CRM
Annual Report

Production
Recycling Applications

CLOSING THE VALUE CHAIN
OF METALS

2013

CRM GROUP

D/2013/0124/1

Contents

Foreword

CRM Group is an R&D organisation active in the field of metal and steel production with the mission to develop new processes, products and applications. In 2013 the total R&D income, combining private, collective and regional activities, was 31 MioEur for 225 employees and researchers.

Within the Group, safety remains our top priority. During the year 2013, CRM deployed a strong safety action plan in all laboratories and pilot facilities, supported by more than 150 safety internal audits.

We also launched a new organisation capable of meeting the current and future challenges of the Group. This organisational change responds to the expectations of our industrial members, ensuring increased efficiency and improved coordination of our activities.

This new group organisation, project orientated and highly flexible, manages 5 operational R&D units:

- Metal production & Recycling: including iron making, electric arc furnace, recycling, valorisation of by-products and environmental issues.
- Metal Processing: including casting & solidification, hot and cold rolling, thermo-mechanical treatment & cooling, physical metallurgy and the development of new generic steels.
- Metal Surface & Coating: including metallic and organic coatings, surface functionalization and the development of new advanced surface properties.
- Metal Application & Construction solution: including building and structure, civil engineering, metal working, assembly and in use properties.
- Industrial solutions: including engineering and thermal technologies, technologies for continuous processing lines, industrial process control and measurement.

In December 2013 the General Assembly validated the take-over of the activities of “Eco Techno Pôle de Wallonie” (ETP-W) by CRM. ETP-W operates several pilot facilities: thermoconversion pilot plant, fluidised bed boiler, fluidisation bench test and circulating fluidised bed pilot plant. Some of these facilities operate up to 50 bars and 1100°C.

This take-over 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 R&D activities will be focused on two main fields: energy, including the production of syngas, and recycling, including the treatment of sludge’s and recovery of metals.

CRM continued to benefit from financial support from the Belgian and regional authorities, as well as from the European Commission. At the European level, CRM participated to numerous research projects, offering many opportunities of co-operation with specialised European partners. In Wallonia, CRM initiated a partnership with two « certified » R&D centres: Sirris (technology sector - multimaterial) and Cenaero (aeronautic industry) ready to share several technical aspects. The partnership has effectively started in 2013.

The present annual report highlights the main achievements of the year 2013 obtained in the steel collective programme shared between ArcelorMittal and TataSteel and in the regional R&D programme in partnership with our partners. Major R&D orientations are focused on the development of new breakthrough technologies, the reduction of processing costs, including a more efficient use of energy and raw materials and a lower impact on the environment. Significant attention is also paid to the recycling process, maximising the recovery of metals and alloying elements.

Paul PERDANG
President CRM

Jean-Claude HERMAN
General Manager CRM

Company members

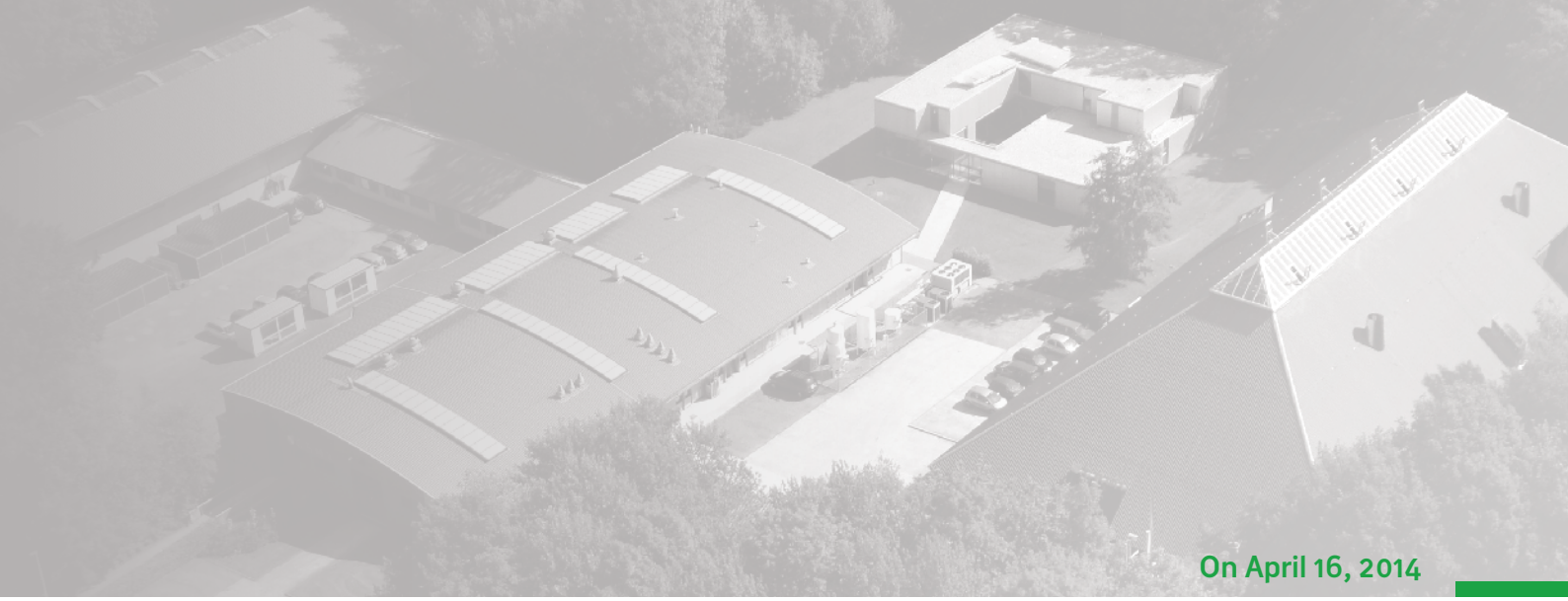
Active Members of CRM

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 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 16, 2014

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
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CBMM Technology Suisse S.A.	Switzerland
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DREVER INTERNATIONAL S.A.	Belgium
EMG Automation GmbH	Germany
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INDUCTOTHERM S.A.	Belgium
INSTITUT BELGE DE LA SOUDURE asbl	Belgium
INTERNATIONAL MANGANESE INSTITUTE	France
MAGOTTEAUX INTERNATIONAL S.A.	Belgium
NDC INFRARED ENGINEERING S.A.	Belgium
NLMK CLABECQ S.A. – Plates	Belgium
NLMK LA LOUVIÈRE S.A. – Strips	Belgium
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PRAYON S.A.	Belgium
PRÜFTECHNIK DIETER BUSCH A.G.	Germany
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TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
TMT	Luxembourg
UMICORE S.A.	Belgium
WINOA S.A.	France
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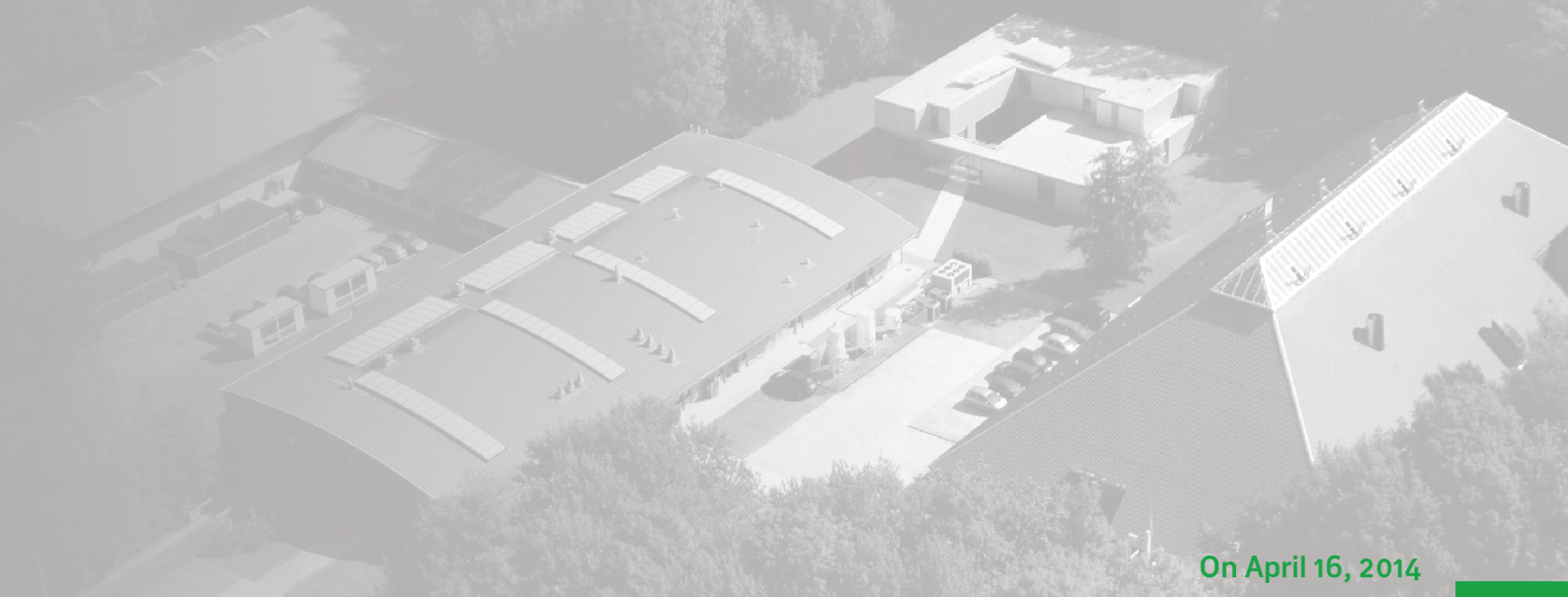
Pierre VILLERS, Inspecteur Général, Direction Générale des Technologies, de la Recherche et de l'Energie de la Région Wallonne

