Annual CRM report 2010

CRM GROUP
CRM

Contents

Foreword

Thanks to a 5 year safety plan, initiated in 2005, the frequency rate of accident with loss time has continuously decreased. In 2010, the CRM has achieved 970 days without accident. Unfortunately, two minor accidents occurred in December 2010, recalling the absolute necessity to maintain a top priority on all health & safety issues.

In 2010, CRM has also been involved in numerous pilot projects conducting new processes up to an industrial stage.

Focusing on innovation in metallic materials and manufacturing processes, five main key-topics have been addressed during the 2010 R&D activities of CRM:

- The environment-friendly metal production, a field involving the sustainable manufacturing of steel and metals, the recycling and valorization of by-products and the environmental aspects. Besides development aiming at improving the productivity and performances of upstream processes, a special focus is dedicated to increase the efficiency in terms of raw materials consumption, environmental constraints and recycling of by-products.
- The energy efficiency where in addition to the reduction of the energy consumption of various processes, it is also aimed at recovering, storing and valorising different types of generated energy.
- The metallurgical & thermomechanical processing of metals including solidification and casting, hot and cold rolling, thermal treatment and the cooling, physical metallurgy and development of new generic steel grade.
- The surface engineering with specific actions in pickling, metallic coating, surface conversion and the design of new coating technologies and surface functionalities.
- The application of solutions and advanced metallic materials as well as of new sensors, an activity covering a very broad field with a special focus on the technical support to SME's and local economy. Thanks to the support of the Walloon Region, a team of almost 6 engineers is directly supporting small and medium size companies with more than 300 significant actions in 2010 related to a broad range of technical fields.

As an independent collective research centre, CRM has continued to benefit from financial support from the Belgian and Regional authorities, as well as from the European Commission.

This annual report gives an overview of the major achievements performed during the past year. As highlighted, a significant progress has been made in all activities.

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CRM asbl integrates CRM Group

As approved during the General Assembly of June 2010, CRM and AMLR are combined in one organization aiming at an optimal use of existing resources through complementary and scientific synergies in terms of competence and equipment, with the ambition to reinforce the innovation capability.

Within the new R&D organization, the CRM remains an independent organization with a gross budget of 13 Mio EUR and an R&D team of around 130 FTE's. Thanks to its statutes, CRM enjoys several unique advantages such as collective centre (equivalent to a so-called De Groote Centre), accredited research centre (Centre "agréé" as recognized by the Walloon Region) and non-for-profit organization (asbl/vzw). CRM therefore is benefiting from favorable grant mechanisms from the European Commission as well as from the Federal and the Regional Belgian Authorities.

The combination of the two laboratories, CRM and AMLR, is aiming at the creation of a laboratory with unique R&D competences, unparalleled breakthrough capabilities and innovation culture.

- This combined operation will result in the creation of a true European and World-class player with around 230 researchers and 30 Mio EUR annual budget.
- The resulting benefits of such a combined operation will be: increased value creation and efficiency, enhanced open innovation through intensified partnership with other industries, R&D centres, equipment builders and Universities.
- The operation will offer a wide range of complementary competences and assets covering almost the complete "cycle of the iron atom" from sintering of iron ore fines to total steel recycling.

The new R&D combined structure will be named "CRM Group".

A unique leadership team and an integration committee have been put in place to settle down step by step the combined operation.

Jacques PELERIN
President CRM

Paul PERDANG
Vice-President CRM

Rob BOOM
Vice-President CRM

Jean-Claude HERMAN
General Manager CRM

Company members

On April 20, 2011

Active Members of CRM

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

And every one 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 BETTEMBOURG S.A.	G.D. Luxembourg
ARCELORMITTAL DUDELANGE S.A.	G.D. Luxembourg
ARCELORMITTAL FRANCE S.A.	G.D. Luxembourg
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

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On April 20, 2011

Associated Members of CRM

AIR LIQUIDE INDUSTRIES BELGIUM S.A.	Belgium
ÅKERS BELGIUM S.A.	Belgium
AMEPA GmbH	Germany
APERAM S.A. (*)	France
AURUBIS N.V.	Belgium
CARMEUSE S.A.	Belgium
CARRIERES ET FOURS A CHAUX DUMONT-WAUTIER S.A.	Belgium
CARSID S.A.	Belgium
CBMM Technology Suisse S.A.	Switzerland
CMI S.A.	Belgium
COMET TRAITEMENTS S.A.	Belgium
DE LEUZE S.A.	Belgium
DREVER INTERNATIONAL S.A.	Belgium
DUFERCO CLABECQ S.A.	Belgium
DUFERCO LA LOUVIERE S.A.	Belgium
EMG Automation GmbH	Germany
FONDERIES MARICHAL, KETIN & Cie S.A.	Belgium
LE FOUR INDUSTRIEL BELGE S.A.	Belgium
GONTERMANN-PEIPERS GmbH	Germany
HARSCO S.A.	Belgium
HERAEUS ELECTRO-NITE INTERNATIONAL N.V.	Belgium
HERSTAL S.A.	Belgium
INDUCTOTHERM S.A.	Belgium
INSTITUT BELGE DE LA SOUDURE asbl	Belgium
INTERNATIONAL MANGANESE INSTITUTE	France
IRM group S.A.	Belgium
MAGOTTEAUX INTERNATIONAL S.A.	Belgium
PAUL WURTH S.A.	G.D. Luxembourg
PEMCO BVBA (*)	Belgium
PRAYON S.A.	Belgium
PRÜFTECHNIK DIETER BUSCH A.G.	Germany
SIEMENS VAI METALS TECHNOLOGIES GmbH	Austria
TECHSPACE AERO S.A.	Belgium
THY-MARCINELLE S.A.	Belgium
TI GROUP AUTOMOTIVE SYSTEMS S.A.	Belgium
UMICORE S.A.	Belgium
WHEELABRATOR ALLEVARD S.A.	France
ZINCOX RESOURCES PLC	United Kingdom

(*) as approved by the General Meeting of April 20, 2011

Organization

On April 20, 2011

Board of Directors of CRM

President

Jacques PELERIN	General Manager Country Wallonia, ARCELORMITTAL

Vice-Presidents

Paul PERDANG	CFO Global R&D, ARCELORMITTAL
Debashish BHATTACHARJEE	Group Director R&D, TATA STEEL GROUP

