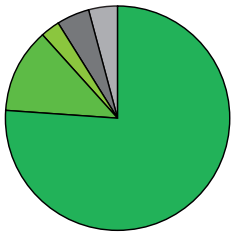
Industrial participations



Grants

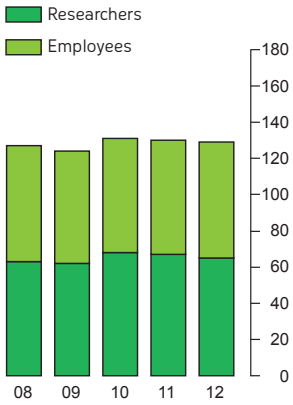


Income by source : 34 M€



Private contracts and valorization 76.14%
Industrial contributions 12.21%
Belgian Public Authorities 2.96%
RFCS / EU 4.57%
Miscellaneous 4.12%

Number of employees



Report on R&D activities

The competence of CRM essentially focuses on metallic materials (steel, non-ferrous metals and associated materials) and supports worldwide its industrial members. The technical fields managed by the CRM teams integrate a large range of activities covering the complete loop of the value creation chain from the transformation of raw materials up to finished products including their recycling after use and end of life.

This expertise is shared between different research and support departments and when needed a collaboration is also searched for with external partners. The main key technical fields to be highlighted are:

- The energy-efficient and environment-friendly metal production, a field involving the sustainable and low-cost manufacturing of steel and metals, the reduction of the energy consumption, the recycling and valorisation of by-products and the related environmental aspects;
- The metallurgical and thermo-mechanical processing of metals from casting to hot and cold rolling, thermal treatment and cooling as well as activities in physical metallurgy and development of new (generic) products;
- The surface treatments and coating technologies with actions dedicated to improve the performances of existing processes or to develop new coating technologies and surface functionalities applicable to a large range of metallic materials;
- The application and use of advanced metallic materials in integrated solutions for different market segments and sectors, an area of large interest for industrial members, SME's and local or regional economy.

The R&D and support activities conducted by CRM in 2012 and selected from the shareable items are illustrated in four thematic sections:

- Design, monitoring and control of innovative manufacturing and processing technologies
- Study and development of new advanced metallic materials and their applications
- Sustainability of natural resources, recycling and valorisation of by-products
- Valorisation, dissemination, international and regional collaboration

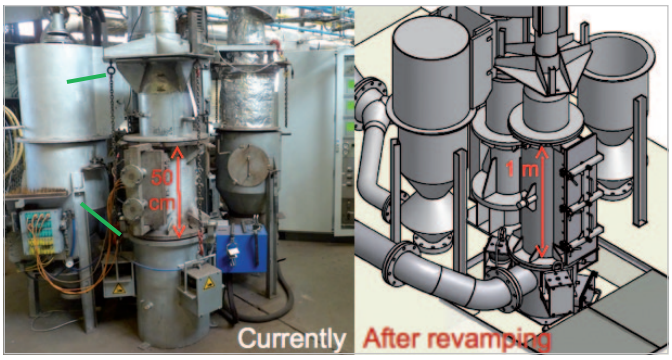
Design, monitoring and control of innovative manufacturing and processing technologies

This first part of the report illustrates through some relevant examples the activities conducted by CRM for the benefits of its industrial members in order to develop new technological approaches aiming to reduce the processing costs, to promote an efficient use of the energy and raw materials, to decrease the environmental impact and to allow the development of new or improved finished products.

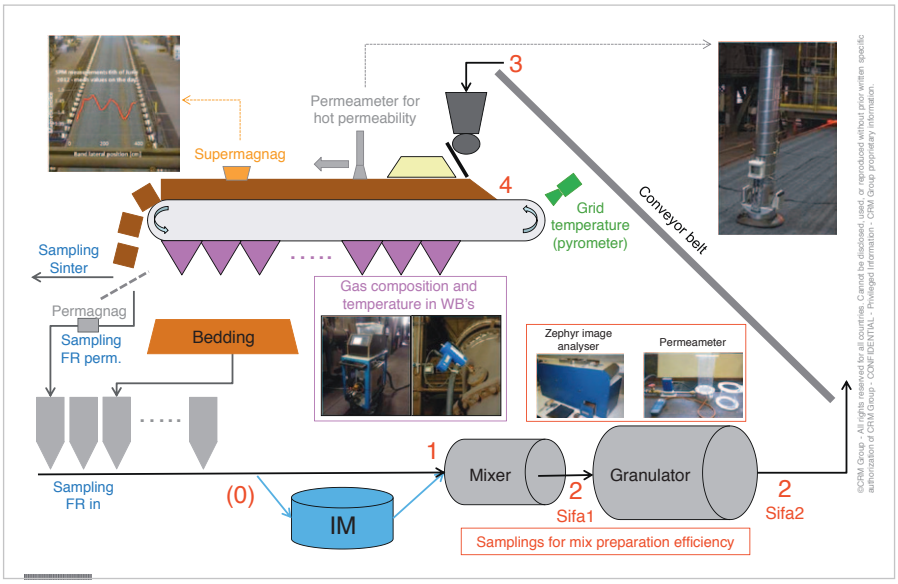
- Starting with the "Upstream" processes, an area of major concern for the Steel Industry managing integrated plants, a first example of recent achievements concerns the "sintering" of iron ores.

In order to propose new industrial lay-outs and process control tools able to help our affiliated Steel companies (ArcelorMittal and Tata Steel) to tackle the challenges of the competitive World economy (variability of raw materials, stringent environmental regulations, ...), two main actions have to be pointed out :

- The permanent adaptation of our pilot sintering unit to enlarge its capabilities. After the modifications made to simulate any kind of waste gas recycling concept, the pilot station has been enabled to work with a bed height up to 1 meter and hence to better characterize the gaseous and dust emissions with notably the on-line measurement of PM (Particulate Matters).
- Industrial campaigns conducted at ArcelorMittal Ghent aiming to support the implementation of new process such as the introduction of an intensive mixer to prepare the blend. Sensors have been installed to evaluate the granulation efficiency and to on-site assess the cold permeability, the size distribution and the shape parameters of the mix. Additional measurements are also performed all along the sintering plant to better control the process: gas composition and temperature in the wind-boxes, hot permeability, magnetic index of the sinter, sampling of sinter and return fines,...).



Sintering pilot station



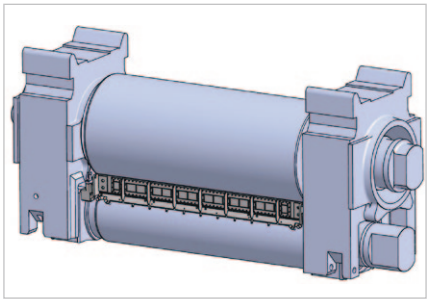
Industrial sinter plant fully instrumented

- In the field of the EAF steelmaking, the extension and industrial application of the dynamic on-line model has been continued with its successful implementation in 2012 at ArcelorMittal Lázaro Cárdenas (Mexico). This plant is operating with a continuous charging of DRI (Direct Reduced Iron). The model is used to monitor the four EAF vessels with the main objectives to better control the carbon content, the melt temperature and the heat weight.

EAF plant operating with DRI – a) DRI before charging – b) Melting process

- The hot deformation and rolling of metals and more particularly of steel is another important domain where CRM is very active. A special focus is put on the development and application of innovative cooling technologies.

A first example concerns the industrial application of a selective roll cooling system for plate mill.



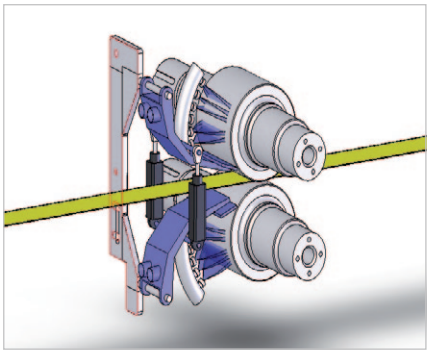
Selective roll cooling for plate mill

Industrial off-line implementation

The objective is to obtain a more homogeneous and efficient cooling of the top work roll thanks to the application of a high turbulence cooling (HTRC) previously developed for the hot strip mill. Based on this experience, it is expected that the thermal fatigue of the work roll will be reduced and the work roll surface defects that currently occurs during rolling will be minimized.

The innovative part of this new cooling header is that the top work- and back-up rolls will be homogeneously cooled down with a minimum water consumption and at low pressure. The cooling system has been constructed and tested off-line in the plate mill of Tata Steel at Scunthorpe.