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

Auditor
Dominique JACQUET-HERMANS



On April 16, 2014

Iron and Steel Committee of CRM

Members

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M. BABBIT
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M. DI FANT
J. HOFFMANN
S. VANDEPUTTE

TATA STEEL
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M. DENYS
W. VAN DER MEER
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

Jean-Claude HERMAN, CEO

Strategy, General Management, External Relations

Sabine Mahy, CFO

Finance and financial reporting

Budget, Accounting, Cost Control

Financial audit, Purchasing, Treasury

Joeri NEUTJENS, COO

Deputy CEO

Human Resources

Performance Management

Business Development & Marketing

Communication

Didier DEPARIS, CAO

Secretary of GA & BoD

Health & Safety

QSE & Infrastructure

Intellectual Property

IT, Library

Griet LANNOO, CTO

Innovation Coordination

Processing

Christian MARIQUE, CTO/CPO

Program Coordination

Production & Recycling

Industrial solutions

Material characterisation

Philippe HARLET, CTO

Surface & Coatings

Applications & Construction Solutions

DTSL

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 operating income:** 31 MioEur
  - Steel R&D Private contract: 20 MioEur
  - Steel Collective R&D: 5 MioEur
  - Other (R&D, Technical assistance): 6 MioEur
- **Number of employees:** 225
- **European grants:** 1.4 MioEur
- **Regional grants:** 1.5 MioEur

Report on R&D activities

It's worthwhile to recall that CRM was funded in 1948 to become the collective research centre for the Steel and Non-Ferrous Metal Industries with laboratories and pilot facilities located at Liège and Gent.

The present activities remain largely focused on metallic materials. They request a very broad range of technical expertise covering the complete loop of the value creation chain from the raw materials, their processing up to finished products and their recycling at the end of life.

The main mission of CRM is to design, for its affiliated industrial members and stakeholders, original and innovative technological solutions and new concept of products with a worldwide support for their implementation, promotion and applications.

Since 2011, all CRM activities have been combined with those of AC&CS into CRM Group. A progressive adaptation of the structure has taken place to lead in 2013 to an internal organisation based on 5 operational units and a common laboratory for the materials characterization:

- 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 activities conducted by CRM during the year 2013 and selected from the shareable topics are illustrated in four thematic sections:

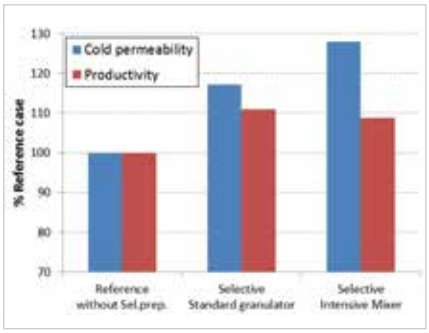
- Design, testing and control of innovative manufacturing and processing technologies;
- Study and development of new advanced metallic materials and their applications;
- Sustainability of natural resources, energy, recycling and valorisation of by-products;
- Valorisation, dissemination, international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

Design, testing and control of 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.

■ A first core competence to be highlighted in the "Upstream" processes concerns the worldwide recognized expertise of CRM in the "sintering" of iron ores. Despite the progressive evolution of the Steel Industry business observed during the last years, especially in Europe, this activity continues to occupy a key position in the integrated steel plants. CRM offers to its main member companies (ArcelorMittal & Tata Steel) a very large and unique panel of services, tools and resources in this field. Thanks to the availability of a fully instrumented and well equipped pilot station and the coupling with a complete mathematical model, the impact of various input materials and innovative processes on sintering performances (productivity, quality, energy efficiency) and emissions (gas and dust) can be assessed. Among the running actions, one deals with the impact of challenging materials (e.a. finer ores and recycled materials) and the corresponding countermeasures (a.o selective pre-processing) in case of lower performances. The selective preparation appears to be an attractive way to compensate productivity losses related to the use of finer ores like for the reference case. It has also been observed that an intensive mixer is not mandatory in all the cases for the selective preparation; a standard granulator, requiring a lower investment cost, gives comparable results when only a part of the mix has to be processed. Another action deals with the design of original waste gas recycling techniques aiming to respect the most stringent environmental regulations. An example to be pointed out

Revamped sintering pilot station

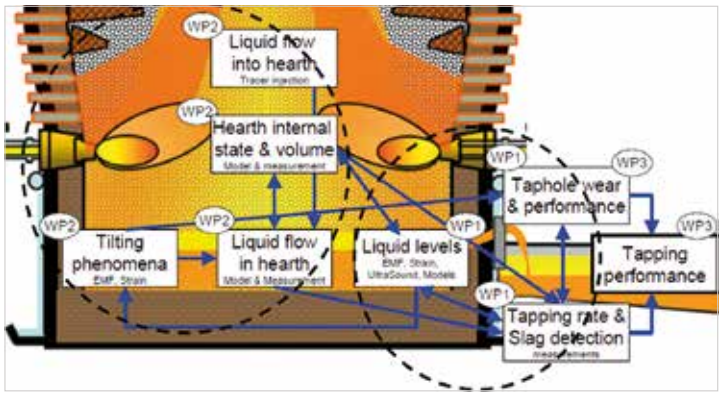


Impact of the recycling of fine materials and the mix preparation mode on sintering performances

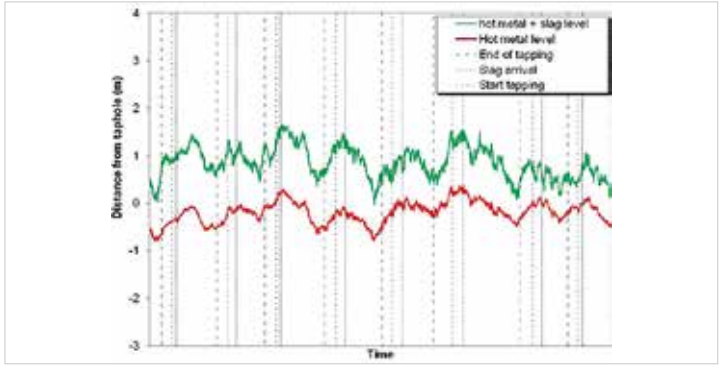
On-site measurement of gas composition and temperature in wind boxes of a sinter plant

is the ability to measure on site the gas composition and temperature in the wind boxes of a sinter plant. The on-line control of the process is also part of the activity with the development of a sensor device called "SUPERMAGNAG" that continuously measures the sinter cake quality directly at strand surface. This device has been recently licensed by CRM to Paul Wurth to take in charge the roll-out and commercialization worldwide.