Administrators

André BOCK	LCE CTO - Vice-President, ARCELORMITTAL
Pinakin CHAUBAL	Process Program Manager, ARCELORMITTAL Research S.A.
Joao FELIX DA SILVA	CEO ARCELORMITTAL LIEGE
Jacques HOFFMANN	Manager R&D, Long Products, ARCELORMITTAL
Michel HOGGE	Professeur, Université de Liège
Sarah JACQUES	Attaché, SPF Economie, PME, Classes moyennes et Energie
Robert JOOS	Directeur Général, Groupement de la Sidérurgie (GSV)
Herwig JORISSEN	Secretaris-Generaal, Centraal der Metaalbewerkers van België
Vincent LECOMTE	Directeur Général, S.A. des Fonderies Marichal, Ketin & Cie
Paul LIAKOS	Secrétaire Général, ACV-Metaal/CSC-Métal
Greg LUDKOVSKY	Vice-President of Global R&D, ARCELORMITTAL
Margriet NIP	Director Product & Market Development, TATA STEEL Strips Products Ijmuiden
Peter SMITH	Director Technical Processes, TATA STEEL Research
Sven VANDEPUTTE	Managing Director, OCAS N.V.
Wim VAN DER MEER	Director R&D Programmes, TATA STEEL RD&T
Dirk VANDERSCHUEREN	Professor, Universiteit Gent
An VAN DE VEL	Scientific Relation Manager, UMICORE Research
José VERDIN	Représentant Centrale de l'industrie du Métal en Belgique (CMB)

Observers

Jean-Claude HERMAN	Directeur Général, CRM
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

(*) as approved by the General Meeting of April 20, 2011

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On April 20, 2011

Iron and Steel Committee of CRM

Members

ARCELORMITTAL Group

J.P. ALLEMAND
M. BABBIT
P. CHAUBAL
M. DI FANT
J. HOFFMANN
S. VANDEPUTTE

TATA STEEL Group

M. NIP
P. SMITH
W. VAN DER MEER
W. VAN RIJSWIJK

CRM

J.C. HERMAN
Ch. MARIQUE

Organization

On April, 2010

Quality Management

CERTIFICAT DU SYSTEME DE MANAGEMENT DE LA QUALITE

ISO 9001 : 2008

Par la présente, le BQA, sa déclare que le système de management de la qualité de la société

CRM (Centre de Recherches Métallurgiques)

CRM

dont le siège est établi Avenue du Bois Saint-Jean, 21 – 4000 Liège - Belgique, a été examiné le 21-12-2009 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 systèmes de qualité et après conclusion du contrat de certification N° DS/AJ/CER/21-12-2009/336 aux termes duquel la firme accepte un contrôle régulier de son système de management de la qualité.

Certificat N° BQA_QMS019_C_2006336
Valable jusqu'au 20-12-2012

D.SIMOENS
Directeur

BQA

DS/AJ/C/21-12-2009

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.

BELAC N° accréditation: 267-TEST NBN EN ISO 17025

BELAC N° accréditation: 267-CAL NBN EN ISO 17025

On January 1, 2011

Departments

General Manager
_ JC. HERMAN

Management Staff
_ G. LANNOO
_ B. MAIRY
_ C. MARIQUE

Steering Committees

Creativity and innovation	G. LANNOO - JC. HERMAN
Technology Transfer and Valorization	JC. HERMAN
Breakthrough projects	C. MARIQUE
Activity clusters	Dpt Heads
Programme coordination	C. MARIQUE
A. Q.	V. TUSSET

Product Technology D1
_ G. LANNOO
_ C. MARIQUE
_ I. TOLLENEER
_ P. NAVEAU

Surface Engineering D2
_ J. CRAHAYX
_ M. BORDIGNON
_ A. SCHMITZ
_ B. SCHMITZ

Sustainable Production & Upstream Process D3
_ B. VANDERHEYDEN
_ P. NYSSEN
_ D. STEYLS

Adv. Materials, Solutions & Sensors D4-D7
_ V. TUSSET
_ G. MONFORT
_ P. FOURNEAUX
_ G. WALMAG
_ G. MOREAS

Support expertise and technical teams

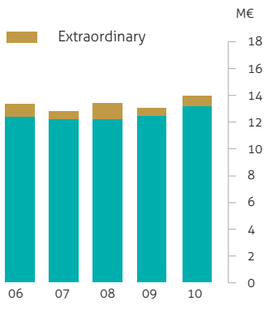
Operational Engineering D5
_ H. UIJTDEBROEKS
_ JP. FISCHBACH
_ E. ABREU
_ JF. NOVILLE

Metal Science D6
_ X. VANDEN EYNDE

Personnel, Finances & IPR D8-D10
_ B. MAIRY
_ J. GREGOIRE

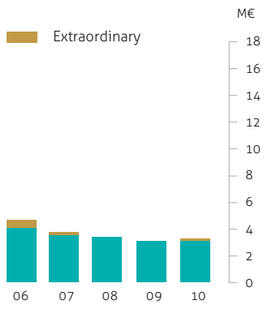
Income data

Income

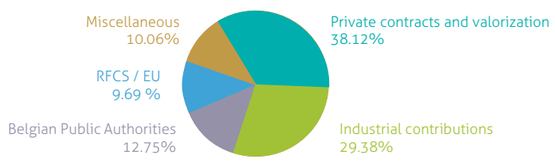


Industrial participations

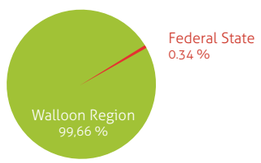
Grants



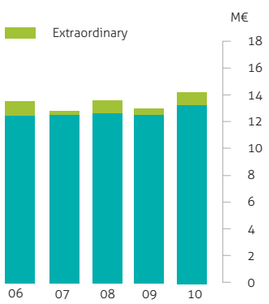
Income by source: 13.451 M€



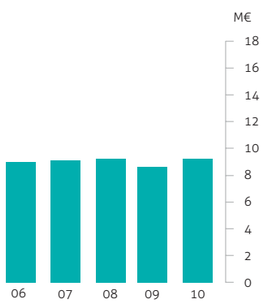
Belgium grants: 1.715 M€



Expenses



Personnel



Number of employees

Report on R&D activities

Technical part

Environment-friendly metal production

Focused on innovation in metallic materials and manufacturing processes, the R&D activities of CRM address five main key-topics:

- The environment-friendly metal production, a field involving the sustainable manufacturing of steel and metals, the recycling and valorization of by-products and the environmental aspects,
- The energy efficiency, where besides the reduction of the energy consumption of various processes, it is also aimed to recover, store and valorize different types of generated energy,
- The metallurgical & thermo-mechanical processing of the metals including the solidification and casting, the hot and cold rolling, the thermal treatment and the cooling, the physical metallurgy and the development of new generic steel grade,
- The surface engineering with actions in pickling, metallic coating, surface conversion and the design of new coating technologies and surface functionalities,
- The application of solutions and advanced metallic materials as well as of new sensors, an activity covering a very broad field with a special focus on the technical support to SME's and local economy.