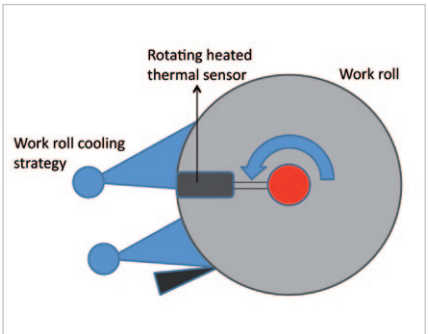
A second example deals with the work roll and product in the hot strip mill. An innovative concept for a combined work roll and strip cooling strategy has been proposed. Water model simulations and continuous hot rolling pilot line trials are used to prove the benefits of this cooling strategy at low pressure. A new



Combined roll and strip cooling

Water model simulations

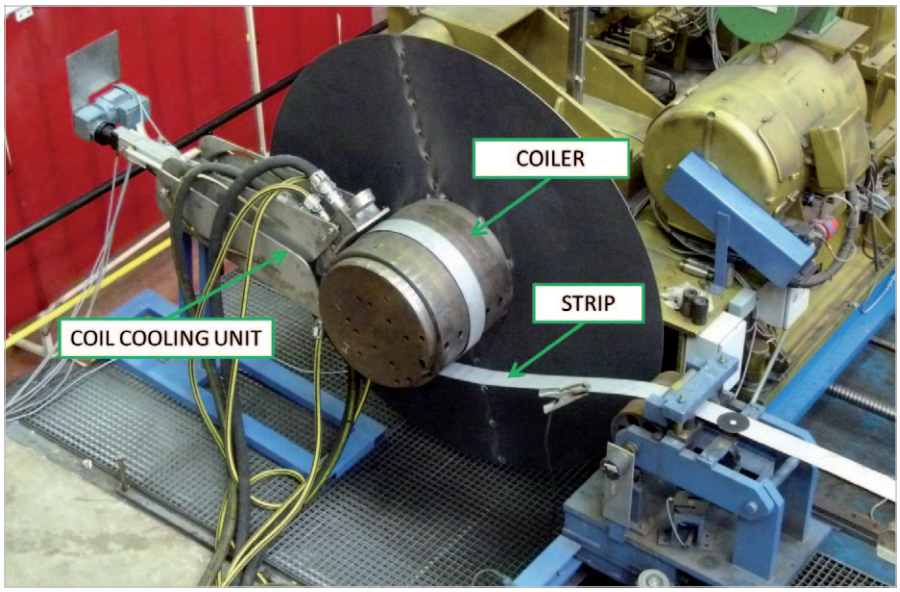
measurement system has also been developed to assess the influence of



Thermal assessment of roll cooling efficiency

different cooling parameters on a heated sensor probe placed in a rotating work roll. With this system, long term trials can be managed to detect and identify slow and progressive evolution in the thermal balance of the roll.

As a last example, let us mention a new device for a direct cooling of the strip during coiling. By applying a continuous cooling only on one side of the strip, more flexibility in the cooling strategy is possible in order to reduce the material properties deviation over the strip length and width.



New coil cooling unit

- The control and mastering of the scale (surface oxide layer) formed all along the hot processing route is another important aspect in terms of metallic yield, production cost and quality of the final products. In collaboration with WINOA and Tata Steel, a new water-free descaling technique applicable at high temperature has been developed (RFCS project "HIDES"). Behind the use of this new mechanical descaling technique, an improvement of the surface quality and a reduction of the heat loss and energy consumption are searched for a large range of low to high alloyed steel grades (with a special interest for the long products).

A dedicated shot blasting device has been constructed for descaling tests at high temperature and different operating parameters were optimised: shot size, air pressure, amount of shots, etc.

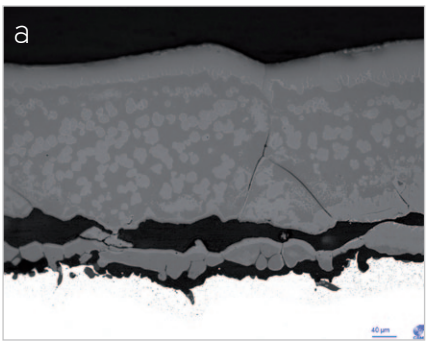
Hot shot blasting machine

Not only a very good efficiency of the descaling is reached under static conditions but also a high quality of the semis surface is observed after rolling (no internal oxidation or visible oxide residues).

The wavy surface after shot blasting disappears after rolling. Typical defects associated to high alloyed steels are no more visible.

For the "Downstream" processes (Finishing and Coating operations), the most significant achievements to be outlined concern the surface preparation, annealing and galvanizing steps.

- In order to significantly improve the galvanisation of Advanced High Strength Steels, CRM proposed a new approach for the preparation and conditioning of the product before annealing. The concept called "Ferrigal" is based on the use of an iron oxide water-based solution



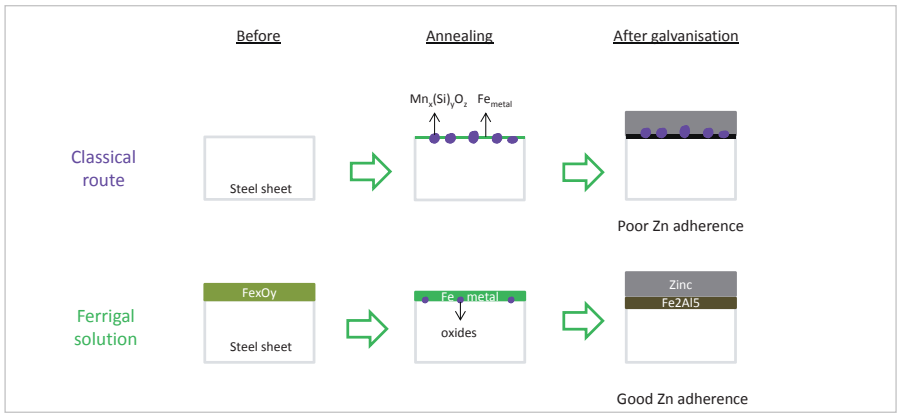
Scale after reheating

Scale after shot blasting

Scale after shot blasting and rolling (20% reduction)

and its deposit at room temperature to create a thin film on the steel surface.

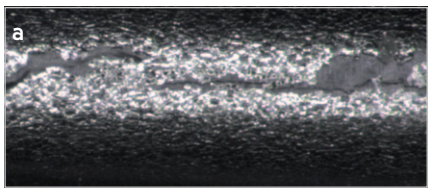
After a severe bending test, it is observed that the substrate galvanised with the Ferrigal treatment shows a very high adherence of the zinc layer whereas important defects are noticed on the sample not pre-treated.



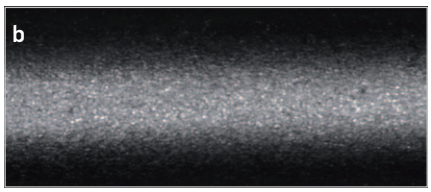
The "Ferrigal" concept

During annealing, the iron oxide layer is dried, sintered and crystallised. It acts as a barrier against the alloying segregation at the steel surface. Under reducing atmosphere, the iron layer is reduced to iron metal that helps to promote a very good galvanisation of steel grades alloyed with silicon, manganese and aluminium.

The concept has been demonstrated through trials performed on several steel substrates including grades such as TRIP780.

