VALorisation and dissemination of EAF technology
VALEAF

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VALEAF is a dissemination project on Electric Arc Furnace technology

**What is a Dissemination Project?**

A Dissemination Project is a way to *valorise* and *diffuse* the most important results obtained in RFCS researches with direct benefits for European steel Industry. It intends to be also a basis for establishing a roadmap for future next research works.
VALEAF Project

What is VALEAF?

Objectives
1. to promote the knowledge and various outputs derived from the European projects in this sector
2. to supply guidelines for the next developments of EAF technologies, to give indications on priorities for research subjects and suggest a clear road map for the technological development in this field

Ways and means
Collection and organisation of ECSC/RFCS Projects of the last ten years
Seminars and workshop across Europe
Construction of a web site
Aim of the seminar

Focus on
the state of the art
about models developed to describe the many aspects of EAF process

Models for improving
the energy efficiency of EAF process

Dynamic EAF process models for on-line monitoring and end-point determination

CRM EAF Dynamic Model
EAF: a Complex System

- Water cooled panels
- Scrap melting
- Oxy-burner
- Supersonic $O_2$ injector
- Electrical arc
- Electrical Arc
- Slag/bath
- Multi phase flow
- Off gas
- Carbon injector

Sources:
- TENOVA
- CRM
- Tenaris
- pTi
- CSM 
EAF: a Complex System
Multidisciplinary Approach

EAF Process (hot metal)

Physics and Mathematics Modeling

Process Simulators
Example 1: Arc Electric Modeling

**Scope of the modeling**
Three dimensional modeling of current and temperature distribution between electrodes and bath coupled with fluid-dynamic conditions using a multi-physics fine volume code for a better understanding of the plasma arc behaviour during the different process phases.
Example 1: Arc Electric Modeling

Benefit of the *Arc Electric Model*

The model allows to design the most appropriate electrical parameters of the arc in order to reduce:

- heat losses
- electrode consumption
Physics and Mathematics Modeling

Example 1: Arc Electric Modeling

The simulation results are in good agreement with actual discharge.
Example 2: Modeling of fume extraction systems

Benefit of the *Fume Extraction System Model*

The model is used to design the best geometrical configuration and the suction power in order to minimize dust emission in the environment.
Physics and Mathematics Modeling

Example 2: Modeling of fume extraction systems
Example 3: Modeling of post-combustion and heat transfer to the scrap in the Consteel® pre-heater tunnel
Example 3: Modeling of post-combustion and heat transfer to the scrap in the Consteel® pre-heater tunnel

Benefit of the Consteel® pre-heater Model

The model allows to define the best configuration to scrap pre-heating.
Example 3: Modeling of post-combustion and heat transfer to the scrap in the Consteel® pre-heater tunnel

CFD model has been set-up for pre-heating section, to calculate in detail the reaction of off-gases from the EAF with air that enters in the zone where the furnace and tunnel are connected.
'EAF Model to determinate the end-point

**EAF Process**
- Charge:
  - SCRAP
  - PIG IRON
  - DRI/HBI
  - HOT METAL
- Slag Formers and Carburizers:
  - LIME
  - DOLOLIME
  - COAL
- Electric Energy
- Chemical Energy
- Products:
  - GAS: CO, H₂, CO₂, H₂O, N₂
  - SLAG: CaO, SiO₂, MgO, Al₂O₃, ..
  - LIQUID STEEL: °C, %C, %P, ..
Example 4: iCSMelt® Process Model

The iCSMelt simulator represents the process in function of time and shows the results depending by charge and operating practices.

Benefit of the EAF Model

The model is used to design the operating practices in order to obtain target values of temperature and composition in the minimum time.
Process Simulators

Example 4: iCSMelt® Process Model - Input/Output

- **Calibration Parameters**
  - Simulation setting
  - Simulation mode

- **Mix charge**
  - Residual steel/slag

- **Operating Practice (OP)**
  - Methane–Oxygen–Carbon
  - Current intensity
  - Tension tap

- **iCSMelt®-PM**
  - EAF Model

- **Electrical caracteristiques**
  - EAF geometrical shape
  - Materials compositions/costs

- **Steel/slag at tapping**
  - Energies consumptions
  - Global heat and Phases
  - Output
  - Time, Cost

- **Steel slag at tapping**
  - Energies consumptions
  - Global heat and Phases
  - Output
  - Time, Cost
From “iCSMelt® Process Model” to “EAF Model”

The *iCSMelt® Process Model* has been the reference for further development/refinement applied on-line in industrial plant.