Environment-friendly metal production

Besides development aiming to improve the productivity and performances of upstream processes, a special focus is dedicated to increase the efficiency in terms of raw materials consumption, environment constraints and recycling of by-products.

For the **sintering** process, CRM helps its affiliated companies (ArcelorMittal and Tata Steel) to increase the recycling of plants reverts and to deal with lower grade and fluctuating irons ores while keeping the operating performances in terms of productivity, solid fuel consumption, sinter quality and pollutant emissions.

An important part of the work concerns the granulation behavior and the cold permeability of the sinter mix. A new measuring device *(Fig. 1)* is used for characterizing the granules, based on an image analyzer assessing their size, distribution and shape. This tool will also be studied at industrial scale for process control purposes.

Fig. 1 Granules image analyzer (Zephyr of Occhio)

The on-line measurement of the sintering quality, as delivered by the SuPerMagnag system implemented at ArcelorMittal Ghent and showing a high robustness during long term campaigns *(Fig. 2)*, is another high potential way to ensure a stable functioning point for the sinter strand. The sensor signal has been integrated inside the plant control system and is complemented with two additional measurements: the sinter cake shrinkage using a laser unit and the sinter permeability through an anemometer.

Another part of the work is focused on the optimal recycling of reverts at the sinter plant. Concerning BOF slag, it has been shown that crushing below 0.5 mm enables improved assimilation during sintering with a beneficial effect on sinter quality and solid fuel consumption. Another issue is about the incorporation of very fine materials in the sinter mix. Selective compaction of such materials shows a good potential for keeping high productivity.

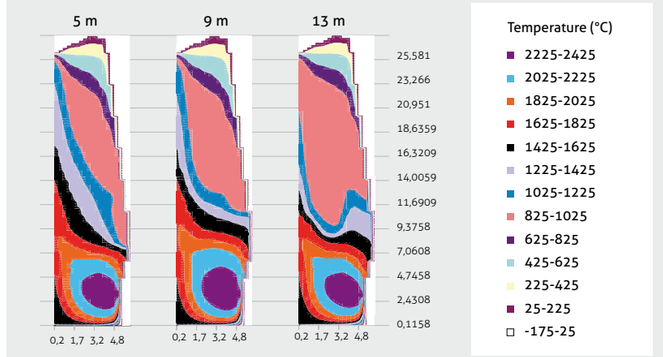


Fig. 5 ULCOS Blast Furnace – Effect of injection level on thermal homogeneity

A set of compaction rollers has been ordered to complete the briquetting press of CRM. Another useful technique when recycling reverts (sludge and dust) consists in their pre-conditioning by intensive mixing prior to their incorporation into the sinter mix. An Eirich intensive mixer with a capacity of 40 liters *(Fig. 3)* has recently completed the set of conditioning equipments available at CRM. *(Fig. 4)*

It has also to be highlighted that a PhD thesis (called "APGRAN") financially supported by the Walloon Region (1st DOCA program) has been launched with the objective to better understand the mechanisms prevailing in the granulation of very fine iron ores, fluxes and other recycled materials.

In the field of the **blast furnace** operation, the challenging aim of the ULCOS project is to reduce by more than 50% the CO_2 emissions of the European steel industry. Steered by a consortium of the main European Steel companies, the project is financially supported by the European Commission. One of the investigated solutions is the blast furnace with top gas recycling, an original idea by CRM.

CRM participated end 2010 to a new campaign with the Experimental Blast Furnace (EBF) at Luleå (Sweden), aiming to optimize the process in order to prepare a larger industrial demonstration. Like in the two previous campaigns (2007 and 2009), CRM contributed with its mathematical models to follow the operations and to analyse the results in real time.

One of the aspects to be defined for the up scaling step is the optimum level of the shaft gas injection *(Fig. 5)* to reach a good thermal homogeneity inside the blast furnace. If the injection level is too high, the thermal exchanges will be insufficient in the centre whilst if the level is too low, the root of the cohesive zone will shift downwards. In both cases and compared to the optimum situation, the coke rate will increase with a negative impact on the CO_2 emissions.

1 Wear replaceable parts
2 Laser distance sensor
3 Counterweight

Fig. 2 Supermagnag sensor at ArcelorMittal Ghent

Fig. 3 Eirich intensive mixer

1 Briquetting press
2 Eirich intensive mixer
3 Pelletizing plate

Fig. 4 Raw materials conditioning units available at CRM

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Environment-friendly metal production

Following its previous testing in different **Electric Arc Furnace (EAF) steel plants** of ArcelorMittal, the CRM model for the EAF has been successfully implemented at the ArcelorMittal Dofasco's twin shell AC furnace *(Fig. 6)* thanks to an excellent collaboration between the steel plant staff and the R&D teams.

Fig. 6 EAF Steelmaking - Hot metal pouring

After a setting for an operating practice with 100% of scrap and a very good accuracy achieved for the on-line prediction of the end-temperature (~15°C) *(Fig. 7)*, the model has been tuned and progressively adapted for hot metal operation. It is currently used by EAF operators for tap temperature control and the results during one year of application is a reduction of the steel tapping temperatures by approximately 10°C leading to a significant decrease of the energy consumption. *(Fig. 8)*

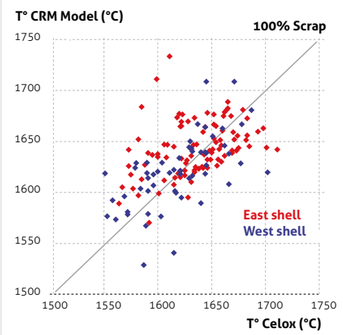


Fig. 7 Temperature prediction in EAF

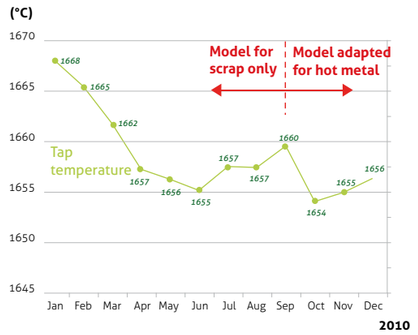


Fig. 8 Evolution of the tap temperature at Dofasco

Let us recall that the prediction of the carbon and nitrogen contents of the steel melt is also included in the EAF model, a development realized in the frame of the RFCS project "LowCN EAF" in close collaboration with ArcelorMittal Differdange and Olaberria.

