Comprehensive overview of the project

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MULTISENSEAF

Credits

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Tables & Figures

List of abbreviations

Abbreviations	Explanation
AC	Alternating Current
CNN	Convolutional Neural Network
DC	Direct Current
EAF	Electric Arc Furnace
KPI	Key Performance Indicator
OES	Optical Emission Spectrometry
RFCS	Research Fund for Coal and Steel

Introduction

In the electric steelmaking route, the EAF process is the phase most critical in terms of energy consumption, metallic losses, and cost. A main problem is the lack of knowledge regarding the characteristics of the charged scrap and its melting behaviour inside the furnace as well as the condition of the slag and steel bath.

The MultiSensEAF project addresses the steel process and process-chain optimization via instrumentation, detection of properties of products, modelling, control and automation, including digitalization, application of big data, artificial intelligence.

The overall objective will be implemented by a three-step process. Newly developed and additional off-the-shelf sensors (OES, acoustic, load cells, camera) will be installed at industrial EAFs to create innovative multi-sensor systems monitoring the critical aspects of the EAF process. Data collected by these multi-sensor systems will be compared with process KPIs and the acoustic/OES-based investigation of the melting evolution, an optimized scrap mix can be determined to reduce energy losses due to an undesirable melting progress. The information gained will be exploited by utilizing a machine learning approach and will be incorporated into process control and decision support systems, preventing excessive oxidation or overheating of the steel. The deeper process knowledge created by the multi-sensor systems and soft sensors will be utilized in KPI and model-based process management and optimization.

By realizing the proposed improvements to the EAF process, the energy and resource consumption and by extend the cost of the steel production can be decreased while a higher metallic yield and productivity is achieved. The improved efficiency is related to a significant reduction of CO_2 emissions and thus contributes to global sustainability and the Green Steel initiative. The transferability of the results to other plants is ensured by application of the multi sensor system at two EAFs with different electrical supply systems (AC/DC), capacities (80t/140t) and general characteristics.

The MultiSensEAF project is conducted by the following partners:

IOB Department for Industrial Furnaces and Heat Engineering / RWTH AACHEN UNIVERSITY	RWTH Aachen University (Coordinator) Department for Industrial Furnaces and Heat Engineering	RWTH
Georgsmarienhütte GMH GRUPPE	Georgsmarienhütte GmbH	GMH
ACCIAIERIE DI CALVISANO	Acciaierie di Calvisano SPA	ADC
FERALPI SIDERURGICA	FERALPI Siderurgica SPA (affiliated entity of ADC)	FER
RINA	RINA CONSULTING - Centro Sviluppo Materiali SPA	CSM
LUXMET	LUXMET OY	LUX
HTT Engineering, spol. s.r.o.	HTT Engineering SPOL SRO	HTT

TU Bergakademie Freiberg
Institute of Iron and Steel Technology

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State of the art

Monitoring of properties of the charged scrap and monitoring of meltdown evolution in EAF

The characteristics of the scrap can affect the performance of the melting process, hence making it necessary to be determined in greater detail. Several European projects[1,2,3,4] have attempted at studying the effect of variable scrap properties on the performance of the process. The requirement of several measurements to correlate the information regarding the condition of the charged scrap with the process results, made the correlation unreliable and the deep monitoring of process evolution was not achieved.

Basket-filling degree and scrap meltdown was assessed in the AdaptEAF project[5]. Although, the usage of a 2-dimensional camera could only help in the estimation of the shape of the scrap heap inside the basket. The current sensors used inside the EAF either provide a global view or monitor specific information. They currently fail to provide any information representing the specific zones inside the EAF, for example, the region in front of the chemical injectors. Some applications of the use of sensors to monitor single sections has been attempted but has had problems with reliability[5]. Also, systems for scrap meltdown monitoring in EAF have been applied[6,7], but at this stage they are not connected with the dynamic representation of the process nor with the scrap charge monitoring.

The online monitoring of the temperature has also been tested within the MELTCON project[8] by installation of optical fibres at the bottom of the vessel but its application was limited owing to the cost, reliability, and necessity to modify porous plugs. The possibility to regulate process evolution based on scrap melting monitoring would significantly improve EAF efficiency.