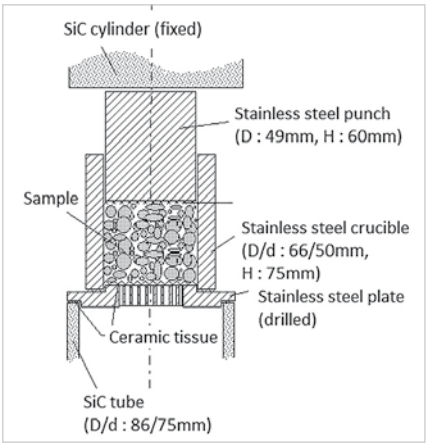
■ Closely linked to the sintering process, the blast furnace operations are also of prime importance for the integrated steel plants. Two European projects (RFCS fund) aim to develop additional methods to better control this highly productive reactor and to further decrease its operational costs and energy impact. With the project "SustainTap", the major objective is to optimize the tapping practices of the blast furnace thanks to a combination of direct level and flow measurements with characterization of the drainage regimes inside the vessel. An original method developed by CRM and based on the use of strain gauges deposited on the external wall of the furnace is applied for that purpose. It allows the detection of the slag and hot metal level inside the reactor and is under implementation in industrial sites such as



Control of liquid flows in blast furnace

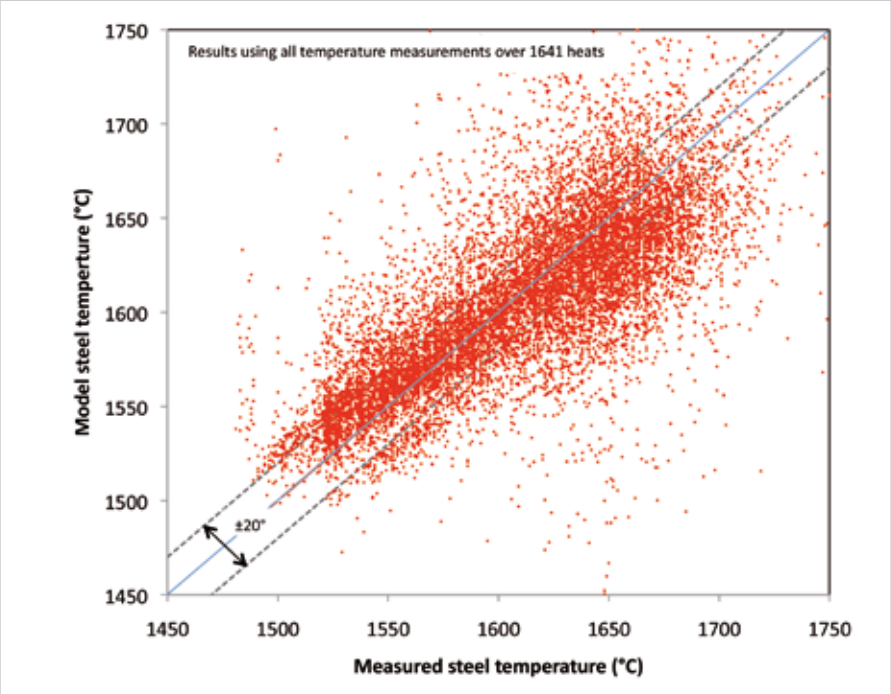


Daily monitoring of the liquid levels in blast furnace



Softening test equipment

ArcelorMittal Fos and Tata Steel Scunthorpe, in close collaboration with TMT that has been recently licensed to valorise this technology worldwide. The second project "CharFoCo" aims to enhance the ability to inject higher amounts of pulverized coal inside the blast furnace in order to reduce the coke consumption whilst keeping sufficiently high gas permeability inside the furnace. Simulation tools are available to assess the behaviour of the injected materials in the raceway as well as the effect of the unconverted coal char leaving the raceway on the blast furnace operation, depending on process conditions and coal properties.



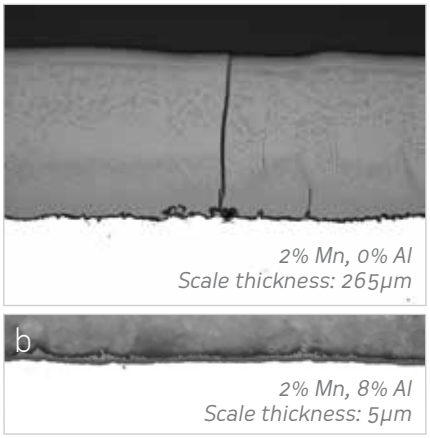
EAF control: prediction of the tapping temperature

■ Besides the integrated steel plants, another strategic production route for the Steel Industry is based on the Electric Arc Furnace (EAF) and the direct melting of recycled scrap or alternative iron sources like DRI (Direct Reduced Iron), hot metal or pig iron. Since several years, CRM is working on the development and industrial application of an on-line metallurgical and process control model for the EAF steel plants. This development is conducted worldwide with applications at ArcelorMittal Dofasco (Canada), Lázaro Cárdenas (Mexico) and Tata Steel Aldwarke (UK). A large range of industrial operations can now be monitored covering the use of 100% scrap, the mixed charging of scrap and hot metal or the continuous addition of DRI. For this last industrial situation, the systematic follow up of the process with the model indicates a very good prediction of the tapping temperature with more than 90.5 % of the heats ranging in the interval +/- 20° C before any optimization actions on the operating mode.

■ Another major field of activity where the CRM competences are highly recognized concerns the metal processing and more particularly the hot and cold rolling operations. To illustrate them, let us more specifically mention the studies conducted to master the surface quality of the rolled products and the development of innovative cooling technologies.

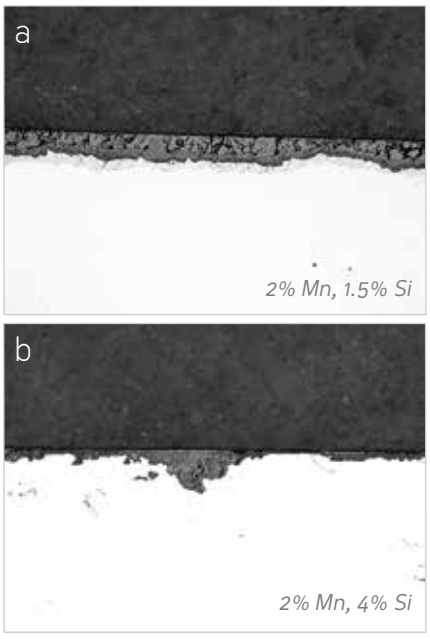
▪ With the development of new advanced high strength steel grades (HSS) alloyed with larger amounts of elements like Al, Si, Mn, ..., the behaviour of the scale formed during the successive thermo-mechanical deformation steps is of prime importance to keep a high surface quality to the final products and to avoid defect formation. Through simulation tests performed in the pilot facilities of CRM and notably the two-stands hot rolling line, the influence of key parameters like the steel composition or the processing temperature can be highlighted:

› A higher content of Al or Si leads to reduce the overall primary scale thickness formed during the semi-product reheating with, as a direct consequence, a greater difficulty to remove this thinner scale before the hot rolling operations.

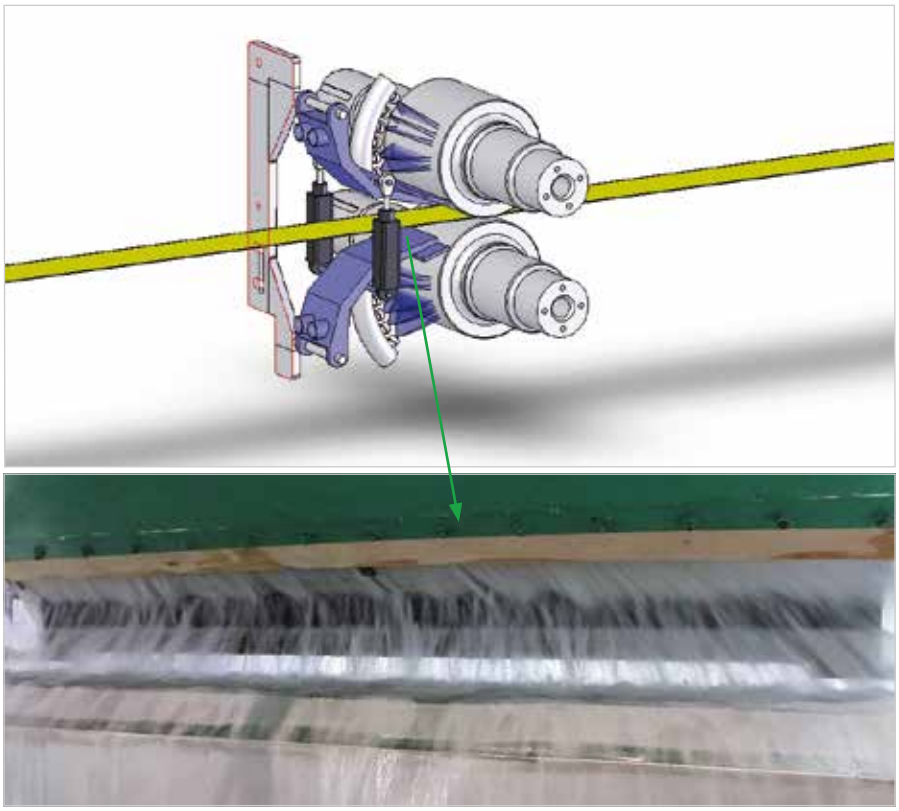


Impact of chemical composition on primary scale formation.

› A similar effect is observed on the tertiary scale resulting from the rolling, cooling and coiling steps with an impact on the quality of the scale-steel interface. Even if the reheating is performed below the Fayalite formation temperature (<1000°C), a significant higher content of Si induces an internal oxidation in the final product with sub-surface scale penetration.