Fig. 9 New design of the Serafin burner

Aiming to secure and optimize the lance/burner operation in EAF and to avoid detrimental blow-back phenomena, long duration campaigns have been pursued with the "SERaFin" sensor placed inside a combined burner and measuring the distance between the burner tip and the scrap pile. Based on the good results obtained, the further industrialization and deployment steps have been engaged for the burner insert design (in collaboration with ArcelorMittal Dommeldange Mechanical Workshop) *(Fig. 9)* and the sensor manufacturing through a collaboration with AMEPA, an affiliated CRM company.

In the field of **recycling**, one important item is the treatment and valorization of metal bearing solid residues coming from several industrial activities. With the support of the Walloon Region, the recyclability of these materials ("Recymelt" project) will be studied using a new 350 kg melting unit *(Fig. 10)* and applying a methodology developed in the frame of a past RFCS project focused on the characterization of low quality scrap.

Fig. 10 The new 350 kg melting unit

Another key subject is the use of organic material contained in the shredder residues, a project coordinated by COMET TRAITEMENTS within the frame of the Walloon Marshall Plan. CRM is more especially involved in the valorization, as reducing agent, of the char produced by the catalytic cracking of these residues. One aspect concerns the preparation of self-reducing briquettes, a mix made with the char and a blend of EAF dust and iron oxide residues conditioned on the briquetting press of CRM to reach appropriate crushing strength properties. *(Fig. 11)*

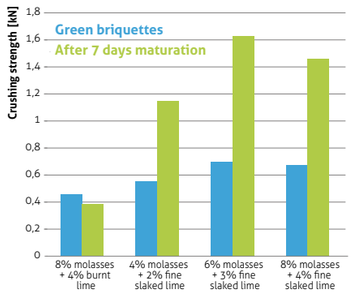


Fig. 11 Preparation of resistant self-reducing briquettes

A second goal is the realization of direct reduction tests in the pilot Rotary Hearth Furnace (RHF) of CRM, having needed the upgrading of the gas cooling and de-dusting system of the installation. *(Fig. 12)*

Stricter control on the environment and severe **air quality** standards imposed by the Authorities force all the activity sectors to take measures for reducing the emissions of the finest particulate matters (PM2.5). With the support of the Walloon Region and the collaboration of two other collective research centres, CENAERO and CERTECH, CRM pursues the development of an acoustic agglomeration method ("PARAGGLO" project) to improve the collection efficiency of existing de-dusting systems by agglomerating the finest particles onto bigger ones. A new installation unit *(Fig. 13)* allows the use of different ultrasonic sources to treat flue gas with a flow rate around 200 Nm^3/h. Let us recall that with the previous smaller installation, an abatement range for the finest particles between 40 and 50% was observed.

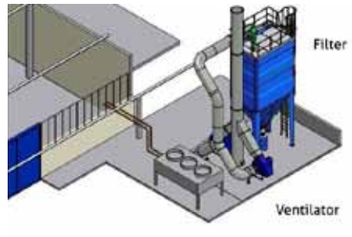


Fig. 12 Upgraded gas cooling and de-dusting installation

Fig. 13 The new acoustic test rig for ultrasound application

Energy efficiency

To illustrate the activities covered by this department recently created, let us firstly focus on developments related to the heat recovery and its storage; an axis largely supported by the Walloon Region.

A first project called "Everfire" aims at the design of specific modules filled with Phase Change Materials (PCM) tuned to recover the heat contained in combustion gases in a medium temperature range (200 to 600 °C). Based on low cost metallic components *(Fig. 14)*, such a module has shown attractive results in terms of corrosion resistance and thermal properties.

A second project concerns the use of solid granular thermal vector to recover, store and exchange heat at high temperature (>500 °C). A hot prototype has been built to test this new concept. *(Fig. 15)*

Another approach based on phase change materials aims at improving the thermal comfort in housing and

Fig. 14 Heat container for medium gas temperature filled with zinc alloy

Fig. 15 High temperature heat exchanger

realizing energy savings in heating and air conditioning. New concepts of steel panels and roofs have been tested in the frame of the projects "Retermat" and "Mirage" (a project of the Marshall Plan coordinated by ArcelorMittal). Large scale tests realized during the summer period in two low inertia steel buildings *(Fig. 16)* have confirmed the effectiveness of PCM to regulate the temperature even in a passive way with a reduction of the ambient temperature by more than 23 °C when the temperature in the reference building exceeds 50 °C. *(Fig. 17)*

Fig. 16 Experimental buildings to test the use of PCM

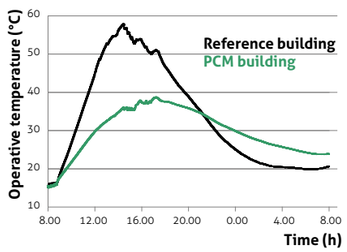


Fig. 17 House thermal regulation with PCM

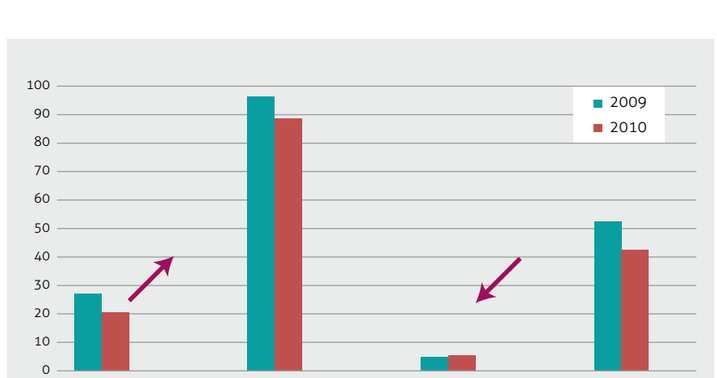
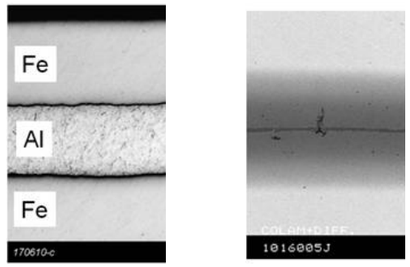


Fig. 18 Energy gain due to solar exposition



After roll bonding — After diffusion treatment

Fig. 19 Multi layers thermoelectric sheet

Let us recall that the building CRM4, largely based on original steel solutions, is instrumented in order to continuously monitor its performances in terms of energy consumption and comfort. A complete survey during the last two years indicates a net positive gain due to the solar exposition with a significant decrease of the heating energy mainly during the winter period and a moderate increase of the cooling consumption during the summer period. *(Fig. 18)*

A last example deals with the development of new thermoelectric cells to generate energy, a project coordinated by UCL inside the Energywal program. The contribution of CRM concerns the metallurgical study of the processing route: roll bonding of aluminum and iron-vanadium sheets followed by a post-diffusion treatment in order to obtain low cost semi-conductors. *(Fig. 19)*

Metallurgical & thermo-mechanical processing

This department covers activities in diverse fields notably in the domain of rolling and physical metallurgy.