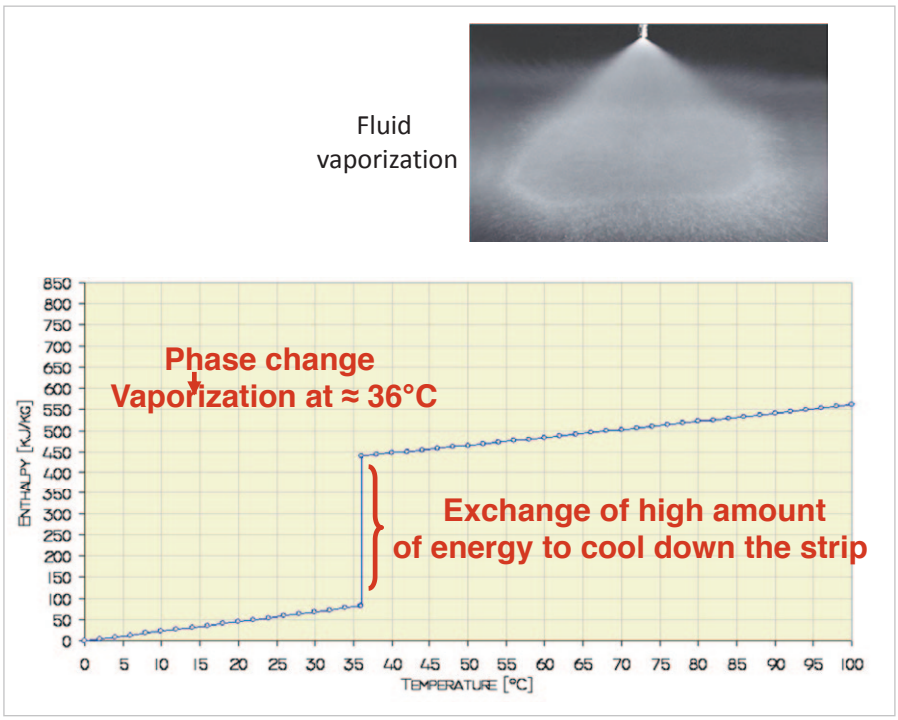


a) Reference (TRIP steel) - Conventional treatment

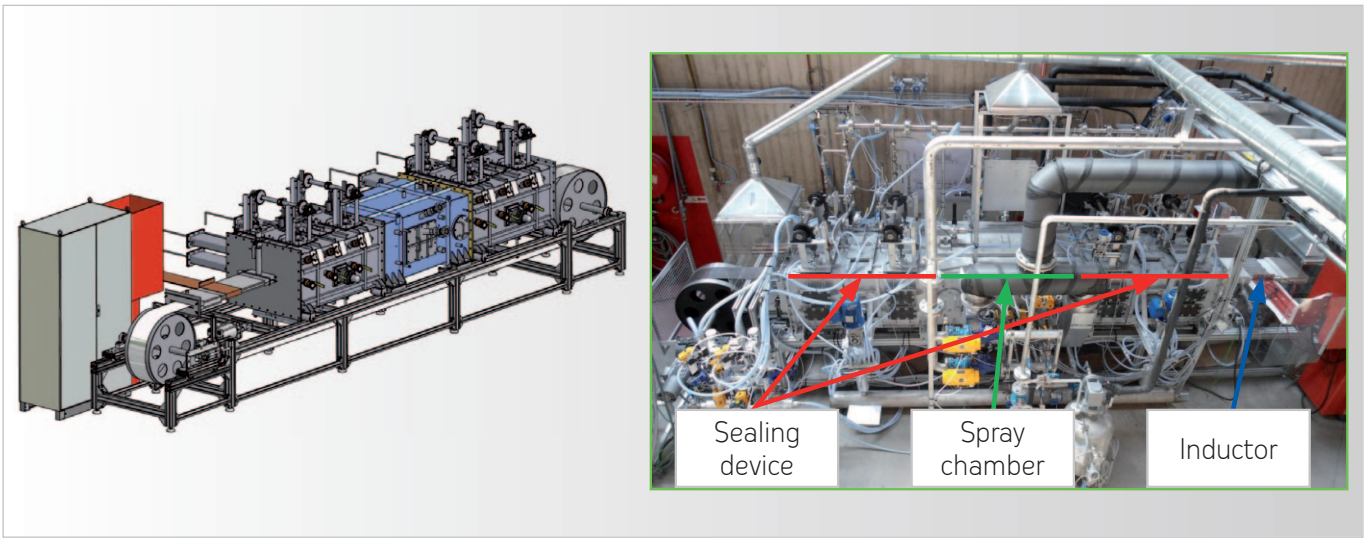


b) TRIP steel processed by Ferrigal

- A second major item to be outlined concerns the support given by CRM to CMI (Cockerill Maintenance & Ingénierie) in the development of a fully new concept of strip cooling for annealing or galvanizing lines (RFCS project "Ultra Dry Cooling"). The basic principle of the concept relies on the spraying of a non-oxidant fluid, changing of phase (liquid to vapour) around ambient temperatures with a significant endothermic effect. High cooling rates without metal oxidation can be obtained with a low electric consumption.



"Ultra dry cooling" for annealing or galvanizing



Endless strip bench for "Ultra dry cooling"

To test the concept, an endless strip bench has been designed and constructed in order to optimize the sealing devices and to perform a complete thermal assessment of the system.

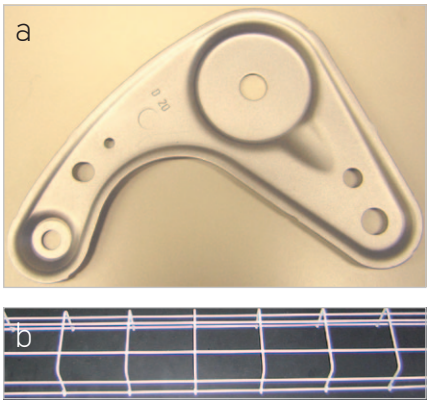
- Industrial activities related to the "batch" galvanisation represent a large economic part of the manufacturing sector. An innovative process able to deliver Duplex products at a lower cost and called "Evaplex" has been proposed by UMICORE three years ago.

  During the 1st phase of a project financially supported by DGO6 (Walloon Region), a consortium constituted by UMICORE, DREVER, CRM and CoRi has developed the concept and realized intensive trial campaigns on the pilot equipment built by CRM. The principle of the process is to evaporate zinc under a moderate vacuum level and to create at the surface of pre-conditioned products a protective zinc-iron layer before, in a second step, to complete the treatment with an organic paint layer. The pilot equipment and the concept have been largely improved during the project and due to a better knowledge on the role of the main process parameters, industrial products of high quality have been successfully treated.

  Based on these very positive results, the second phase of the development has been launched again through the financial support of a the Walloon Region (DGO6) under an Eureka label project with a consortium composed by UMICORE, DREVER, CRM and a French partner, Galva 45. The objective is the design, building, installation and start-up of a new industrial equipment able to process industrial massive pieces up to 3 meters in length in a 8m^3 furnace.

"Evaplex" pilot installation

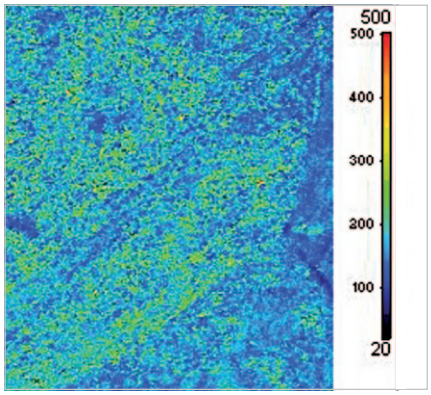
DGO 6



Automotive part and cable support processed by Evaplex

Study and development of new advanced metallic materials and their related applications

Besides the more classical activities linked to the so-called physical metallurgy and dedicated to gain new basic knowledge and support the development of generic concepts for high performance steel grades, CRM also devotes a large effort to other metallic products where its competences in technologies, metal knowledge and in process-product interference are valorised.

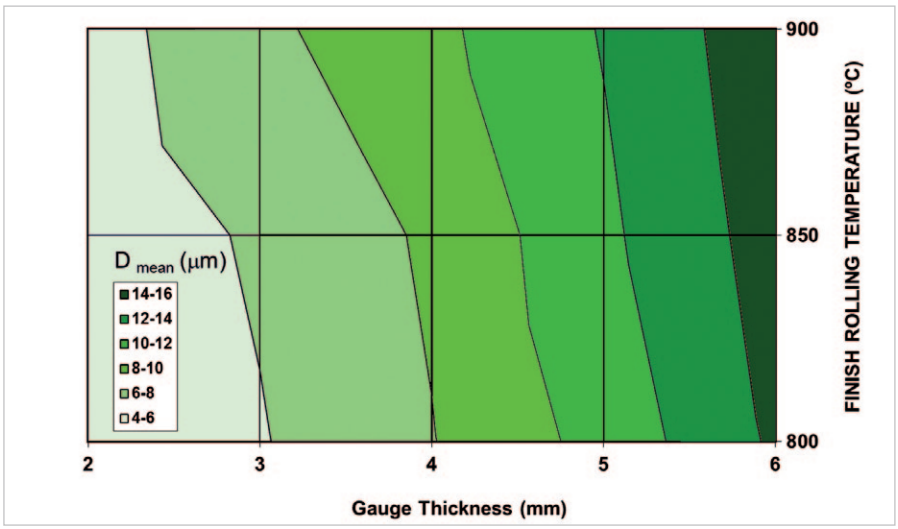


Mapping (20µmx20µm) of carbon in a 0.4 C martensitic steel after tempering at 130°C

Several examples have been selected to illustrate these various activities, starting with the high strength steels field.

- For modern advanced high strength steels (AHSS) exhibiting a martensitic phase, the final thermal treatment (the "tempering" step) has a strong impact on their mechanical properties and behaviour by finely modifying the martensitic structure. The current metallurgical knowledge shows limitations in a correct prediction of this evolution and on its effect on the in-use properties. Using sophisticated characterization techniques such as high-resolution diffraction, TEM and nano-SIMS, CRM has identified the different stages of carbides precipitation in a 0.4 % C martensitic steel as well as their distribution at a nano-metric scale in the microstructure.