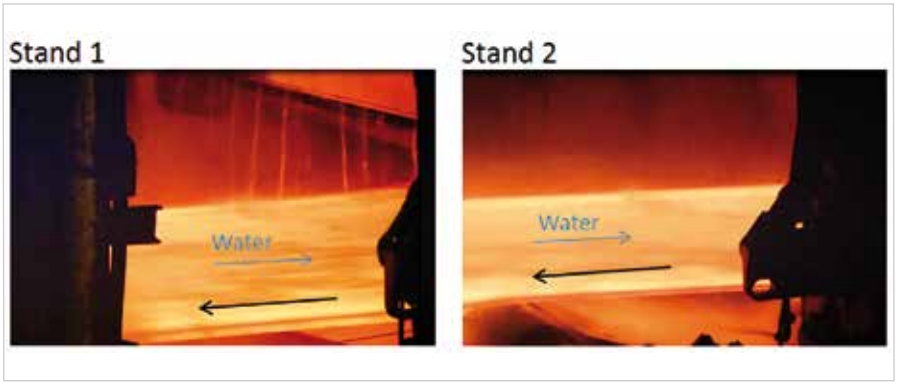


Impact of chemical composition on tertiary scale and steel-scale interface



Combined roll and strip cooling

- With the objective to simultaneously achieve a more homogeneous and efficient cooling of the work roll and the strip in the hot strip mill, a combined system has been built by CRM and industrially tested at ArcelorMittal Fos (RFCS project Intercool). No problem was observed during the industrial campaigns with notably a very good water evacuation without any excessive flow even when the wipers were fully open.

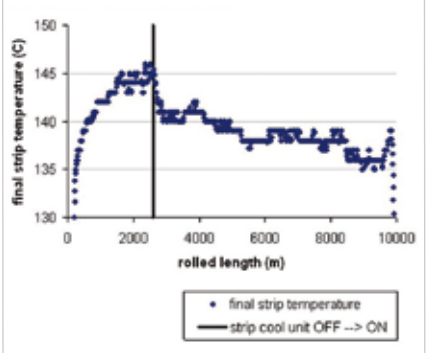


Industrial trials with combined interstand cooling

- Another example of cooling technology relies on a similar approach for the cold rolling mill with the objectives to suppress the defects related to a too high temperature in the rolling gap, to enhance the lubrication efficiency and to boost the line productivity. Based on the CRM water pillow cushion technology (WPC), a new strip cooling header has been designed and implemented at Tata Steel IJmuiden. The industrial trials have confirmed the possibility to substantially reduce the strip temperature and to allow an increased rolling speed. In the frame of the same RFCS project (Incool), a high turbulent work roll cooling is also constructed to be tested in 2014 at the ArcelorMittal tin plate mill of Tilleur (Liège).

WPC strip cooling header

Industrial implementation of WPC



Reduction of the strip temperature thanks to the WPC unit

■ For the "Downstream" steps (Finishing & Coating), a particular attention continues to be paid to the development of new generation of advanced high strength steels (AHSS) having to be galvanized. One of the operating actuator to be controlled is the atmosphere inside the furnace where the products are prepared and annealed before the hot dipping in the galvanizing bath. A key-parameter to be known is the thickness of the ultra-thin oxide film formed at the surface of the strip during the thermal treatment. A measurement system, named "OTTM" (Oxide Thickness & Temperature Measurement) developed by CRM several years ago and based on a spectroscopic reflectance and interferometry concept, has been very recently upgraded to extent its capability to measure very thin oxide layers from 30 nano-meters to 150 nano-meters. Developed with the support of the RFCS program, it has been tested in the CRM multi-dip simulator and in the galvanizing pilot line, demonstrating the possibility to monitor the growing of the fine oxide layer, for a wide range of steel grades, in industrial conditions: long measurement distance (1.5 m), high temperature environment (~ 800°C).

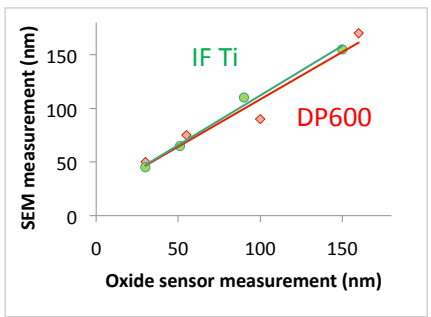
■ A novel and original approach to process AHSS steels difficult to be galvanized relies on the application of an iron oxide water-based solution before entering the furnace for the annealing step. Continuous trials performed in the CASTL line have shown that a homogeneous and well controlled oxide thickness can be obtained. A post-treatment was also tested to prevent the ageing of this iron oxide layer and the loss of its adherence properties. The processed strip can hence be kept in air before the annealing and galvanizing treatment.

Continuous deposit of an iron oxide protective layer

■ Besides the continuous coating treatment of metallic products in highly productive lines, the "batch" galvanisation also represents an important part of the industrial activities for the manufacturing sector. An innovative concept has been proposed by UMICORE to deliver Duplex products at a lower cost than the conventional processes. After several steps of development at the laboratory and pilot scale, this concept called "EVAPLEX" has reached the pilot industrial demonstration phase. Associating UMICORE, DREVER, GALVA 45 and CRM, and thanks to the financial support of the Walloon Region (DGO6), an Eureka project is running to commission and test during the summer 2014 a large industrial equipment in order to process pieces up to 3 meters in length in a 10 m^3 vacuum vessel combined with a shot-blasting unit for the surface preparation of the products to be galvanized and painted.

■ A last example of new "coating" process to be mentioned concerns the introduction of micro-size particles in paints in order to deliver to the final products additional properties and surface functionalities. This development is conducted in collaboration with SOVITEC, in the frame of a "CWality" project financially supported by the Walloon Region for the benefit of SME's. A fully new dedicated unit, satisfying health and safety prescriptions, has been designed and built by CRM to test the new concept and comprises powder spraying units, a powder recycling system and a paint curing installation.

OTTM unit in the pilot galvanizing line



Validation of the OTTM measurements

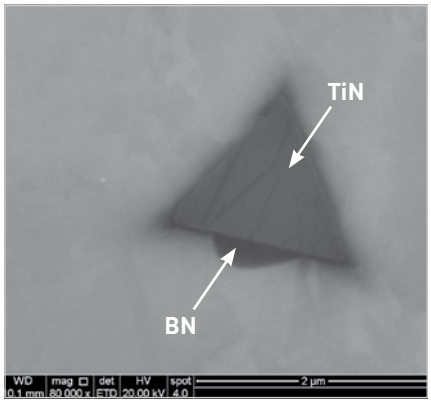
The industrial EVAPLEX version

Equipment for the powder injection in paint coatings

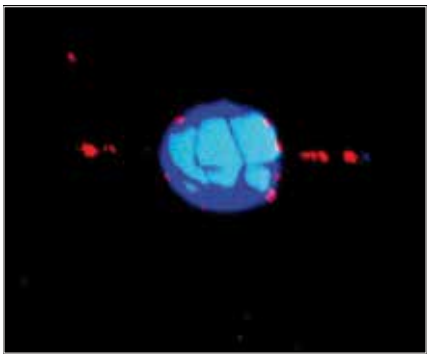
Study and development of new advanced metallic materials and their applications

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 space is attributed to the development of other metallic products where the competences in physical metallurgy, technologies and process-product interactions can be industrially valorised.

■ A first example illustrating the activities in product development relates to a detailed investigation on boron micro-alloyed steel grades more and more used for advanced applications requiring high forming and resistance properties. One of the basic objectives is to finely identify the location of the boron components in the microstructure and the nature of the precipitates to which boron is associated. Sophisticated analytical techniques are needed for this purpose such as the SEM-FEG microscope (to distinguish between different nitride particles) or the TOF-SIMS spectrometer (to obtain a mapping of the Boron distribution in the vicinity of Al/Mg oxides).

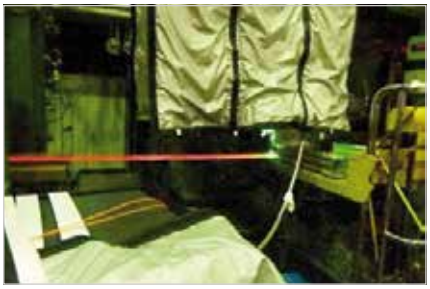


SEM-FEG picture of nitride precipitates (80000x) in a boron-steel



TOF-SIMS mapping of particles in a boron-steel (50µm x 50µm) (B in red, Al in blue, Mg in grey)

■ During the hot rolling of strip, the on-line evaluation of the microstructure evolution can be a helpful solution to better control the final steel properties or to master the mill pre-setting. Through a collaborative RFCS project associating ArcelorMittal, CRM and other European partners, a laser ultra-sonic sensor for in-situ measurement of the strip microstructure has been tested in the CRM Gent pilot line for simulating the deformation of the austenitic phase between the 1st and 2nd stand of an industrial mill and its further transformation into ferrite. Despite the inherent vibrations of the strip during rolling and the presence of scale, encouraging results have been obtained when comparing the austenite grain size measured with a reference Optical Microscope (LOM) and the laser ultra-sonic sensor (LUS).