The field of **hot rolling** is focusing a large part of the activities from which one can distinguish three main axes of development: the control of the work roll degradation, the mastering of the strip oxidation and the application of advanced cooling technologies that also concern the cold rolling and annealing lines.

The improvement of the **work roll** performances is studied in several projects. In the frame of the RFCS project "WINROLLS", dedicated to the roughing mill (with ArcelorMittal Dunkirk as pilot plant), industrial work roll grades supplied by Åkers are tested through continuous hot rolling trials. Differences have been observed between HSS, semi-HSS and High Cr steel grades for their cracking proneness caused by thermal fatigue degradation. *(Fig 20).* Other trials have shown that the grinding process has an impact on the oxide formation and thus the degradation of the work rolls during hot rolling.

A new RFCS project ("LPROLLCOAT") involving a consortium of seven partners (including ArcelorMittal and Tata Steel) has been launched to cover the rolling of long products. Extending the life of the work rolls by applying available wear resistant coatings or new generation of wear and thermal barrier coatings is aimed at. Inside this project, the ROLLSCOPE unit, able to assess the roll degradation and developed by CRM for the roughing and finishing hot strip mill, will be adapted to be used inside a medium section mill. *(Fig. 21)*

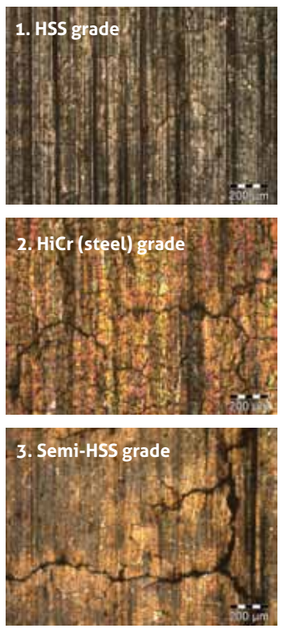


Fig. 20 Impact of roll grade on strip cracking network

The pre-conditioning by thermal oxidation of the work rolls used in the finishing hot strip mill is tested in a dedicated pilot installation by realizing cyclic treatments at the roll surface with specific burners. *(Fig. 22).* The formation of a thin oxide layer on the roll before its implementation in the stand offers a very promising way to extend the length of rolling campaign.

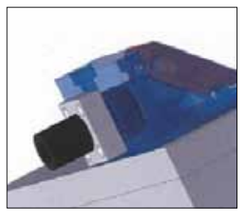


Fig. 21 Adapted rollscope head

Fig. 22 Pilot line for roll pre-oxidation

The control of the **scale formation and behavior** all along the hot processing route remains an important target. Trials conducted in the pilot continuous hot rolling line of CRM *(Fig. 23)* have indicated that the rolled-in scale defects in hot rolled strip could be significantly reduced if the cracking pattern of the oxide layer is better controlled. The creation of a fine cracks network could help to reduce the roughness at the interface steel-oxide, the extrusion of fresh metal and the scale adherence. Operating parameters such as the line tension *(Fig. 24)*, the diameter of the work rolls, the presence of a looper or a pinch roll are intensively studied to assess their influence on the scale cracking behavior. During these tests, the strip surface is on-line monitored by using the microscope unit developed by CRM. *(Fig. 25)*

Fig. 23 Continuous hot rolling trial

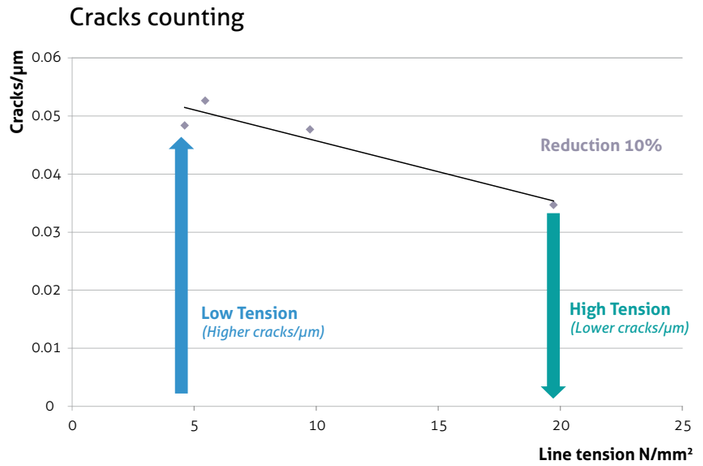


Fig. 24 Effect on line tension on strip crack pattern

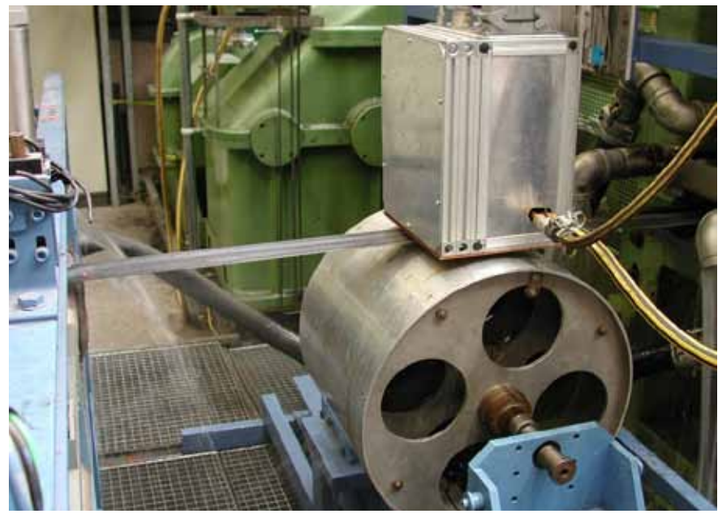


Fig. 25 On line-microscope

Metallurgical & thermo-mechanical processing

Fig. 26 Industrial prototype for the roll cooling in a sheet pile mill

By the application of a **new cooling strategy**, the thermal fatigue of big grooved work rolls in long products rolling can be strongly reduced with the same coolant flow and pressure. To validate this new High Turbulent Roll Cooling (HTRC) technology, different industrial prototypes have been developed for the sheet piling finishing mill at Arcelor Mittal Belval *(Fig. 26)* and the medium section mill at Tata Steel Scunthorpe.