To control the processing of high strength steels, it is necessary to perfectly know the metallurgical phenomena (recrystallization, precipitation, ...) occurring during their deformation (particularly the hot rolling) and to develop tools allowing to fix the right operating conditions and to predict the main final characteristics of the products like the grain size, a microstructural parameter having a major influence on the mechanical properties. In the frame of the RFCS project "MicroTools", Silicon and Niobium–alloyed steels are more specifically under investigation. Using the results of hot torsion tests and of simulations made with improved version of hot rolling predictive models , dedicated process regime maps can be established where the evolution of important parameters (austenitic grain size, recrystallized fraction after the last pass) are given as a function of process conditions (finishing rolling temperature, final gauge thickness). Increasing the final gauge thickness



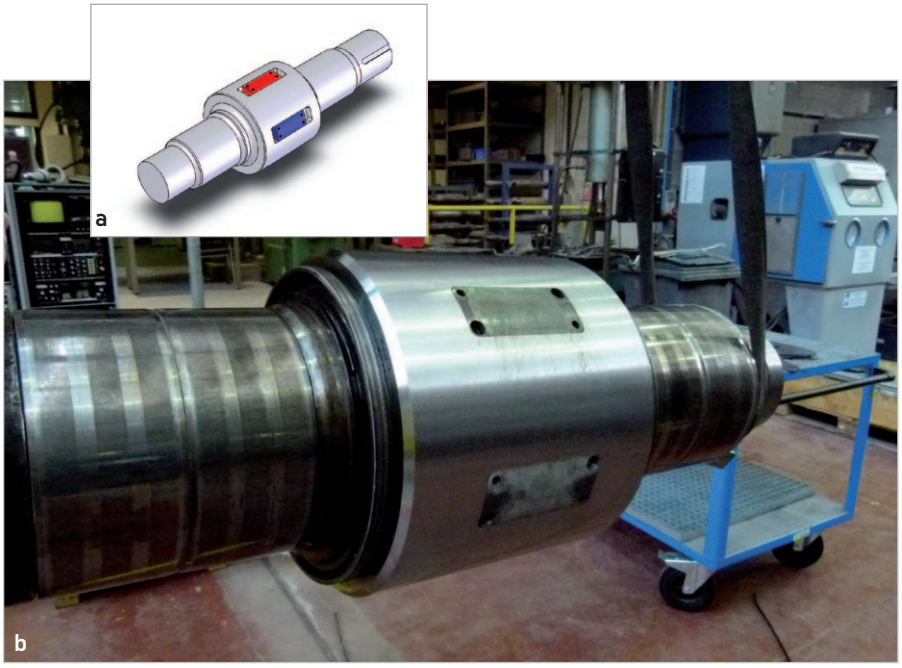
Process regime map to predict austenitic grain size after hot rolling

(i.e. decreasing the total deformation level in finishing mill) or increasing the finishing rolling temperature leads to a larger final austenite grain size and to a softening of the product, everything being similar.

With the aim to better master the hot rolling process and the inter-stands evolution, the possibility to use an in-situ measurement of the microstructure change is tested in the frame of the RFCS project "MicroControl" (associating ArcelorMittal,CRM, Kimab, Imagine Optics and CNRC-IMI). A laser ultra-sonic sensor has been designed for that purpose and tested for a first campaign in the CRM continuous hot rolling line. Indeed, this pilot line allows to assess the sensor reliability and capability in a near-industrial environment reducing the risk and cost of the real industrial implementation planned in a further step.

- As already mentioned, a large effort is also devoted to other metallic products and application fields.

A first major example concerns the "work rolls", a specific "product" of prime importance for the Steel Industry but also for other industrial sectors having to process by rolling metallic products. This activity is conducted in close collaboration between CRM, its steel members and the roll-making companies affiliated to CRM: Marichal-Ketin, Åkers, Gontermann-Peipers.



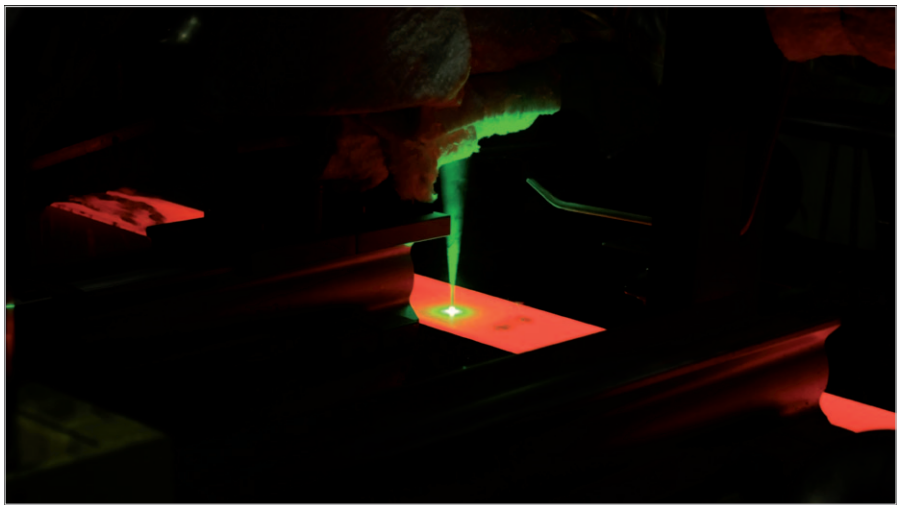
Application of the "inserts technique" to test roll materials (a: sketch, b: picture)

The performances of new roll grades supplied by Åkers for the slab roughing mill, have been assessed in the frame of the "WINROLLS" RFCS project. Applying the technique of the "inserts", where different pieces of work roll materials can be placed inside one roll and submitted to continuous hot rolling tests in the pilot line of CRM, a direct comparison between reference and new roll grades is made possible. The rolling conditions for these trials were based on the industrial working practice of ArcelorMittal Dunkirk.

For the long product rolling, several approaches have been launched aiming to improve the wear and degradation behaviour of the work rolls in order to significantly extend their life in service.

New ceramic and cermet materials are being evaluated for the rod mill. The aim of this RFCS "CERROD" project is to gain a detailed understanding of the cost-applicability of ceramic/cermet work roll material.

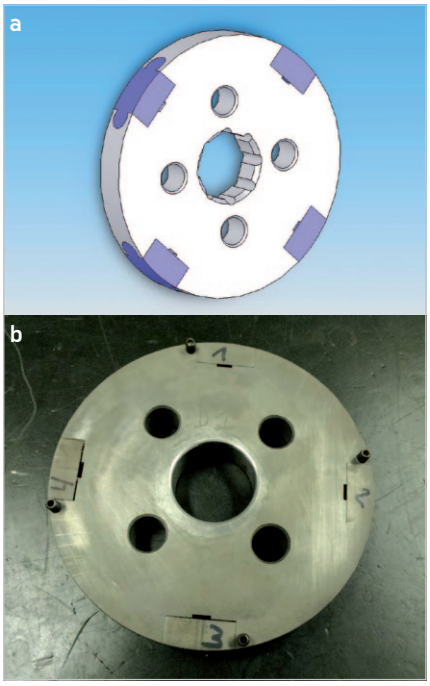
A dedicated hot rolling simulator is used to perform tests close to industrial conditions while checking up to four different materials in one set of test.



Microstructure characterization with a laser ultra-sonic sensor

Hot rolling simulator

The application of coatings to protect the roll surface (“LPROLLCOAT” RFCS project) involves techniques such as the high velocity oxy fuel process (HVOF) or the cold gas dynamic spraying process (CGDSP). Dedicated trials are performed on a twin disk machine to select the most promising solutions before to realize continuous pilot mill trials.

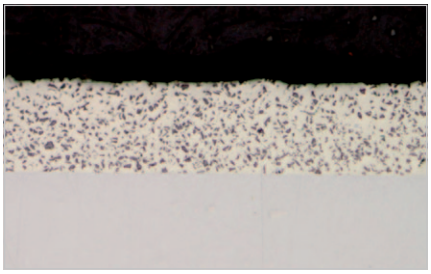


Testing of coated work rolls (a : sketch, b : picture)

The basic understanding of the stress evolution inside the roll is necessary to identify innovative corrective actuators able to reduce the cracking proneness (“ROLLSTREM” RFCS project). A first measurement campaign has been run at the Tata Steel Scunthorpe Rails & Sections Mill to establish the wear pattern at the end of a rolling campaign.

In-plant measurement of the roll degradation

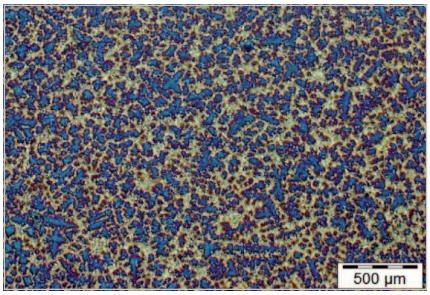
For the cold rolling area where chromium-coated rolls are used, a major issue is the banning of hexavalent chromium salts in the EU from 2016 on. In the “CrFreeRolls” RFCS project (CRM, ArcelorMittal, Äkers and TataSteel), alternative wear-resistant coatings for skin-pass mill rolls are searched for. Options studied by CRM are electroplated coatings based on hard nanocrystalline Ni- and Co-based alloys or composite coatings (a metal matrix reinforced with ceramic particles).