Deep understanding of chemical reactions in liquid bath

The internal reacting volume in the EAF is a complex system due to the presence of several chemical species, energy provided by an electric arc (plasma) and, chemical reactions in solid, liquid and gas phases. This is important for relevant phenomena relating the interaction between O_2, C, CaO, steel and slag, that are still not managed dynamically as slag foaming, steel bath oxidation, dephosphorization and decarburization. Current online systems involving

[1] RFSR-CT-2013-00002 "ConoptScrap 7/2005 – 6/2008
[2] RFS-CR-03031 "Dynamic control of EAF burners and injectors for oxygen and carbon for improved and reproducible furnace operation and slag foaming - EAFDynCon" 9/2003 - 2/2007
[3] RFSR-CT-2014-00007 "Optimization of scrap charge management and related process adaptation for EAF performances improvement and cost reduction - OptiScrapManage" 7/2014 - 12/2017
[4] RFCS-CT-2007-00008 "Cost and energy effective management of EAF with flexible charge material mix - FLEXCHARGE" 7/2007 - 12/2010
[5] RFSP-CT-2014-00004 "Adaptive EAF online control based on innovative sensors and comprehensive models for improved yield and energy efficiency - AdaptEAF" 7/2014 - 6/2017
[6] M. Aula. "Optical emissions from electric arc furnaces" [Doctoral Dissertation] University of Oulu, 2016
[7] M. Aula: Decreasing EAF electrode wear in stainless steelmaking by controlling the arc exposure, 5th European Steel Technology and Application Days ESTAD2021, Stockholm, Sweden
[8] RFSR-CT-2013-00002 "Determining process conditions for online monitoring of temperature and carbon content in the electric arc furnace to optimize end point control - MELTCON" 7/2013 - 6/2016

dynamic mass and energy balances[9],[10],[11],[12] can represent, with small accuracy, the kinetics of the reactions. Application of off-gas detection for bath decarburization monitoring did not become reliable enough to manage problems such as the abnormal cases of high C content in the steel at tapping. For this reason, the project will include a deep thermodynamic study of reactions following several publications as state of the art. Researchers have investigated the manganese (Mn) and phosphorus (P) distribution experimentally, and published models to express P and Mn distribution as a function of temperature and chemical composition of the slag components. In RFCS-project "DePhos"[13] one dephosphorization model was developed using the extensive thermodynamic database for steel slags containing P_2O_5 from literature.

The investigations of the P-distribution from the past are characterized using long test durations, very small metal and slag samples and very low slag basicity. According to Kovtun et.al.[14], the calculated phosphorus and manganese distribution using different literature correlations and FactSage 7.2 were compared with measured values. The influence of temperature and FeO on the distribution of phosphorus has been extensively studied in the past. Literature results on the influence of basicity, MgO and Al_2O_3 on phosphorus distribution are contradictory. The authors of [14] and [15] concluded, that further investigation is needed to understand how the chemical composition of slag affects the Mn and P distribution. The main factors/coefficients for describing scrap melting and reactions for individual cases are still open to question.

Chemical injection modules in EAF

Chemical energy demand in modern EAF technology has increased up to 50%. This is due to the application of gas burners for the melting of solid scrap, O_2 injection to obtain chemical reactions in liquid bath and slag foaming practices through injection of C with O_2. In particular, the development of wall mounted oxy/fuel modules provide multiple functions like variable gas injection on solid scrap (burner mode), supersonic oxygen injection directly on steel bath (lancing mode), and combined injection of oxygen and carbon for slag foaming practice (foaming).

In the conventional configuration, chemical inputs have fixed points of injections. While benefits to moving flame and O_2[16] are obtained thanks to an increase of Delta T and amount of scrap involved by flame leading to an increase of heat transferred. Traditionally flame / lance motion was done by lance and / or burner manipulators inserted into the furnace via the open slag door. This solution is limited to the slag door position only and requires relatively large space and machinery around the furnace enabling also an increase of energy losses.