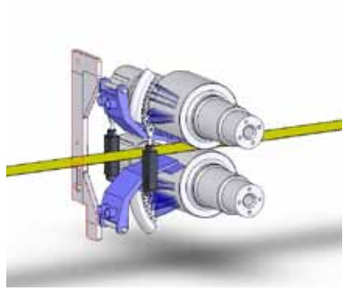


Fig. 27 New concept for interstand roll and strip cooling

In the frame of another RFCS project, a more efficient combined roll and strip cooling is developed through feasibility trials made in the pilot continuous hot rolling line. The possibility to integrate an interstand or skin cooling in the line with a minimum water pressure could reduce energy costs and open the possibility to improve the strip temperature homogeneity and quality. *(Fig. 27)*

In order to reduce the scatter in the material properties over the strip length and width, a new cooling device *(Fig. 28)* is proposed for the coiling stage. It aims for more flexibility by continuously cooling the strip on one side during coiling.

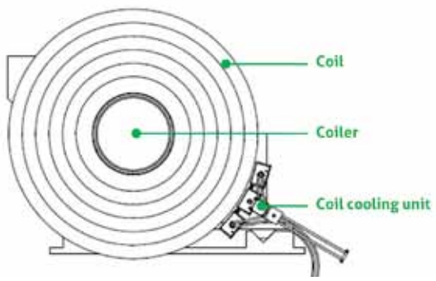


Fig. 28 Optimized strip cooling during coiling

Let us finally mention that all the development in **roll cooling technologies** can be tested in a largeful scale "Cooling Platform" recently upgraded. *(Fig. 29)*. This cooling platform measures 6 m by 9 m and 4 m in height. It contains a water tank of 20 m³, powerful pumps up to 500 Nm³/h, a heat flux measurement system and a control/acquisition cabinet. Full scale cooling headers on dummy rolls for long product and strip mills can be tested as well as full size simulations and study of finishing stand units (lubrication, work roll cooling and skin cooling) and interactions between them.

Fig. 29 Roll cooling platform

In the field of the **physical metallurgy**, the acquisition of basic knowledge concerning advanced high strength steels remains an important subject.

A first example concerns the case of silicon and/or niobium alloyed steels and the study of the metallurgical phenomena occurring during their hot rolling. By means of torsion tests, the effect of the niobium content on the static and dynamic recrystallization of austenite is investigated, *(Fig. 30)* allowing to quantify the retarding effect of niobium for the applied deformation conditions. These data can be integrated in the CRM "StripCam" hot rolling model used to preset the rolling conditions and to predict the final mechanical properties of the hot rolled strip.

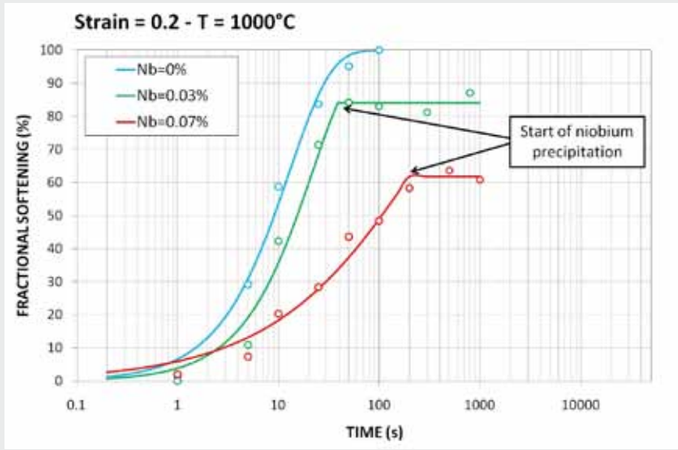


Fig. 30 Effect of Niobium on steel recrystallization

A second example refers to a deeper understanding of the martensite behavior during a tempering process. As one of the main constituents of modern advanced high strength steels, the martensite has a strong impact on the mechanical properties. Using extensive dilatometry experiments CRM has identified different stages of tempering during reheating and isothermal treatments of such types of steel.

Surface engineering & coating technologies

Buckling and strip tracking are commonly observed problems in continuous lines with annealing furnace.

They are sources of product downgrading and/or loss of productivity. A way of gaining control over the strip flatness into the furnace would be of great help. In the frame of a new RFCS project, CRM is charged to develop a sensor measuring the strip shape across the width inside the annealing furnace. The sensor is placed outside of the furnace and collects the image through an already existing opening. *(Fig. 31)* Laboratory tests and a first feasibility trial in the CRM pilot line indicated that a precision of 1mm could be reached for this type of measurement.

Fig. 31 Flatness sensor in the pilot line

In order to improve the **metallic coating** of advanced high strength steels, the development of sol-gel solutions has been pursued aiming to create a thin layer of iron oxide at the steel surface in order to allow a strong reactivity of the strip during hot dipping in liquid zinc. Various chemical solutions containing iron oxide have been developed to reach a good adhesion to the steel substrate and no powdering behavior before galvanization. Techniques like TGA and Drop Shape Analysis *(Fig. 32)* are used to characterize the interaction between the sol-gel solution and the steel substrate during first contact. This RFCS development is conducted with OCAS, Tata Steel and MPIE.

In the field of the product characterization, let us recall the sensor able to on-line measure the waviness of coated products with industrial tests realized at ArcelorMittal Avilès and Tata Steel Segal. *(Fig. 33).* A new RFCS pilot project will start in July 2011 to prepare the industrial version in collaboration with AMEPA and the two mentioned industrial lines.