Cr-free roll: New electroplated Ni-SiC composite coating

- Another field of development concerns the production of low cost thixotropic steel grades for foundry and forging applications. In a project coordinated by Marichal-Ketin with the support of the Walloon Region (“Marshall Plan”), the aim is to cast small ingot sections close to the liquidus temperature in order to obtain the desired solidified microstructure.

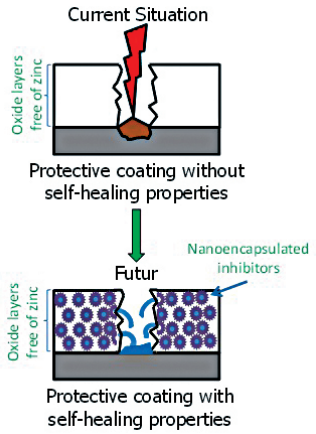
Low superheat casting in foundry



Example of thixotropic structure in small ingot

- New protective coatings free of zinc are searched for indoor and outdoor applications. This development of new products is conducted in the frame of the “CLEARZINC” project supported by the Walloon Region and the European Fund for Regional Development. Among the various explored solutions, two options appear more particularly promising: - the deposit by electro-deposition of a metallic oxide coating based on aluminium and silicon components. Homogeneous films having an average thickness between 600 nm and 1000 nm allow an acceptable protection

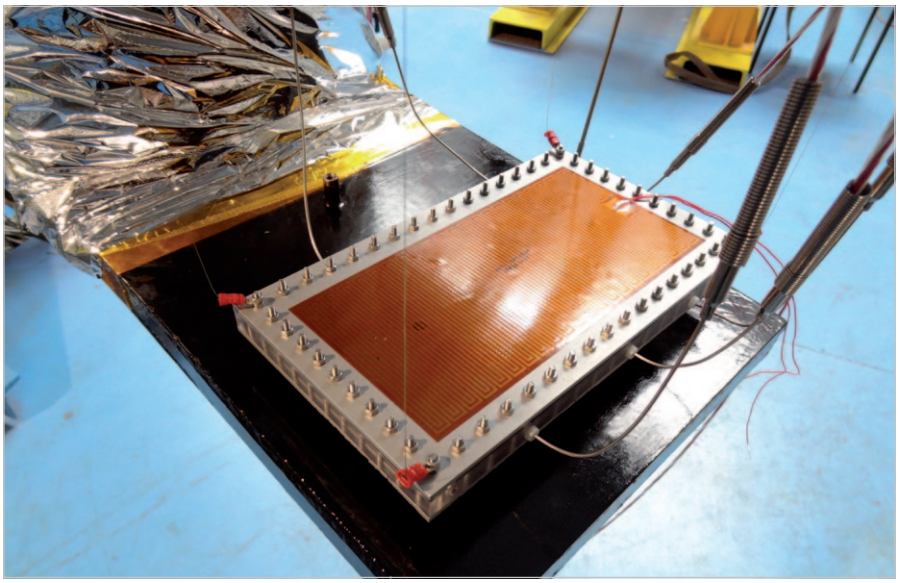
New Zinc-free coating after cyclic humidity test



New concept for zinc-free coatings

of the substrate in outdoor exposure (18 days) providing the environment is not too aggressive. The aluminium –silicon oxide film shows a good adhesion on steel substrate and promotes the further adhesion of paints. – a second solution involves a similar oxide film but with an additional introduction of nano-encapsulated inhibitors giving self-healing protective properties to the product.

- A last relevant example of association of materials (metallic and non-metallic ones) can be shown through a project conducted in collaboration between WALOPT (a company based in Wallonia) and CRM for the benefit of ESA (European Space Agency). It concerns the control of the thermal inertia of small satellites (less than 100kg). During orbital period, these low thermal inertia satellites see their temperature largely fluctuating which is highly detrimental for the embarked equipment and electronics. Their thermal inertia can be increased with the help of heat storage media such as Phase Change Materials (PCM). Due to their high latent heat, PCM can store large amounts of energy into a small volume without increasing the global mass of the system. CRM has designed and built a heat storage device allowing to reach this objective. Based on this first successful development, ESA has granted WALOPT and CRM a new project for the development of a similar heat storage device for larger launchers. This project is going to start in 2013.



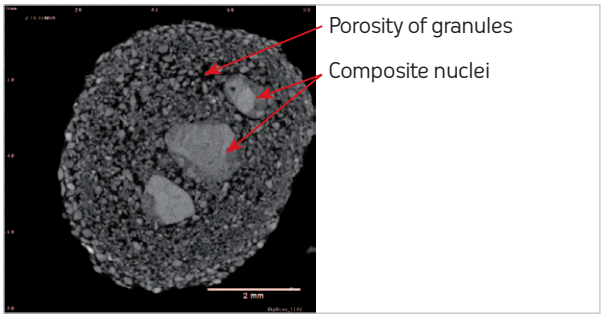
Heat storage device filled with PCM

Sustainability of natural resources : Efficient use of raw materials, recycling and valorisation of by-products

As already underlined in the introduction, the expertise and competence of CRM in R&D and technology are largely devoted to the development and promotion of new processing routes, minimizing the environmental impact and favouring the recycling and valorisation of by-products and end-of-life products, turning them in valuable materials for closing the loop of the metals value chain.

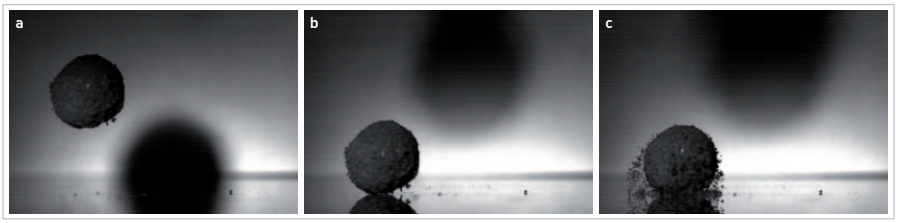
Preconditioning units available at CRM: Briquetting, intensive mixer, pelletizer

The conversion of by-products (slag, dust, scale, sludge, turnings,...) into secondary raw materials generally requires to firstly modify their size mainly when they are present as very fine particles and to mix them with other residues for reaching appropriate chemical & mechanical properties before recycling. Dedicated pre-conditioning techniques such as intensive mixing, pelletizing or roll-compaction are necessary in that prospect and large scale equipment are available at CRM. In order to support the processing of these very fine materials, a fundamental study is running (First DoCa (PhD) thesis) to get a more comprehensive knowledge about mechanisms governing the mix granulation. This activity, financially supported by the DGO6 (Walloon Region), is conducted in close collaboration with the University of Liège and the Institute of Chemical Technology (ICT) of Prague. Among the techniques used, it is worth mentioning the X-ray tomography, allowing to finely analyse the structure of granulated materials.



Tomography analysis of a compacted granule

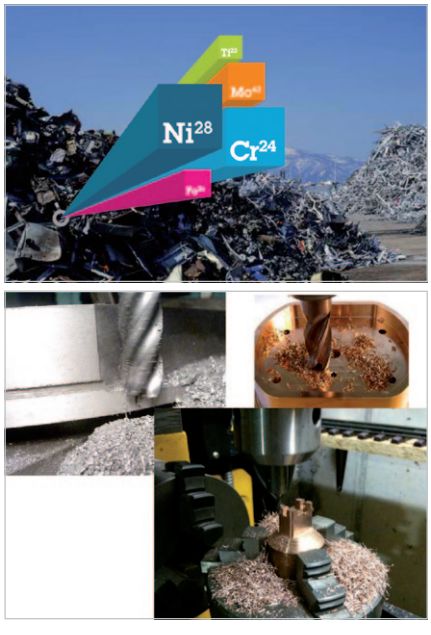
Another original approach is the use of a high speed camera during falling tests in order to characterize the granules breakage mechanisms, a very important aspect to predict their behaviour during further processing. This study will help to optimise



Granule behaviour during impact test

the preparation of challenging input materials a.o. in sinter plants, allowing to use lower grade ores or increased proportions of secondary raw materials (fine residues rich in Fe, CaO or C).