In the past trials have been done to apply functions of movement on chemical injections in EAF but these applications have been not satisfactory till the development of "Oxymo" system of "HTT Engineering" patented [17],[18] and tested without a large expertise in the definition of

[9] P. Nyssen et al.: Implementation and on-line use of a dynamic process model at the ArcelorMittal-Dofasco Electric Arc Furnace. METEC InSteelCon, SteelSim 2011

[10] Masoero, D. et al.: iSteel: Tenova innovative approach for energy saving and environmental friendship in the melt shop. 10th European Electric Steelmaking Conference EEC 2012, Graz, Austria

[11] Pierre, R., Kleimt, B., Dettmer, B., Schliephake, H.: Quality and cost optimal charge material selection for the EAF. 10th European Electric Steelmaking Conference EEC 2012, Graz, Austria

[12] Kleimt, B., Pierre, R., Dettmer, B., Deng, J., Schlinge, L., Schliephake, H.: Continuous dynamic EAF process control for increased energy and resource efficiency. 10th EEC 2012, Graz, Austria

[13] RFSR-CT-2014-00005 "BOFdePhos: Dynamic on-line monitoring and end-point control of dephosphorization in the BOF"

[14] Kovtun, O., Korobeinikov, I., C S., Shukla, A.K., Volkova, O.: Phosphorus Partition Between Liquid Crude Steel and High-Basicity Basic Oxygen Furnace Slags. Steel research int. 2021. 92, 8

[15] Assis A. N; Tayeb, M.; Sridhar, S.; Fruehan, R. J. MDPI Metals, 2019, 9, 116

[16] RFSR-CT-2015-00031 "Improvement of electrical arc furnace operations with support of advanced multiphysics modeling SIMULations of the EAF process - SimulEAF" 9/2015 - 8/2018

[17] Industrial pattern registed by Czech Patent Office (Urad prumysloveho vlastnictví) CZ28712 U1 " Combined nozzle for blowing oxygen and fuel into a melting furnace"

[18] Patent for "Combined burner for injection of oxidising gas and fuel to a melting furnace" CZ307407 B6

optimal motion settings[19]. To make optimal use of these devices it is necessary to set further parameters devoted to motion control and to do it is still necessary to gain expertise in evaluation of motion effectiveness on e.g. scrap meltdown.

Dynamic process control systems

Most software for process control and measurement systems are mainly devoted to global process monitoring. They do not provide a detailed description about specific areas or reacting volumes inside the EAF. Therefore, developments have begun to provide the capability to simulate the whole EAF process based on dynamic mass and energy balance[20] giving a global view of the process without indication on behaviour of EAF sectors or on injections devices.

Based on the above description, the control concepts for liquid steel production, mainly in EAF, moved from static control based on fixed operating diagrams to dynamic online controls, using measurement systems, sensors and process models based on dynamic mass and energy balance for determination of the current process state[9,10,11,12].

In addition, the optimization of the process productivity as well as the material and energy consumption require the installation of new devices (lances, sensors) connected with the existing control systems[10,11]. To support this development, several ECSC and RFCS projects were performed, and numerous activities are also reported in the literature[21,22,23,24]. Many of them focused on the energy balance, as well as the control of the electrical and chemical energy input and the melt temperature[11,12,23]. Within this context, the online analysis of the EAF off-gas played a vital role[12,21,25].

In terms of process control systems, several applications[3,13] have been defined to couple the process parameters and simulations together with relevant sensors to monitor Key Performances Indicators (KPI's) such as foaming index and energy losses. These KPIs are also used to suggest process modifications (online guidelines). Despite its advantages, the control systems fail to describe specific sectors inside the EAF as it is difficult to obtain the data for validation from those specific sectors.

Artificial intelligence (AI) methods have been applied to enable a deeper process understanding[22], but missing availability of new sensors and modelling approaches limit their usability. Therefore, a dynamic online process control system able to manage electrical and chemical parameters based on the melting evolution or including spatial description of reacting volume are still not available.