Microstructure measurement with a laser ultrasonic sensor

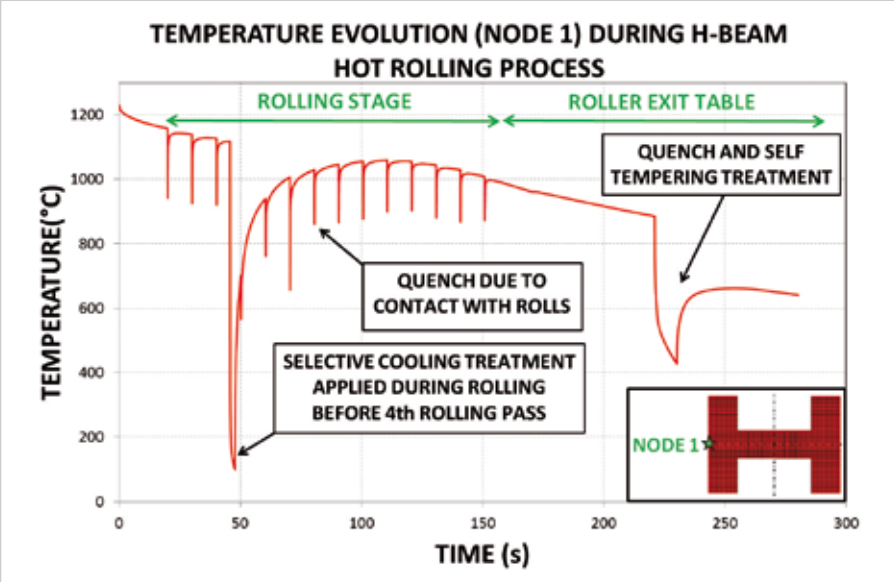
Strip speed (m/s)	**Deformation temp.** (°C)	**Reduction**	**γ grain size** (LOM)	**Grain size** (LUS 2echo)
0.2	1120	20%	60 µm	83 µm
0.5	1180	20%	50 µm	89 µm
0.2	1040	20%	65 µm	83 µm
0.5	1100	20%	55 µm	81 µm

Microstructure grain sizes: Comparison between optical microscopy and ultrasonic sensor

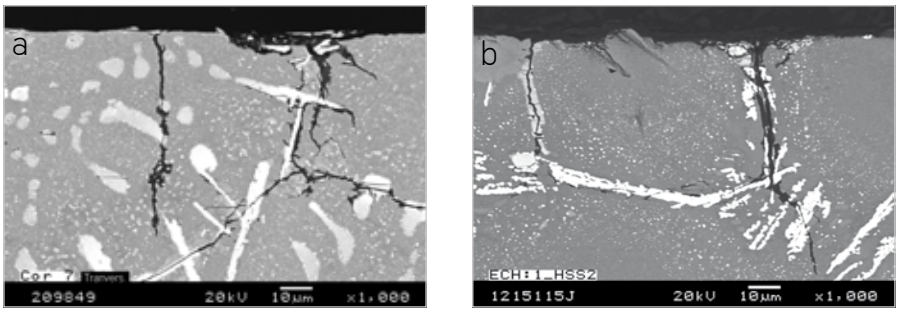
■ The development of high quality long products and their processing control is another important field of activity for CRM. Devoted to the beam production, a 2D finite difference model nicknamed “Profilecam” has been built by CRM. It allows the prediction of the beam thermal evolution during rolling as well as the phase transformation changes during cooling. A selective cooling treatment is integrated in the model.

■ Since several years, the behaviour of the roll materials needed as well for the hot deformation as for the cold rolling is recognized by the Steel Industry as a priority item considering their impact on the production cost, the plant productivity and the quality of the rolled products. New challenges, such as the future banning of the use of Cr 6+ components, are also modifying the scope with the need to find alternative solutions for the chromium-coated rolls applied for the cold rolling or the temper mills. Thanks to an intense collaboration between CRM, its steel members ArcelorMittal & Tata Steel and the affiliated roll-makers: Åkers, Marichal Ketin, Gontermann Peiper, a significant progress has been achieved at different levels.

› As a first illustration of the actions conducted by the CRM experts in this field, let us mention the capability to simulate and reproduce at the laboratory and pilot scale the incidents and defects observed in industrial conditions. Through the combination of different testing methods such as a hot rolling simulator, a fire cracking tester (to simulate rolling incident) and continuous pilot rolling trials, it is possible to reproduce defects observed in industrial rolls and to better assess the critical key-elements to be improved for manufacturing new roll grades.

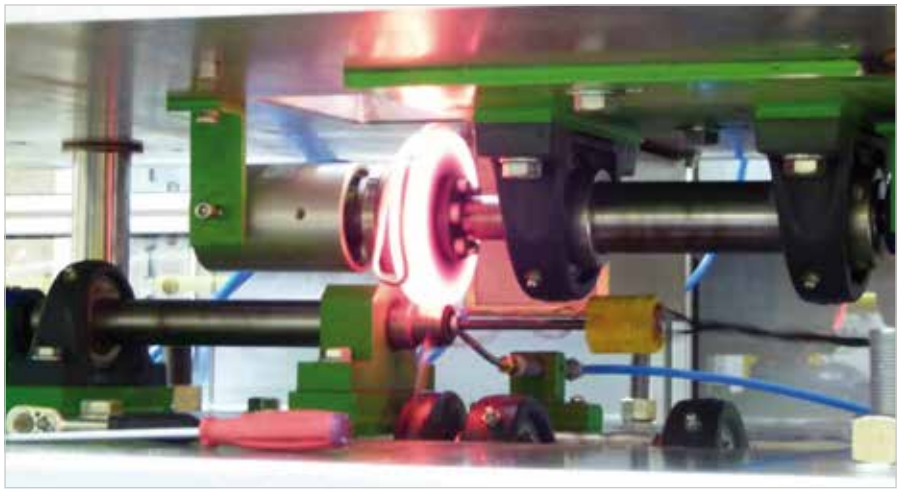


Temperature evolution during H-beam rolling



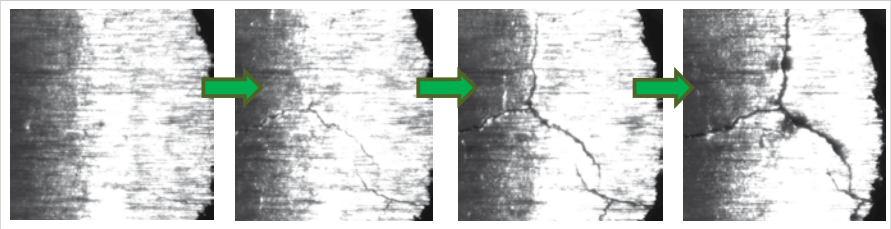
Cross-section of cracked roll samples : a. Industrial roll / b. Simulation test

› The continuous hot rolling trials and the application of the “insert” technology approach allow the simultaneous assessment of different new roll qualities or the application of protective coating layers. Combining these trials with the on-line monitoring of the roll surface evolution (using the “Rollscope” unit developed by



Hot rolling simulation

Hot rolling trial with inserts



In-line follow-up of the crack propagation during pilot rolling

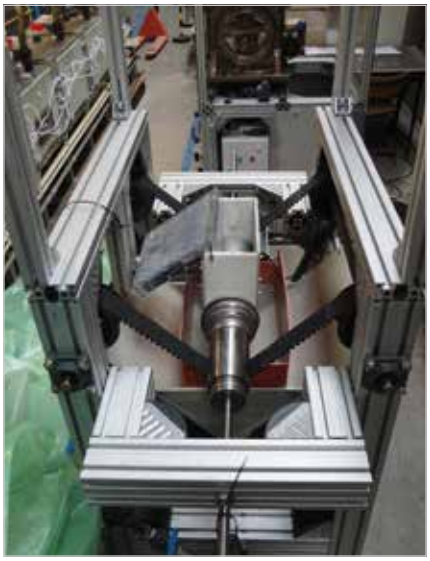
CRM), it is possible to finely characterize in-situ the formation and propagation of cracks at the upper surface of the working rolls.