Another valorisation route for solid residues rich in metallic components is studied by CRM. It involves a mechanical pre-conditioning followed by a complete melting in an adapted furnace in order to separate the metallic fraction from the mineral gangue. During the project "RECYMELT", supported by the Walloon Region (DGO6) and associating CRM, BCRC, CTP, ULg-Gemme and ISSEP, more than 30 by-products from various industrial sectors (foundries, industrial recyclers, cement industry, stainless steel…) have been collected, fully characterised (chemical and physical properties) and processed at CRM (crushing & compaction) prior to melt them in a new 350 kg induction furnace. Very positive results have been obtained at this pilot scale with a high yield in terms of metal recovery and a very



Examples of metallic by-products

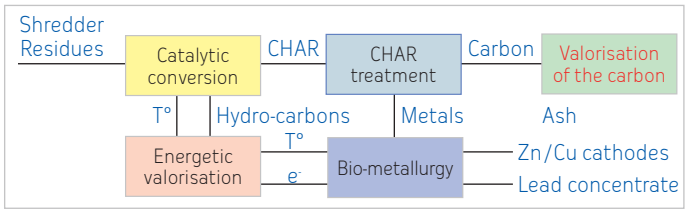
Melting trial in a 350 kg induction furnace

low environmental impact (no hazardous gas and dust emissions). Based on these attractive results, an industrial recycling campaign has been performed at APERAM Châtelet. Around 3 tonnes of by-products

Conditioned by-products ready for industrial recycling

have been mixed and compacted as briquettes by CRM before to be successfully recycled at the EAF plant of APERAM with the target to valorise their metallic content (Ni, Cr, Mo, Si, …)

CRM also supports COMET TRAITEMENTS, a Belgian company active in the metal recycling and operating large shredding installations. In the frame of the "Phoenix" project (coordinated under the Walloon Marshall Plan), actions have been launched to valorise fine Fe-rich oxides shredder residues (SR) and a char resulting from the catalytic cracking of the organic part of shredding residues. Using these materials, self-reducing briquettes have been fabricated in view of their further processing and recycling either through



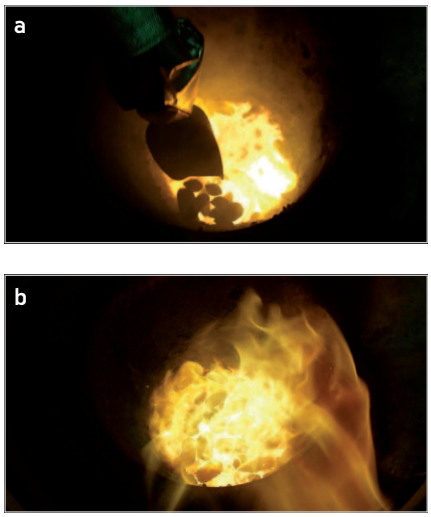
The "Phoenix" project lay-out

a direct reduction route to obtain a DRI product (Direct Reduced Iron) or through a direct melting in an EAF (Electric Arc Furnace) shop.

Recycling of self-reducing briquettes in a rotary-hearth furnace

Briquetting tests realized at CRM have shown that the mechanical resistance of the mix is very good. The input of char seemingly improves the compaction and the binder effect compared to the poor results obtained when using fine coal, a component more commonly used for this operation. Melting trials of these self-reducing briquettes have been realized in the 350 kg induction furnace of CRM to simulate their EAF recycling route, comparing different mix compositions.

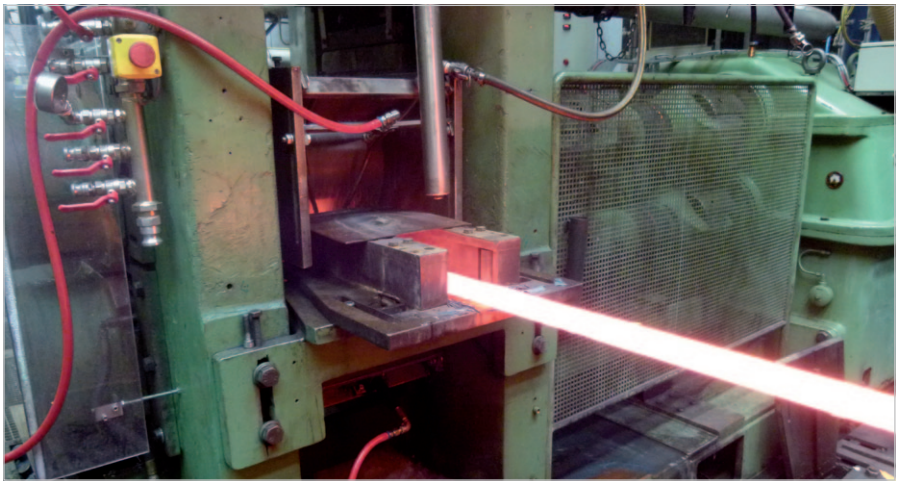
The briquettes have been progressively incorporated in molten steel.They withstand without problem the thermal shock and no dangerous projections happen during or after their incorporation. Emitted fume samplings showed that the emissions of



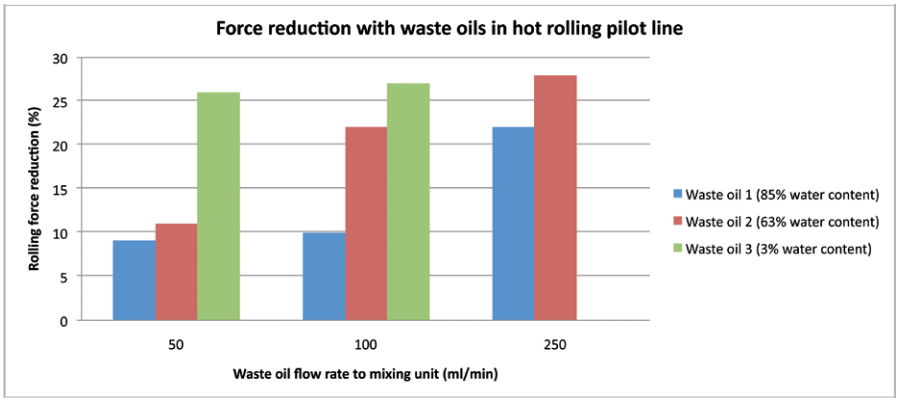
Melting of self-reducing briquettes (a : charging, b : melting)

VOCs (volatile organic compounds) are greatly reduced in the case of briquettes made with char as reducing agent instead of coal. This result is largely due to the removal of the volatile components from the char during its production by catalytic cracking.

- A last example of recycling approach to be mentioned concerns the re-use of waste oils for the lubrication in the hot strip mill. During hot rolling, specific oils, generally applied as an emulsion, are used to lubricate the work roll cylinders and the strip. With the aims to better meet the environmental regulations and to reduce the production costs, waste oils coming from other processing steps like cold rolling or annealing or from other industrial sectors are tested in the continuous pilot rolling line of CRM. For this hot rolling application, the use of complex and costly emulsifiers is not necessary to keep a stable emulsion during several cycles like for the use in cold rolling. Trials on the hot rolling pilot line showed that the lubrication efficiency with waste oils are equal to conventional fresh hot rolling oils. The trials were performed with a multiple lubrication application unit to compare simultaneously different lubricants. Detailed analysis and laboratory tests have also indicated the non-toxic impact of these recycled oils.



Rolling trials with recycled oils

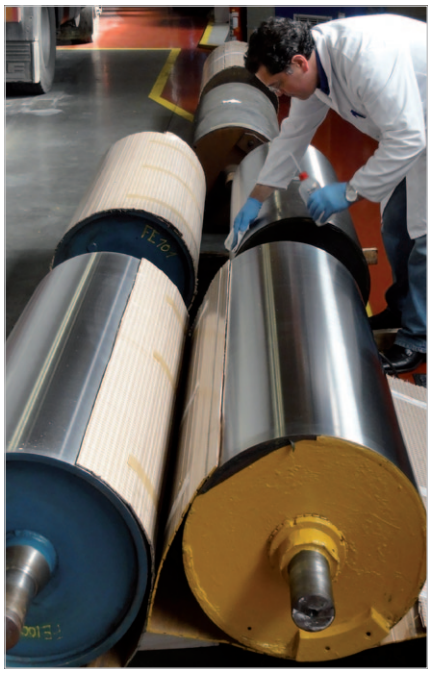


Lubrication performances of recycled oils

Examples of waste oils

Valorisation, dissemination, international and regional collaboration

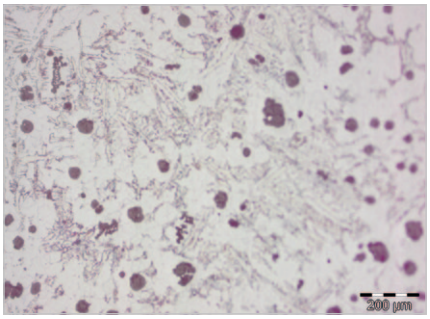
With the financial support of the Walloon Region (DG06), a team of almost 4 guiders having access to the whole competence and equipment of CRM is directly answering to the requests of SMEs. This type of activity covers a very broad range of expertise and technical fields.



On-site metallography

Industrial Instrumentation Seminar

An example of support frequently offered concerns the use of the mobile facilities for characterizing on-site the nature and composition of metallic materials (portable spectrometers and in-situ metallography). To support a company active in the production of coated rolls, the nature of the material, either steel or iron based rolls, has been determined. As the portable spectrometer cannot analyse iron based materials, on-site metallography has been successfully applied.