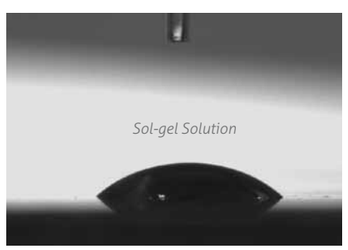


Fig. 32 Drop shape analysis on steel substrate

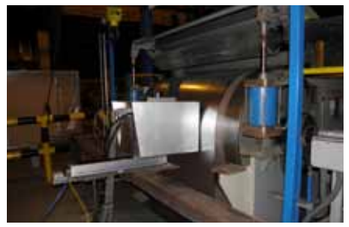


Fig. 33 a Wavimeter in industrial line

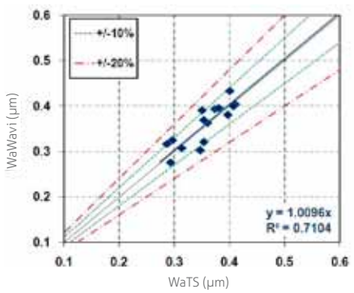


Fig. 33 b Industrial results with the waviness sensor

A new batch galvanization process called "EVAPLEX" has been proposed by UMICORE to deliver Duplex products. It is based on the deposition on finished products of a zinc vapor phase created under a moderate vacuum level and further completed with an organic paint layer in order to deliver optimal corrosion protection. A pilot prototype has been built by CRM to test and develop this technology. *(Fig. 34)* Several samples can be treated during one test campaign. *(Fig. 35).* This project, supported by the Walloon Region, also associates Drever, ArcelorMittal and CoRi.

Fig. 34 The Evaplex vessel

Another innovative project supported by the Walloon Region aims to incorporate very fine particles in the zinc layer just after the wipers before the zinc gets solidified. The objective is to master the injection of glass beads with a mean diameter below 10 µm and 5µm. Intensive laboratory trials have led to encouraging results allowing to design a prototype adapted for testing the concept in the CRM pilot coating line. *(Fig. 36)*

For the **surface conversion** of metallic products, the Chromium-free solution designed by CRM and licensed to Deleuze SA under the name "Silicalloy" is continuously adapted to meet the specifications of new markets. This development is conducted in the frame of projects supported by the Marshall Plan and the Walloon Region.

Another associated topic concerns the development of new protective coating

Fig. 35 Sample rig in the Evaplex vessel

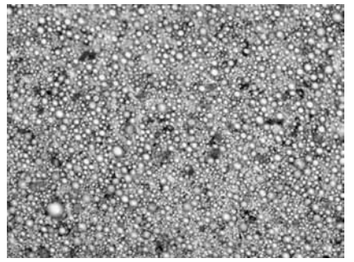


Fig. 36 Glass beads of 5 µm sprayed in a zinc coated steel

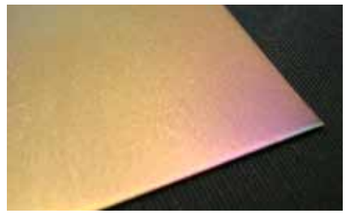


Fig. 37 New zinc free coating

free of zinc ("Clearzinc" project). Thanks to the support of the Walloon Region and of the European Fund for Regional Development, CRM is actively working on two potential solutions, the design of protective and self-healing coating based on metallic oxide solutions and the application of thin film having a Silicium based composition. *(Fig. 37)*

Experimental products can be processed combining the use of equipment available at CRM. *(Fig. 38 a & b)*

It has also to be mentioned that in the frame of this EFRD project, several major equipments have been ordered that will be delivered and implemented in 2011:

Fig. 38 a Multidip simulator

Fig. 38 b Laboratory roll-coater

a new SEM-FEG unit and additional components for the CASTL line: a roll-coater, a drying furnace and a strip guiding unit.

Application of advanced metallic materials, solutions and new sensors

As previously indicated, this activity covers a broad range of expertise and aims to support the initiatives of the Federal or Regional Public Authorities as well as the CRM industrial members, the local economy and the SME's.

Several examples have already been mentioned in this report but let us illustrate some additional topics.

Advanced metallic materials

In line with the initiatives of the "Pôle Mecatech" and of the Walloon Region (Marshall Plan), CRM is contributing to the project "Thixowal" coordinated by Marichal Ketin. This project aims to develop a new processing route able to cast and shape in a very short and compact way new steel grade components exhibiting excellent properties. The concept is based on the formation from the solidification stage of a thixotropic and equiaxial microstructure offering a good proneness to high deformation under moderate force. *(Fig. 39)*

Fig. 39 Casting a thixotropic product at Maréchal Ketin

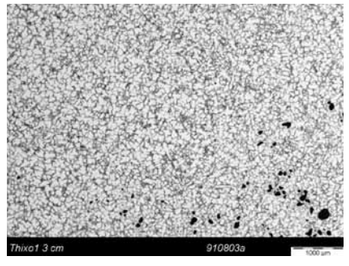


Fig. 39 Microstructure of a thixotropic steel product

Fig. 40 The BIHSTRO chair at Essen

Advanced steel solutions

Imagined by the Belgian designer Damien Bihr, the *BIHSTRO* chair developed with the support of CRM, is made from Steel and PCM (Phase Change Material). This seat stores up heat during the day and releases it when temperatures fall again at night. It is a first step towards the production of outdoor furniture collection benefiting from the same thermo-ergonomic qualities. This development has been the subject of two exhibitions, one at Paris ("Le génie de la matière", February 12 to March 7, 2010, Centre Wallonie-Bruxelles) and a second one at Essen ("Multiple Plan - Design crossroads in Belgium" - October 29 to November 21, 2010 - Red Dot Museum - Germany). *(Fig. 40)*

Sensors and measurement techniques

In the frame of the "Mint" project (Marshall Plan) coordinated by CMI and aiming to develop an integrated and innovative approach of the "intelligent maintenance", CRM develops a new 2D sensor to monitor the wear of an edge shear machine operating at ArcelorMittal Ferblatil. *(Fig. 41)*

Fig. 41 2D Profilometer at Ferblatil

The views delivered by the optical profilometer can be transformed into clear profiles allowing to follow the wear of the shear blades with a very good accuracy. *(Fig. 42)*

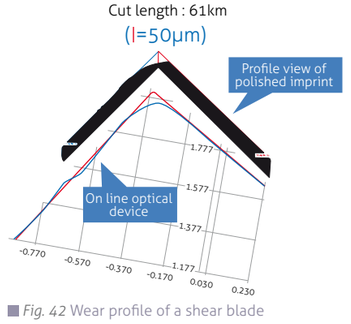


Fig. 42 Wear profile of a shear blade

Another sensor studied with the support of the Walloon Region concerns the instantaneous determination of the corrosion rate of metallic materials. ("Predicor" project). It is based on non-destructive electrochemical techniques and is focused on the corrosion that develops in cooling circuits where structural carbon steels are exposed to water types differing by their temperature, hardness and salt content. The ability to control the right inhibitor level is also aimed at. A fairly good correlation between average corrosion rate determined by weight loss and electrochemical measurements is observed. *(Fig. 43 a & b)*