An example is the *EAF Model* that is used on-line on AST Terni plant.
A result produced by studies on EAF is a monitor system that integrates measurements and models in order to predict the process status.
The EAF monitor system shows customizable trends in order to drive the EAF process starting from suggestions to operators and arriving to closed control loops.

Estimation of melting progression during the EAF process on AST plant.

The model simulates the melting process in the EAF from the scrap charging.

Input data:
- Weight and composition of scrap
- Electrical energy
- Thermal energy
- Other additions

The model provides the output as a function of time.

The graphs show the trends of:
- Electrical, Chemical and Burner Energy
- Melting Progress
- Scrap, Steel and Slag Weight
- Temperature
- Steel composition (%C, %Mn)
- Slag composition (%FeO, %SiO₂)
Conclusions

International state of the art

The complexity of the phenomena occurring during the complete melting process of the charge mix in the Electrical Arc Furnace (EAF) has led, through physics and mathematics modeling and process simulators, to represent the multiphysics phenomena involved, such as:

- homogeneous (gas-gas) and heterogeneous (gas-solid and gas-liquid) reacting flows;
- conductive/radiative/convective heat transfer;
- thermo-fluid-mechanical interaction;
- electric arc: interaction between electrodes and bath
Future work

To develop multiphysics numerical simulation tools for the EAF process, coupling fluid flow, energy and mass transfer as well as selected thermodynamic calculations, with the aims of energy savings, reduction of CO₂ emissions and improved yield.

- Improve process knowledge
- Reduce risks
- Reduce costs

Decisions on plant modifications and operating practices can be taken without carrying out on-site experiments.
Thank you for listening

Valorisation and dissemination of EAF technology - VALEAF
## Reference to ECSC/RFCS projects

### List of ECSC/RFCS Projects with relevance to the Advanced EAF Modeling Mix Charge

<table>
<thead>
<tr>
<th>Number of contract</th>
<th>Title</th>
<th>Report of the VALEAF list</th>
<th>Participants</th>
<th>Date Start/End</th>
</tr>
</thead>
<tbody>
<tr>
<td>7210-PR/205</td>
<td>Characterisation of the scrap density</td>
<td>1.18</td>
<td>CRM, IRSID, Profilarbed, FERRIERE NORD</td>
<td>2000-07-01/2003-06-30</td>
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<tr>
<td>RFSR-CT-2005-00003</td>
<td>Control and optimization of scrap charging strategies and melting operations to increase steel recycling ratio</td>
<td>1.37</td>
<td>CRM, ARCELOR, CSM, MEFOS, NLMK, TATA</td>
<td>2005-07-01/2008-12-31</td>
</tr>
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Homogeneous reacting flows

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<tr>
<td>RFSR-CT-2003-00031</td>
<td>Dynamic control of EAF burners and injectors for oxygen and carbon for improved and reproducible furnace operation and slag foaming</td>
<td>1.36</td>
<td>BFI, CRM, GERDAU, GMH, Profilarbed</td>
<td>2003-09-01/2007-02-28</td>
</tr>
<tr>
<td>RFSR-CT-2009-00004</td>
<td>Sustainable EAF steel production</td>
<td>1.49</td>
<td>FERRIERE, CSM, DEW, IMPERIAL COLLEGE, Marienhütte, RWTH-IOB, Tecnocentro</td>
<td>2009-07-01/2012-06-30</td>
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**Heterogeneous reacting flows**

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<tbody>
<tr>
<td>7215-PP/073</td>
<td>Steel production and quality improvement at the EAF by hydrocarbon injection into the electric arc</td>
<td>1.2</td>
<td>CSM, Profilarbed, MEFOS, Techint, ASO, RWTH-MCH</td>
<td>2002-07-01/2005-06-30</td>
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<td>2003-09-01/2007-02-28</td>
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<tr>
<td>ECSC 7210-PR/131</td>
<td>Neuro-Fuzzy systems to improve the control of the electric arc furnace process</td>
<td>1.45</td>
<td>ARCEALIA, BFI, CSM, CENIM-CSIC, MEFOS</td>
<td>1999-07-01/2002-06-30</td>
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## Off gas