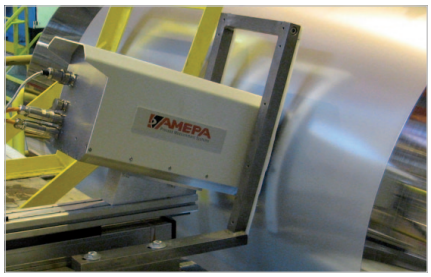
On-line microstructure of spheroidal graphite cast iron (magnification : 100x)

- On October 10 & 11, 2012, CRM has organized a workshop on " Industrial Instrumentation " where several sensors and measuring systems developped by CRM have been demonstrated. More than 125 people have attended this event with representatives from 11 different countries (including Europe, North America and Asia) and 55 companies and organizations.

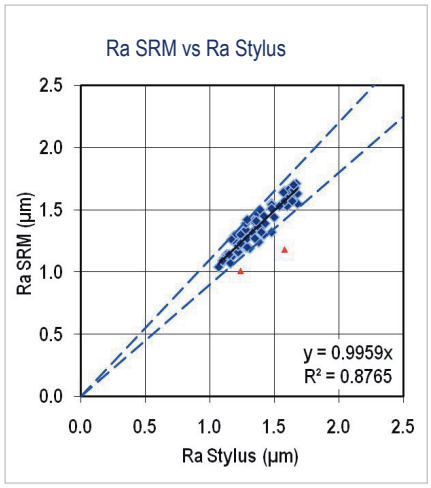
The presentations were focused on the on-line measurement by smart vision during production, the on-line microscopy on moving products, the chemical analysis at stand-off, the remote measurement of geometrical characteristics, the expertise in temperature measurement and pyrometer technologies and the in-situ metal characterization with a mobile laboratory.

Industrial Instrumentation Seminar

To illustrate the valorisation of these sensors, let us more especially mention the "Surface Roughness Measurement (SRM)", a device licensed to AMEPA and aiming to on-line measure the roughness of moving flat products. Around 15 industrial plants (annealing & galvanizing lines) are today operating with this system in Europe (Austria, Belgium, Germany, Spain) and in China.

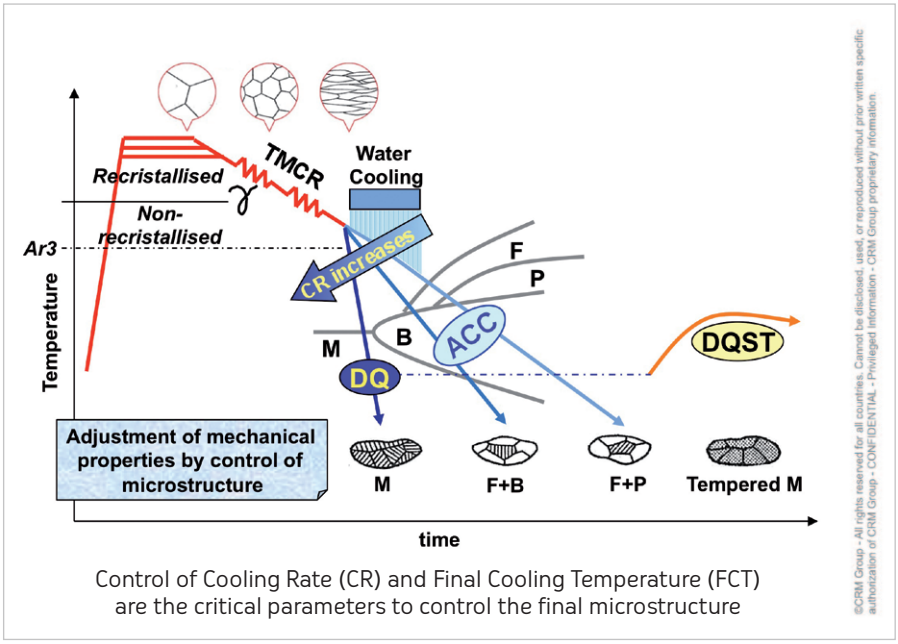


Surface Roughness Measurement (SRM)



On-line measurement of the steel strip roughness

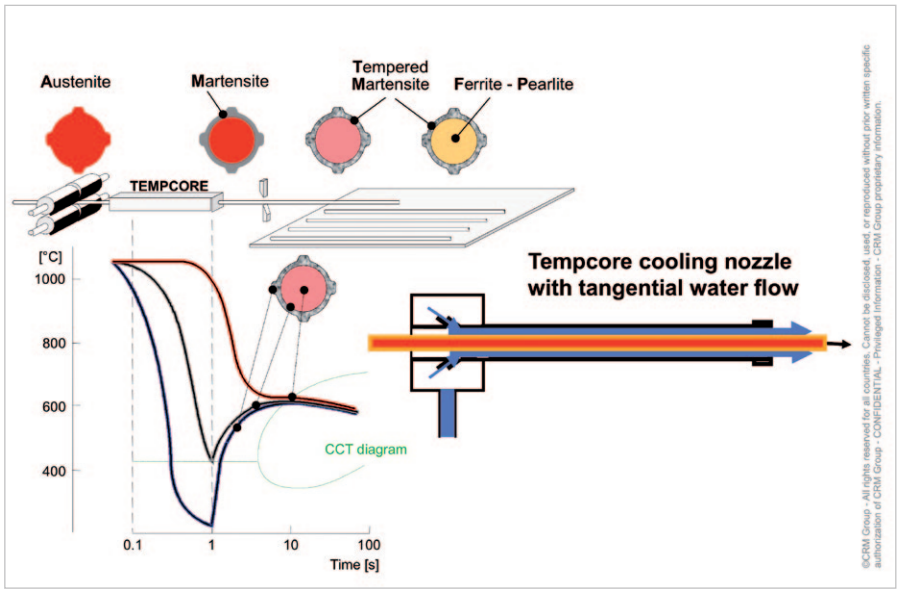
- As already mentioned, one of the key competences of CRM concerns the development of cooling technologies applied for the mechanical and thermal processing of metallic materials. The use of water cooling to control the microstructures and to adjust the final mechanical properties instead of consuming high cost alloying elements makes these technologies a very effective and low cost solution to produce high quality products. When mature and industrially proven, these technologies can be worldwide deployed in collaboration with CRM industrial members. Two relevant examples can be more particularly pointed out:



Control of Cooling Rate (CR) and Final Cooling Temperature (FCT) are the critical parameters to control the final microstructure

Tuning of steel properties by water cooling

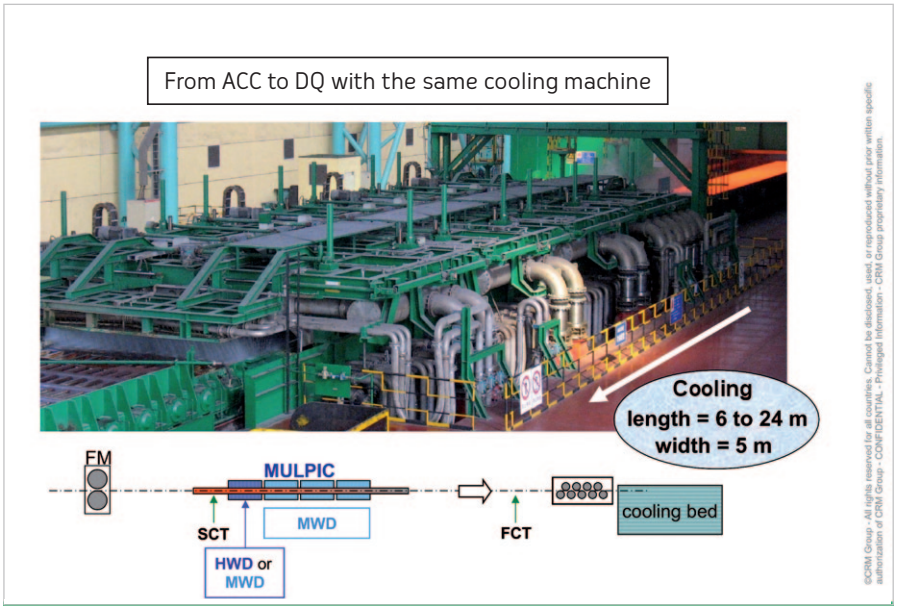
- The "Tempcore" process, a quench and self-tempering process initiated in the seventies, is designed for the manufacturing of high quality concrete reinforced bars. A specifically adapted cooling box is located near the exit of the finishing stand to quench the bar surface with a high cooling rate during a limited time. The thickness of the external layer is transformed in a hard martensitic phase, later reheated and tempered by the core of the product during the final slow cooling. This process is largely implemented in the World with more than 80 licensees mainly located in Europe, Asia and India