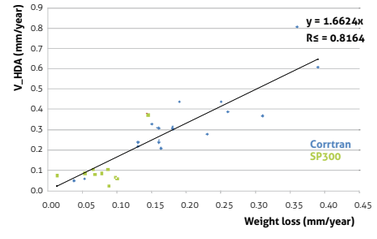


Fig. 43a On-line monitoring of the steel corrosion

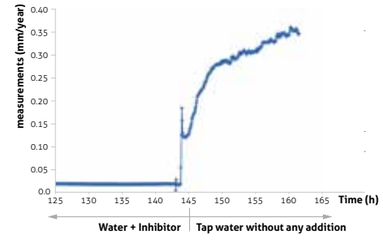


Fig. 43b On-line monitoring of the steel corrosion rate in water

Application of advanced metallic materials, solutions and new sensors

Guidance & Technological watch:

Thanks to the support of the Walloon Region, a team of almost 6 engineers is directly supporting small and medium size companies with more than 300 significant actions in 2010 related to a broad range of technical fields. The possibility for these SME's to take profit of the "Chèques Technologiques" offered by the Walloon Region under the management of AST (Agency for Technological Stimulation) has to be particularly underlined.

One of the frequently requested expertise concerns the in-situ determination of the composition and structure of metallic components. The realization of replica made on a massive piece is a way to obtain a deep characterization of the metal microstructure through a non-destructive metallographic method. *(Fig. 44 & 45)*

Fig. 44 Replica sampling on a massive element

Fig. 45 Microstructure analysis of replica

Another field of recognized competence is the evaluation of the behavior of metallic products when submitted to a high temperature and harsh environment such as observed in the urban incinerator where thermal, corrosion and stress solicitations are important notably for the steel tubes of the heat exchanger. *(Fig. 46)*

Fig. 46 Exchanger tubes corrosion in an urban incinerator

Let us also mention that CRM in collaboration with other Research Centres has taken part to the conference and exhibition "Metamorphoses – The Revolution of Materials" organized at Liege in the frame of the "Forum des Entrepreneurs" (October 20 & 21, 2010) with a special focus on the item "Materials and Housing".

Publications & Conferences

Jean-Louis Collet, Catherine Elgoyhen, Liesbeth Barbé, Griet Lannoo
"Impact of Nb and hot processing parameters on the bainite transformation"
"Societé française de métallurgie et de matériaux" Annual Meeting 2010, June

D. Espinosa, G. Lannoo, J. Malbrancke, G. Moreas and M. Picard
"Study of the scale behaviour in the finishing mill to improve the strip surface quality"
Revue de Métallurgie 107, 225–235 (2010)

L. Jacobs, B. Vervaet, H. Hermann, M. Agostini, J. Kurzynski, NG. Jonsson, J. Perez, K. Reuver, H. Van Steden
"Improving strip Cleanliness after Cold Rolling"
4th International Conference on Tribology in Manufacturing Processes. Proceedings 753-768. Nice, France, June 13 - 15, 2010

Nicolas Legrand, Jean-Luc Borean, Jochem Munz, Hugo Uijtdebroeks, Pierre Montmitonnet, Toufik Bouache, Jesus-Maria Perez, Jaroslav Horsky
"New Cooling techniques for enhanced roll bite lubrication in cold strip rolling"
The 10th International Conference on Steel Rolling, Beijing 2010

D. Debrabandere, X. Vanden Eynde, F. Reniers
"Effects of hydrogen addition in nitrogen atmospheric pressure plasma on its optical and electrical properties and silicon-based deposits compositions"
Conference on High Tech Plasma Processes (HTPP) ULB - June 2010

D. Debrabandere, X. Vanden Eynde, F. Reniers
"Plasma jet atmospheric pressure plasma: Effects of H2 addition in N2 main plasma gas on the optical and electrical plasma characteristics and on Si-based film composition, AVS-57 (American Vacuum Society International Symposium and Exhibition)"
Albuquerque (NM, USA), October 17-22, 2010.

Hugo Uijtdebroeks, Bart Vervaet, Griet Lannoo, Jean-Claude Herman, Dirk Vanderschueren, Patrick Vanpoecke
"Towards a Cost and Energy Efficient Leading Edges Hot Strip Mill"
The 10th International Conference on Steel Rolling, Beijing 2010

B. Vervaet, D. Avedian and C. Pesci
"New lubrication technology for the hot strip Mill"
Revue de Métallurgie 107, 237–244 (2010)

Annual CRM report 2010

Publications & Conferences

C. Mathy, G. Monfort, B. Vanderheyden, V. Tusset (CRM)
"Liquid Steel Process: Advanced On line Sensors under development at CRM"
15th CCATM Bejing September 2010

G. Moreas, V. Tusset (CRM), W. Bilstein (Amepa GmbH)
"On-line industrial roughness and topography measurement for continuous lines"
15th CCATM Bejing September 2010

V. Tusset (CRM)
"Tip Top Lam Cladding: Rapid Manufacturing Laser titanium parts"
CETAS Meeting held in Esch/Alzette GD Luxembourg-February 2010

V. Tusset (CRM)
"About the Launching of proposals for recommended method by ICASI"
The 10th ICASI meeting Bejing November 2010

V. Tusset (CETAS chairman)
"Preparation of CETAS 2011 conference"
The 10th ICASI meeting Bejing November 2010

V. Tusset (CRM)
"L'organizzazione CETAS e la partecipazione ai circuiti interlaboratorio per le analisi chimiche"
Analisi chimica dei Materiali Metallici-AIM Milano November 2010

V. Tusset (CRM)
"L'analisi, diCarbonio, Zolfo,Azoto, Ossogeno, Idrogeno C, S, N, O, H"
Analisi chimica dei Materiali Metallici-AIM Milano November 2010

LIEGE

Avenue du Bois Saint-Jean, 21
Domaine Universitaire du Sart-Tilman (P59)
4000 Liège - Belgique
T. +32 (0)4 254 62 11
F. +32 (0)4 254 64 64
crm@rdmetal.ulg.ac.be

GHENT

Technologiepark, 903c
9052 Zwijnaarde (Ghent)
Belgique
T. +32 (0)9 264 57 64
F. +32 (0)4 264 58 34
crm@agt0.ugent.ac.be

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www.crm-eur.com