› Among the competences and means available at CRM, it is worthwhile to recall the existence of a mobile microscopy platform able to quantify the roll degradation after industrial rolling campaigns directly in the plant roll shop.

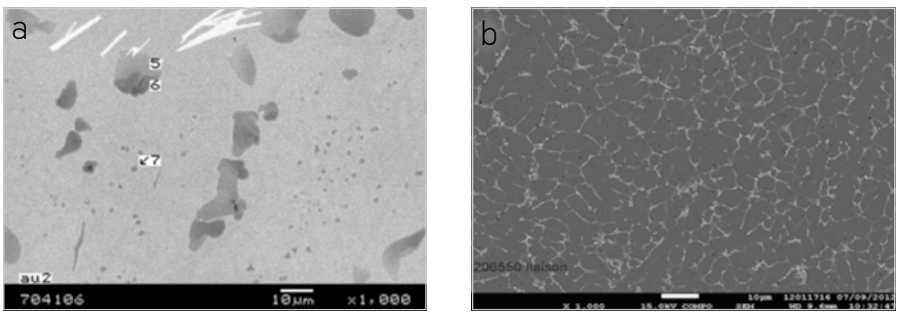
Surface roll inspection in an industrial workshop

› New roll manufacturing processes are also explored in order to gain higher mechanical properties and better performances in use for the hot rolling applications. The laser cladding approach appears to be a promising technology in that prospect by delivering a finer microstructure, an improved thermal fatigue resistance and a higher quality bonding zone compared to the more conventional "spin-casting" route.

› As previously mentioned, the near future banning of Cr 6+ components imposes to find alternative solutions with a specific focus on the rolls used in cold rolling and temper mills. To study the alternative options, a testing rig has been built at CRM allowing the deposit by electroplating of hard composite coatings. This plating rig has been designed to limit the coating deposition to the central section of the roll but it is sufficient to further perform pilot line tests with the processed roll. For the illustrated case, the roll is coming from the pilot installation of Tata Steel at IJmuiden.



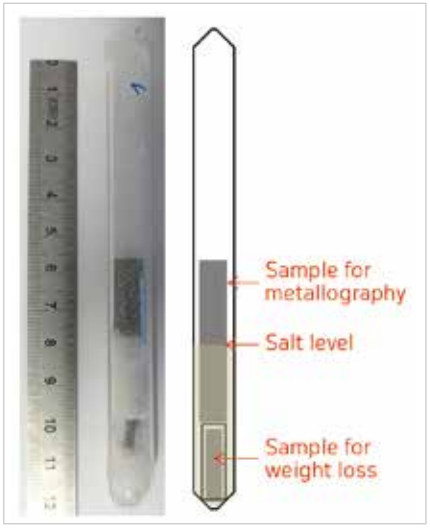
Experimental electro-plating rig of CRM



Microstructure of HSS roll (1000x): a. Spin-casting / b. Laser-cladding

■ A domain where improved knowledge and advanced materials are particularly requested concerns the energy sector and the development of new power generation systems (solar power plants, new gas-steam turbines). New materials able to withstand high temperature and in very aggressive environment are mandatory. With the financiel support of the Walloon Region (DG06), CRM has conceived and built an experimental testing platform to characterize the behaviour at high temperature and in highly corrosive media of a large range of metallic materials (Metalex project). It is possible to assess their resistance in contact with molten salts or metals during high pressure tests (2 to 40 bars) or in the presence of corrosive gaseous atmospheres at high temperatures up to 1400°C.

High temperature corrosion test



Glass-sealed container for corrosion tests

Study and development of new advanced metallic materials and their applications

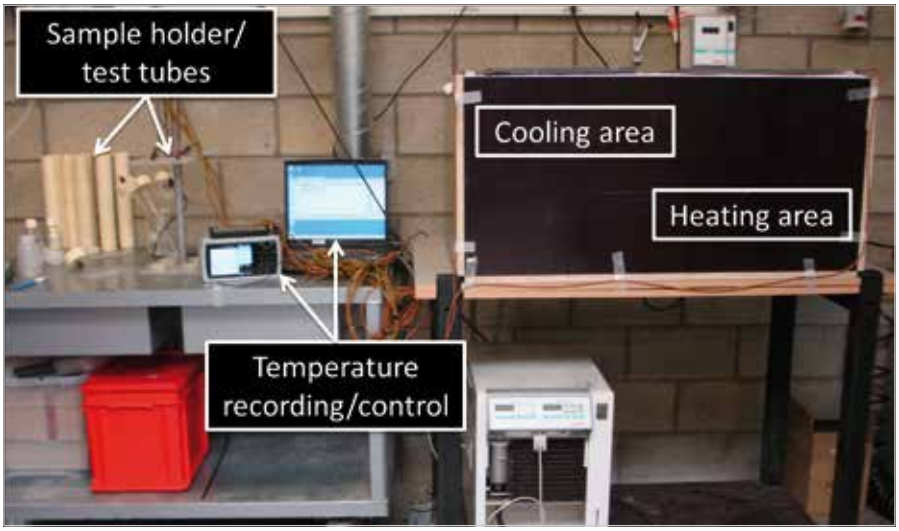
Roll-forming installation

Example of formed HSS piece

■ The production of new generation of advanced high strength steels also imposes to master their final applications and notably their forming and shaping in the customer's shop. A dedicated project called "SteelPro" and supported by the Walloon Region (DG06) aims at providing to SME's or local mechanical workshops the knowledge and simulation tools allowing to promote the use of these new materials. A pilot forming line able to process coils or sheets (strip width up to 450 mm, thickness: 0.2 to 1.5 mm) is available at CRM to realize experimental trials and to support the development of new simulation modelling tools.

■ Through a collaborative study between CRM and WALOPT, the use of PCM (Phase Change Materials) for Space Thermal Applications has been demonstrated for low thermal inertia satellites. Based on these positive results, the ESA (European Space Agency) has extended the collaboration to the application of this original heat storage concept to launcher of larger size. The objective is again to keep the units embarked in the launcher within strictly controlled temperature limits. An active control through the use of adapted PCM aims to significantly reduce the mass of the launcher whilst increasing the thermal inertia of the whole system. The present step of the study includes "earth" condition testing to assess the behaviour of the heat storage system to vibration, vacuum, thermal and mechanical resistance. A new measurement device allowing to determine the specific heat in liquid and solid states as well as the latent heat of transformation has been built by CRM to test large samples and to better simulate the space reality.

European Launcher



Measurement platform to characterize heat storage concept

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.

■ At the request of the Walloon Region, a project aiming to integrate the "EcoTechnoPôle de Wallonie" (ETP) inside the CRM organization has been launched in 2013 and officially finalized at the early beginning of 2014. The ETP is a research centre expert in pyrolysis and gasification, equipped with large scale pilot facilities. Initially dedicated to the coal products processing, the activities have been progressively diversified towards the energy valorisation of a broad range of fluxes, wastes and by-products like the biomass, the sludges from the steel industry or from the sewage treatment, the fine particles from the plastic or the glass industry, … . Among the pilot equipment available at ETP, let us more specifically mention: - a flexible thermo-conversion unit able to perform pyrolysis

Examples of recycled by-products
a. Organic residues / b. Wood components

Pilot thermo-conversion unit of ETP-W

The power plant of ETP-W

or gasification tests in fixed bed under high pressure conditions (up to 45 bars);

- a 2 MWh power plant able to work with different fuel sources;
- a compaction unit for granular materials (3t/h);
- a press filter for oily sludges.

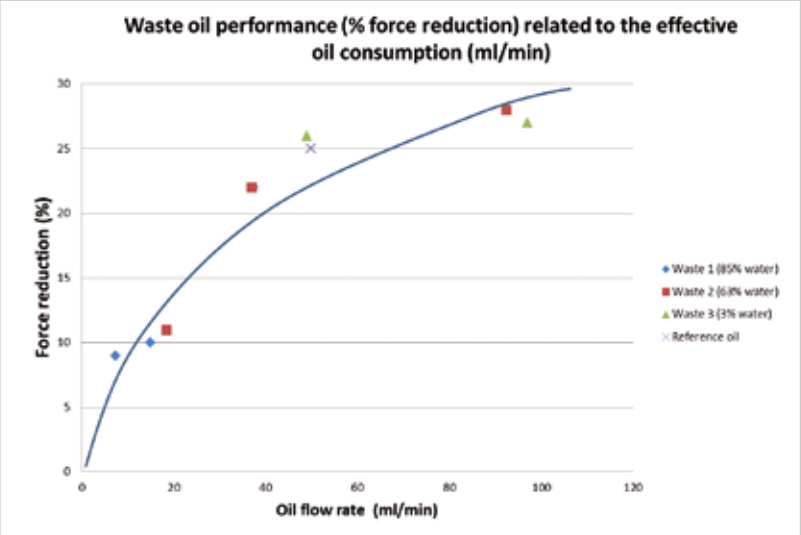
All these equipment complement those already available at CRM for the conditioning and processing of by-products (intensive mixer, pelletizer, roll compacter).