The "TEMPCORE" process for rebars

World licensees of TEMPCORE

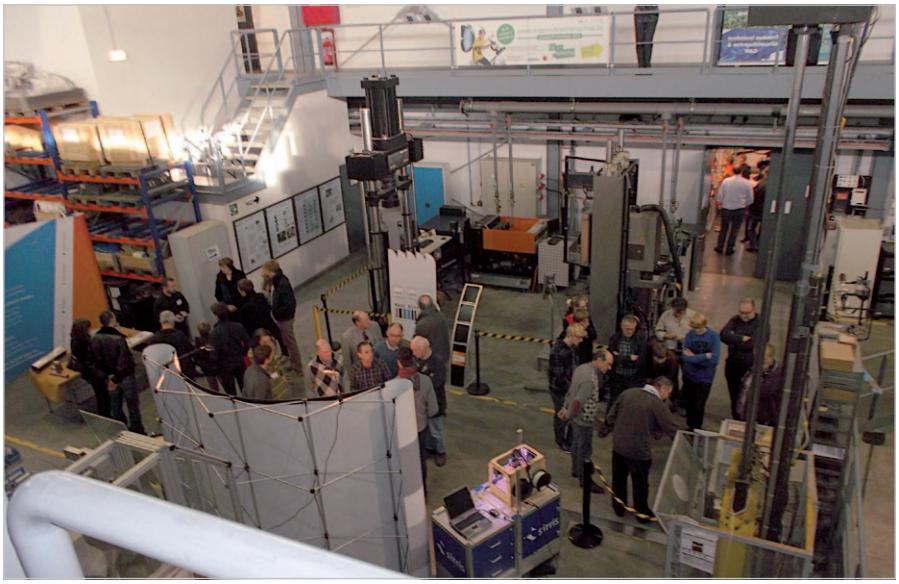
- The "Mulpic" process, a dedicated technology to produce high quality plate, a strategic product for the pipeline installations and the large gas and oil transport networks. Installed at the exit of the plate finishing mill, this multipurpose interrupted cooling equipment is based on the water pillow technology of CRM. Currently, plate thicknesses from 10 to 120 mm on a maximum width of 5 m can be treated through the MULPIC installation by modulating a large range of possible thermal treatment from ACC to DQ cycles. This technology has been licensed to SIEMENS-VAI and more than 18 installations exist in the World.



The "MULPIC" process for plates

The "MULPIC" process in the World

- During 2012, CRM took part to different exhibitions, fairs and conferences. To be especially mentioned, the "Day of the Science 2012", an event associating the partners of the Material Research Cluster in Gent on November 25th, 2012. Organised in the laboratories in Zwijnaarde, a broad audience has been invited to see how science and technology and more specifically material science are part of our daily life and to which extent research and technology are leading cards for our future.



The "Science Day 2012"

Valorisation, dissemination, international and regional collaboration

- CRM has always actively participated 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.

- Accord-Wallonie: An association regrouping the 22 collective research centres certified by the Walloon Region.

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

- WARE (Wallonia Alliance for Research in Energy), an initiative of the Walloon Region aiming to gather all Walloon Research Centres and Universities having R&D activities in the large range of energy aspects.

MATERIALS RESEARCH CLUSTER GENT

- The Material Research Cluster Gent is an initiative in which seven partners (OCAS, Gent University, Sirris, BIL, Clusta, CRM, SIM and its division Flamac) share communal laboratories with a strong focus on metals.

CReSus
Centre for Resources Recycling and Sustainability

- A recent new association to be mentioned concerns CRM and the ULg department of Mineral Processing (GeMME) to strengthen the collaboration in a dedicated «Resource and Recycling» association named "CRESUS".

- At the European level, CRM takes actively part to the following organizations and initiatives:

The European Steel Technology Platform (ESTEP) brings together all the major stakeholders in the European steel industry. CRM is chairing the WG Profit and is also involved in two other working groups dealing with "Energy efficient steelmaking" and "Efficient use of natural resources".

Raw Materials Alternate Recycle Extract

The European Innovation Partnership (EIP) called "Raw Materials Initiative (RMI)". CRM has acted in 2012 on behalf of ESTEP to prepare in ad-hoc working groups several technical proposals on the treatment of steelmaking slags and on the carbothermic processing of sludge and dusts.

RIES
RESEARCH INITIATIVE FOR EUROPEAN STEEL

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.

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

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 to 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, required to reach long term sustainability for Europe in terms of global competitiveness, ecology and employment. It associates no fewer than 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

Publications & Conferences

E. Malfa, P. Nyssen, E. Filippini, B. Dettmer, I. Unamuno, A. Gustafsson, E. Sandberg, B. Kleimt
Cost and Energy Effective Management of EAF with Flexible Charge Material Mix
Proceedings of the 10th European Electric Steelmaking Conference, 25-28 September 2012, Graz

G. Walmag, S. Flament, J. Malbrancke, G. Moreas, M. Sinnaeve
Development of New Materials Based on On-Site and Laboratory Evaluation Methods for Understanding Work Roll Surface Degradation
Iron & Steel Technology (A Publication of the Association for Iron & Steel Technology), November 2012, vol 9, N°11, p 77-86

J.P. Collette, P. Rochus, R. Peyrou-Lauga, O. Pin, N. Nutal, J. Crahay
Prototyping of a Phase Change Material Heat Storage Device
Proceedings of the 63rd International Astronautical Congress 1-5 Octobre 2012

A. Mertens, Q. Contrepois, T. Dormal, V. Tusset et al
Ti alloys processed by selective laser melting and by laser cladding: microstructures and mechanical properties
Proceedings of 12th European Conference on Spacecraft structures, Materials & Environmental Testing, 20-23 mars 2012, Noordwijk

Jean-Pierre Birat, Jean Borlée, Hervé Lavelaine, Dominique Sert, Patrick Négro, Koen Meijer, Jan van der Stel, Peter Sikstrom
ULCOS Program : an update in 2012
4th International Conference on Process Development in Iron and Steelmaking, 10-13 June 2012, Luleå

J. van der Stel, G. Louwerse, D. Sert, J. Borlée, A. Hirsch, R. Lin, A. Feiterna, N. Ecklund, M. Pettersson, L. Sundqvist, J. Lovgren, M. Zagaria, C. Feilmayr, M. Grant, O. Ansseau, M. Sihvonen, J. P. Simoes, J. Adam, W. Küttner, R. Schott, A. Babich, S. Born
Low CO_2 Ironmaking by Top Gas Recycle Blast Furnace, the ULCOS developments in Europe
Scrap Supplements & Alternative Ironmaking VI conference, 28-30 October 2012, Baltimore

Jean-Pierre Birat, Jean Borlée, Anne-Laure Hettinger, François Saunier
Clean Steels in Europe
Plenary Lecture of 8th International Conference on Clean Steel, 14-16 May 2012, Budapest

M. Dormann
Potentiel de valorisation d'un déchet en filière métallurgique
Journée Innov'action Déchets, 31 mai 2012, Gembloux

B. Vanderheyden
SPIRE : Sustainable Process Industry through Resource and Energy Efficiency - opportunities for Wallonia-Brussels and possible synergies with Sweden
International Seminar on Sustainable and Resource Efficient Materials – A raw materials and recycling perspective, 17-18 December 2012, Uppsala

G. Walmag, S. Flament, J. Malbrancke, G. Moreas, M. Sinnaeve
Development of new materials based on site and laboratory evaluation methods for understanding work roll surface degradation
AISTech 2012, 7-10 May 2012, Atlanta

V. Tusset
Advance in analytical techniques for liquid steel process and metallic surface characterization
RATEC2012 «Recent advance in analytical techniques for steelmaking industry», 28-30 November 2012, Tokyo

V. Tusset
Future of control in metal industry
11th ICASI (International Committee of Analysis for Steel and Iron Industry) General Meeting, 31 October 2012, Bejing

V. Tusset
Future of the online control of molten metal
CCATM 2012 (International Conference & Exhibition on Analysis & Testing of Metallurgical Process & Materials), 1-3 November 2012, Bejing

F. Berger
Elaboration de couches d'oxydes métalliques en vue de la protection contre la corrosion des bandes d'acier laminées à froid
3ème Journée Scientifique du Portefeuille Revêtements Fonctionnels, 13 décembre 2012, Mons

G. Moreas. G. Monfort. P. Albart, A. Leroy, C. Mathy, O. Lemaire, S. Flament, J.P. Fischbach
Industrial Instrumentation 2012, 10-11 October 2012, Liège

G. Moreas. G. Monfort
Needs and constraints for wireless sensors in the steel industry
10th work meeting of the Wireless Community, 31 May 2012, Leuven

J.C. Herman
CRM Group towards an excellence centre turning innovation into value creation
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P. Harlet
Development of high-added value products through application of advanced coating technologies
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C. Marique
Valorizing the competence for the benefits of industrial members and favouring the synergy between different industrial sectors
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J. Neutjens
Business development approach in CRM Group
GRD "CRM Group, a multi-competence R&D organization in metallic materials supporting multi-sectorial needs", 5 December 2012, Liège

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