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<tr>
<td>7215-PP/027</td>
<td>Scrap continuous charging to EAF</td>
<td>1.7</td>
<td>ORI Martin, Techint, CSM</td>
<td>1999-07-01/2002-06-30</td>
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<tr>
<td>7210-PR/170</td>
<td>Control of CO-postcombustion inside EAF with the FTIR (fourier transformed infrared) spectroscopy system</td>
<td>1.9</td>
<td>RWTH-IEHK, UNIV Reading, SWT, Messer Griesheim</td>
<td>1999-07-01/2002-06-30</td>
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<tr>
<td>ECSC 7210-PR/328</td>
<td>Development of operating conditions to improve chemical energy yield and performance of dedusting in airtight EAF</td>
<td>1.30</td>
<td>CSM, BFI, RWTH-IOB, ORI, GMH, TKN</td>
<td>2002-07-01/2005-06-30</td>
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<tr>
<td>RFSR-CT-2003-00001</td>
<td>Emissions reduction through analysis, modelling and control</td>
<td>1.33</td>
<td>TATA Steel, CRM, GERDAU, ISQ, LECES, MEFOS, BFI</td>
<td>2003-09-01/2007-02-28</td>
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<tr>
<td>RFSR-CT-2006-00004</td>
<td>Improved EAF process control using on-line offgas analysis</td>
<td>1.41</td>
<td>RWTH-IOB, CRM, CSM, DEW, Marienhütte, ORI, TENOVA, THYSSEN, BFI</td>
<td>2006-07-01/2009-06-30</td>
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<td>ECSC 7210-PR/131</td>
<td>Neuro-Fuzzy systems to improve the control of the electric arc furnace process</td>
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<td>ARCEALIA, BFI, CSM, CENIM-CSIC, MEFOS</td>
<td>1999-07-01/2002-06-30</td>
</tr>
<tr>
<td>RFSR-CT-2006-00033</td>
<td>Control of nitrogen oxide emission at the electric arc furnace</td>
<td>1.51</td>
<td>RWTH-IOB, CSM, DEW, ORI, RIVA</td>
<td>2006-07-01/2009-06-30</td>
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### Multi phase flow

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<td>7210-CB/206/141/502/123/903</td>
<td>Improvement of the EAF performances through an optimisation of the foaming slag practice</td>
<td>1.4</td>
<td>CRM, CSM, Profilarbed, BFI, MEFOS</td>
<td>1995-07-01/1998-12-31</td>
</tr>
<tr>
<td>RFCS-CT-2007-00008</td>
<td>Cost and energy effective management of EAF with flexible charge material mix</td>
<td>1.39</td>
<td>CSM, CRM, FERALPI, GERDAU, GMH, MEFOS, OVAKO, BFI</td>
<td>2007-07-01/2010-12-31</td>
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<td>RFSR-CT-2006-00004</td>
<td>Improved EAF process control using on-line offgas analysis</td>
<td>1.41</td>
<td>RWTH-IOB, CRM, CSM, DEW, Marienhütte, ORI, TENOVA, THYSSEN, BFI</td>
<td>2006-07-01/2009-06-30</td>
</tr>
<tr>
<td>RFSR-CT-2012-00006</td>
<td>Control of slag quality for utilisation in the construction industry</td>
<td>1.58</td>
<td>FEhs, CSM, GERDAU, RIVA, BFI</td>
<td>2012-07-01/2015-12-31</td>
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#### Electrical Arc

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<tr>
<td>7210-PR/077</td>
<td>Improved utilisation of fossil fuel by injection through hollow electrodes in the EAF</td>
<td>1.1</td>
<td>CSM, MEFOS, RWTH-MCH, Techint, A. Rubiera</td>
<td>1998-07-01/2001-06-30</td>
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<tr>
<td>7210-CB/130, 131, 208</td>
<td>Characteristics of a hot-air/oxygen fuel burner for increasing the input of fossil energy into the EAF and comparison with conventional burners</td>
<td>1.13</td>
<td>ATZ-EVUS, BSW, CRM</td>
<td>1996-07-01/1998-06-30</td>
</tr>
<tr>
<td>RFSR-CT-2003-00024</td>
<td>Monitoring system for controlling and reducing the electrode consumption in DC EAF plants</td>
<td>1.35</td>
<td>CRM, CSM, Profilarbed, BFI</td>
<td>2003-09-01/2006-08-31</td>
</tr>
<tr>
<td>ECSC 7210-PR/129</td>
<td>Improved control of electric arc furnace operations by process modelling</td>
<td>1.44</td>
<td>Profilarbed, Arcealia, CRM, CRP HT</td>
<td>1999-07-01/2002-06-30</td>
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### Heat Transfer

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