■ In the field of the by-products pre-processing (mixing and briquetting), it is worthwhile to mention a dedicated study conducted for Recyco (an Aperam subsidiary company active in the recycling of austenitic dusts and sludges) and aiming to optimize the operating conditions of the plant. By combining pilot scale trials using the CRM briquetting press and industrial test campaigns, important improvements have been identified and applied at the industrial scale.

■ The recycling and valorisation of residues rich in metallic components represents another important activity of CRM. As already underlined, it implies to mobilize several competences in product characterization, in conditioning and processing techniques. With the financial support of the Walloon Region (DGO6), CRM, in collaboration with GeMME (ULg), is developing an experimental device to allow the complete characterization of fine granular materials (<5 mm) coming from the crushing of recycled parts (electronic appliances, automotive components, light steel scrap, ...) (Iliade project).The objective is to rapidly characterize and chemically identify large sets of such materials in order to determine their commercial value and to sort them on a more accurate basis than the current manual sorting still today largely applied. The method under investigation is based on a combination of an hyperspectral image processing of the products illuminated in a suitable way and of an XRF or LIBS analysis for identifying the elements not recognized by the first method.

Fine metallic crushed residues

LIBS measurement equipment



Lubrication performance of recycled oils

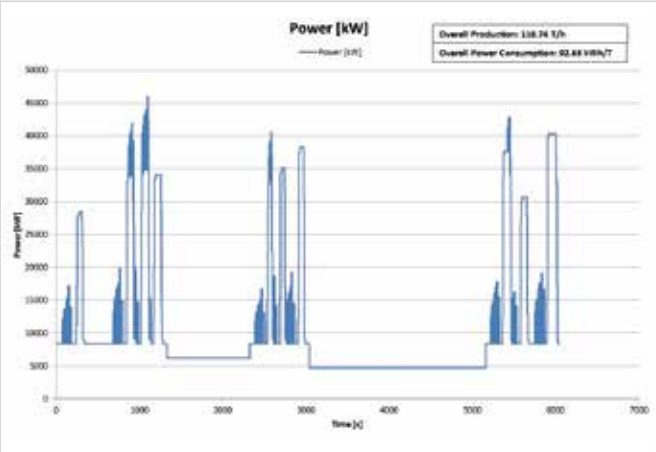
Rolling trial with recycled lubricant

■ Another example of recycling approach under investigation at CRM is the re-use of waste oils for the lubrication of the strip and rolls in the hot strip mill. These waste oils can originate from other processing steps like the cold rolling operation, the annealing lines or even from other industrial sectors. Trials realized in the pilot rolling line of CRM have confirmed a lubrication efficiency with the waste oils fully similar to conventional fresh rolling oils with a similar positive impact on the force reduction during the hot deformation steps. Industrial trials are planned during the year 2014 in the HSM plant of ArcelorMittal Dofasco (Canada).

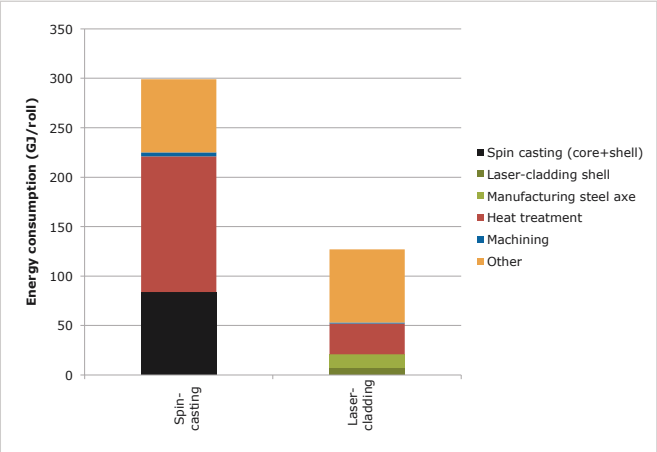
■ As already outlined, the control of the energy consumption during the various processing or manufacturing steps and/or its reduction through the introduction of new or optimized technologies are current objectives of several CRM projects. They are illustrated through two different examples:

› To better assess the energy consumption in the hot strip mill, a new simulation model nicknamed “E-Stripcam” has been developed in the frame of a RFCS project. For different operating modes of the hot strip mill, it allows to predict in real time the total electric energy consumption as well as the microstructural evolution of the steel strip and its mechanical properties. Developed for the ArcelorMittal plant of Avilès (Spain), it can be transferred to any other hot strip mill. It is applied as a guide decision tool and delivers, as additional information, the production ratio (ton/h) and the specific electricity consumption (kWh/ton).

› As previously indicated, new roll manufacturing processes are explored notably by application of the laser cladding approach. In the frame of a research supported by the Walloon Region (DG06-Greenomat program), the focus is placed on the energy balance and the possibility to reduce the materials consumption. Compared to the conventional “spin-casting” route, needing two different operations to firstly cast the metal of the axis before to deposit the metal of the envelope, the manufacturing of rolls by laser-cladding the envelope directly on the recycled roll axis would allow an energy reduction of more than 50% whilst recycling several times the axis material before rejection. Further investigations are needed to completely define and assess the scope of applications of this new technology.



Model prediction of the energy consumption during hot rolling



Energy consumption to manufacture work rolls

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-situ sampling of a corroded tank

■ With the financial support of the Walloon Region, 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. A common issue for a great number of industrial companies remains the corrosion behaviour of the materials used for their business. Thanks to its capabilities in mobile characterization techniques allowing to determine in-situ the nature, composition and microstructural state of metallic materials, CRM can help to solve industrial problems, such as illustrated here with an in-situ sampling of corroded products inside a brewery tank.

■ Also in relation with this guidance and knowledge dissemination role, CRM has actively contributed during the year 2013, to different conferences, seminars and fairs. Let us more specifically mention:

- "Metamorphoses", an event organized by SPI on January 30 & 31, 2013 at Liège with technical items dedicated to the surface coatings, the energy, the recycling and the measurement systems;
- the seminar "From resource to recycling efficiency" organized by AiLg on October 15, 2013 at Liège;
- "Eurofinish", an European fair on the surface treatments (Gent – October 23 & 24, 2013) with a specific focus placed by CRM on the new capabilities in surface functionalization;
- the event "Looking at Materials under Combined Durability Conditions"

The "Eurofinish" stand

Participation to "Métamorphoses"

The "Wavisurf" measurement device

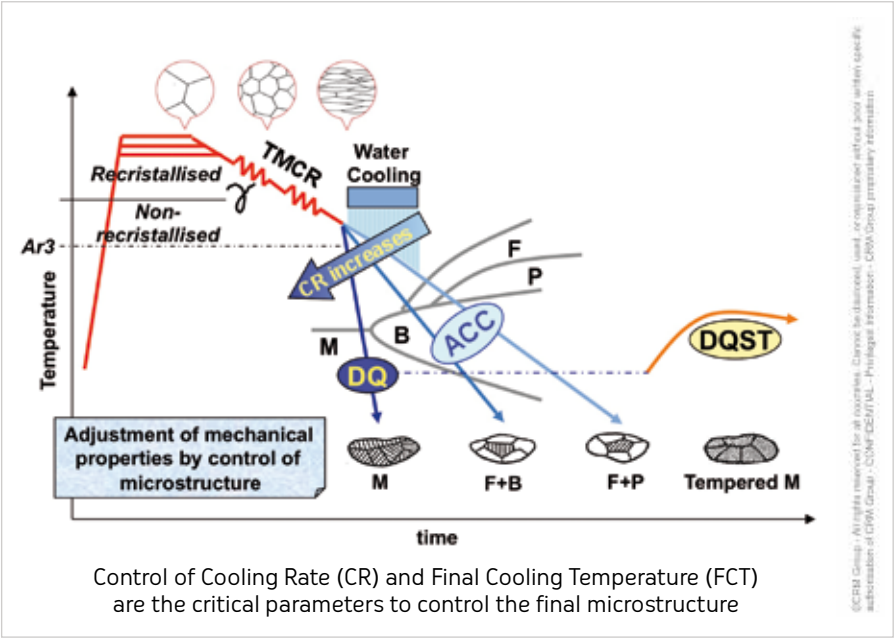
It is able to on-line determine the waviness of the moving galvanized strip at the end of the line. This sensor will complement the characterization possibilities of the sensor "SRM (Surface Roughness Measurement)" licensed to AMEPA and today operating in around 15 industrial plants around the world.

■ Another major key competence of CRM concerns the development of cooling technologies applied for the mechanical and thermal processing of metallic materials. The use of a 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.

coordinated by SIM (Strategic Initiative Materials) in association with M2i, the Dutch Materials innovation institute (November 13, 2013 at Gent).

Covered topics included material behaviour in dredging and deep sea mining, steel in extreme conditions, extreme sealing systems, corrosion/abrasion in agriculture application and new developments in detection and monitoring.

■ The valorisation of the sensors or measurement techniques developed by CRM has also to be pointed out. Industrial trials are running in the frame of a pilot & demonstration project supported by the RFCS program to test in two industrial lines (ArcelorMittal Spain and Tata Steel Segal) the new sensor called "WaviSurf".

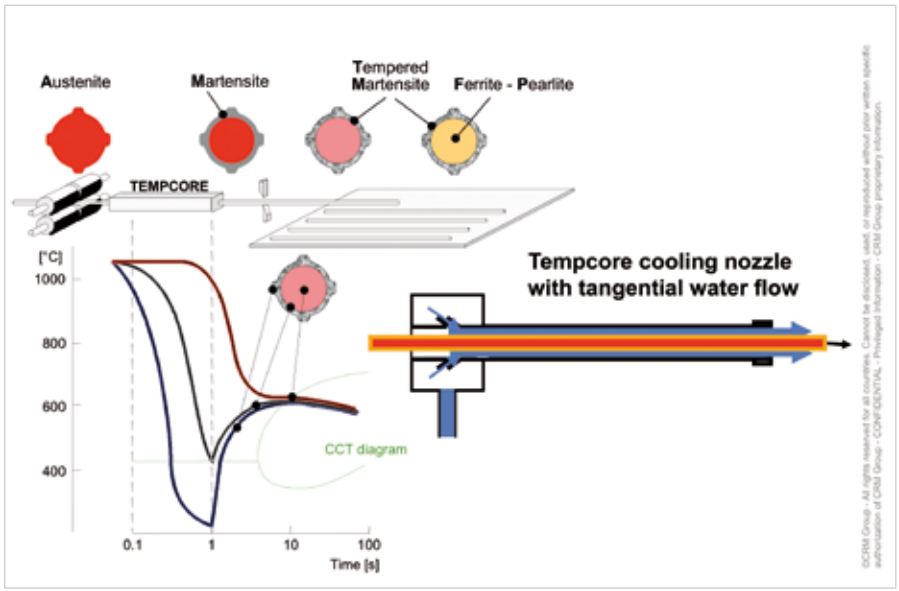


Control of Cooling Rate (CR) and Final Cooling Temperature (FCT) are the critical parameters to control the final microstructure

Tuning of steel properties by water cooling

Two technologies are today largely worldwide deployed:

› The "Tempcore" process is a quench and self-tempering process 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 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 85 licensees mainly located in Asia and India. The most recent example of implementation concerns the plant of ArcelorMittal at Zaragoza (Spain) with an unique multi-slit installation.



The "TEMPCORE" process for rebars

The Tempcore installation of ArcelorMittal Zaragoza

The MULPIC® installation of NLMK Clabecq

› The MULti Purpose Interrupted Cooling or MULPIC® Technology is a water-based controlled cooling system in the production of steel plate. The system provides the highest degree of accuracy in cooling to generate homogenous mechanical properties in the rolled steel product. A typical application for the product is Oil & Gas pipeline with stringent toughness requirements. Installed after the exit of a steel plate rolling mill stand this technology is based on a concept developed by CRM. Plate thicknesses from 5 mm to 120 mm are cooled by the provision of a large range of achievable cooling rates from accelerated cooling (ACC) to Direct Quench (DQ). The technology is licenced to Siemens VAI in the UK and more than 20 installations are in operation around the world.

The MULPIC® process in the World

The MULPIC® installation of Shagang

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.

- Accord-Wallonie: 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 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 a large range of energy aspects.

- 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, EIP and future 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). 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".

In 2011, the European Commission launched a consultation process on the European Innovation Partnership (EIP) called "Raw Materials Initiative (RMI)". In order to allow the Steel industry to be present in this initiative, CRM has acted in 2012 on behalf of ESTEP to prepare in ad-hoc working groups several technical proposals.

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, 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

B. Vanderheyden
Closing the Loop of Metals
Conférence inaugurale sur les Matériaux Critiques, Salon Métamorphoses, Liège, 30-31 janvier 2013

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
BHM Berg- und Hüttenmännische Monatshefte, Volume 158, Issue 1, pp. 3-12, January 2013

K. Vasseur, B. Vanderheyden, K. Van Acker, J. Bil, E. Pirard, K. Vrancken
KIC as catalyst for innovation - Introductory workshop Belgium
Brussels, June 20, 2013

R. A. Jaimes, F. van Loo, J-F. Douce, M. Schöngut, M. Evrard, F. Stepanek, E. Pirard
Effect of Raw Material properties on the Kinetics of Iron Ores Granulation
6th International Granulation Workshop, Sheffield, 26-28 June 2013

M. Dormann
Cross-sectoral recycling opportunities in metallurgical vessels
Conférence AILg – From resource to recycling efficiency, Liège, October 15th 2013

C. Georges, T. Sturel, P. Drillet, J.-M. Mataigne
Absorption/desorption of diffusible hydrogen in aluminized boron steel
ISIJ International, Vol 53 (2013), N°8, pp. 1295-1304

C. Georges, X. Vanden Eynde
Parameters governing the diffusible hydrogen pick-up during the annealing of galvanized Dual Phase steels
Proceedings of the International Galvatech Conference, Beijing, China, 2013

B. Vervaet, H. Uijtdebroeks, L. Jacobs, M. Hamide, A. Ait Bengrir
High efficiency strip and work roll cooling for a higher cold rolling mill output
9th International Rolling Conference Venice, 2013

N. Nutal
Phase Change Materials used for thermal control of systems - Applications, technology, developments
Salon Métamorphoses, Liège, 30 janvier 2013

L. Bordignon, X. Vanden Eynde
Influence of the annealing atmosphere composition on zinc wetting
Gavatech'13, September 24-26, 2013, Beijing – China

Jana Ondrouskova1, Michal Pohanka1, Bart Vervaet
Heat flux computation from measured temperature histories during hot rolling
Materials and technology 47 (2013) 1, 85–87

C. Fedorciuc-Onisa, H. Uijtdebroeks, P. Adriaen
Application of selective roll cooling technology in a reversing multipass stand of a hot rolling mill
9th International & 6th European Rolling Conference 'Rolling 2013', June 10-12, 2013, Venice, Italy

B. Vervaet, H. Uijtdebroeks, L. Jacobs - M. Hamide, A. Ait Bengrir
High efficiency strip and work roll cooling for a higher cold rolling mill output
9th International & 6th European Rolling Conference 'Rolling 2013', June 10-12, 2013, Venice, Italy

G. Walmag, S. Flament, J. Malbrancke, G. Moreas, M. Sinnaeve
Advanced techniques for a better understanding of work roll degradation in HSM and for the design of new roll grades
9th International & 6th European Rolling Conference 'Rolling 2013', June 10-12, 2013, Venice, Italy

C. Vergne, J. Malbrancke, M. Moujib, C. Gaspard
Experimental approaches to bring out damage mechanisms observed in service on HSM work rolls and aiming at improving roll performances through new roll grade design
ABM 50th Rolling Seminar – Processes, Rolled and Coated Products, 18 to 21 November 2013, Ouro Preto, MG, Brasil.

G. Walmag, S. Flament, J. Malbrancke, G. Moreas, M. Sinnaeve, P. Hocks
Leading edge methodology for a better understanding of work roll degradation in HSM and for the design of new roll grades
ABM 50th Rolling Seminar – Processes, Rolled and Coated Products, 18 to 21 November 2013, Ouro Preto, MG, Brasil

T.C Mitchell , H. Uijtdebroeks
Cooling (HTRC) at ArcelorMittal Dofasco's Hot Strip Mill"
AIST Northern Chapter Dinner Presentation Implementation of High Turbulence Roll, October 16, 2013 , Burlington

J. Malbrancke, H. Uijtdebroeks, G. Moreas, C. Fedorciuc-Onisa
On-line evaluation of work roll degradation in hot rolling mills (POSTER)
9th International & 6th European Rolling Conference 'Rolling 2013', June 10-12, 2013, Venice, Italy

V. Tusset
Nuove tecniche analitiche per l'analise nel processo dei metalli liquidi
e per la caratterizzazione delle superfici metalliche - Analyse CSNOH nei metalli
Seminario Ing.dei Material- Analyse Chimica -Universita di Padova 5 giugno 2013

V. Tusset
Sensorik
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