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[19] Brhel J., Viotto A., Lui S., Fennert M., Teuber M. : Development and operation experience of HTT OxymoTM burner / oxygen injector with moving flame and moving supersonic oxygen jet in two modern electric arc furnaces. Estad 2019 Dusseldorf, Germany

[20] Frittella, P. et al.: iCSMelt applications to EAF operating practice optimization. AISTech 2011

[21] RFCS-CT-2006-0004 "Improved EAF Process Control using On-line Offgas Analysis - OFFGAS" 7/2006 - 6/2009

[22] ECSC 7210-PR/129 "Improved control of electric arc furnace operations by process modelling" 7/1999 - 6/2003

[23] RFSR-CT-2013-00002 "Determining process conditions for online monitoring of temperature and carbon content in the electric arc furnace to optimize end point control - MELTCON" 7/2013 - 6/2016

[24] RFCS-709620 "Continuous Performances monitoring and calibration of model and control functions for liquid steelmaking processes" PerMonList

[25] Ojeda C., Ansseau O., Nyssen P., Baumert J.-C., Thibault J.-C., Lowry M.: EAF process optimisation tool using CRM dynamic model. 2nd ESTAD 2015, Dusseldorf, Germany

Problem description

The emphasis on steel production using an Electric Arc Furnace (EAF) has further increased owing to the goal of transforming towards a 'Green Steel' production. Possibly, the EAF route may take the lead role in primary steelmaking. Currently, various shortcomings of the EAF process limit its efficiency and performance. Furthermore, increased digitalization efforts are required and problems concerning reliability need to be addressed. The current state of the art only provides a global view of the EAF process. Deeper understanding of various zones within the EAF is required to allow for better process optimization. In order to address these issues, the MultiSensEAF project will spearhead the development of new sensor equipment, soft sensors and process models. These developments, coupled with the already existing equipment inside the EAF, will improve and provide reliable data for process monitoring, decision support and control systems. Implementing the proposed measures should help in highlighting irregularities and undesirable process conditions in advance, reduce resource consumption and improve process stability.

Ambition and project objectives

Beyond the state of the art, the MultiSensEAF project aims to use new sensors along with off-the-shelf sensors including OES sensors, load cells, and cameras. Along with the already available sensors, the new sensors are expected to provide new datasets describing the charged scrap as well as scrap meltdown evolution in the EAF. Systems and soft sensors will be used for data collection and analysis to provide correlations between scrap characteristics and melting performance.

Furthermore, the project will include a deep thermodynamic study of reactions following several publications as state of the art. The multi-sensor systems will provide new data about slag conditions like composition, temperature, foaming state as well as on the hot heel transferred between heats. In combination with already available data like off-gas composition innovative soft-sensor will be developed to determine the carbon content of the melt as well as decarburisation rate of the melt during the refining stage.

Data provided by the multi-sensor systems especially regarding scrap meltdown evolution will be used to develop and implement improved movable injector operation strategies for optimized scrap meltdown and slag foaming.

New process control systems will be obtained by implementing the process description in EAF sectors in correspondence with the different injection systems and sensors. The system will acquire data from the innovative multi-sensor systems for scrap characterization, monitoring of scrap meltdown evolution and refining stage of the EAF process while machine learning methods will give possibility of data analysis. All the systems will result in improvement performances of EAF and reduction in CO_2 emissions.

The overall objective of the MultiSensEAF project is to develop, implement and test multi-sensor systems for an optimized EAF process control. The project objectives include:

- Development of new scrap proximity sensors integrated in movable head injectors installed and tested at one industrial EAF
- Development and implementation of innovative multi-sensor systems for scrap meltdown monitoring in melting phase, slag conditions, thermal status detection and hot heel in refining phase through merging different principles of detection, OES sensors, camera images, focused radar measurement and acoustic measurements at two industrial EAFs
- Development of innovative soft sensor for scrap characterization based on a scrap meltdown monitoring using multisensory approach

- Development of soft-sensor approach to determine liquid bath decarburization rate and content of C in the bath through off gas detections.
- Application of improved movable injector operation strategies for optimized scrap meltdown and slag foaming
- Testing and integration of the sensor data into existing KPI and model-based process management systems to optimize EAF operation.

Proposed approach

To conduct the MultiSensEAF project, several technologies and methods are applied. The following sections will describe these in more detail. In figure 1 an overview of the new and additional sensors, the multi-sensor system as well as the process control systems to be developed and tested is presented.

The final systems will comprise of innovative multi-sensor systems established by combining existing sensors with additional off-the-shelf and new proximity sensors. Based on the data delivered by the hardware sensors, new soft sensors will be developed employing partly also machine learning and AI methods to characterise the scrap, monitor scrap meltdown, detect hot heel and slag conditions as well as monitor melt decarburisation. The data provided by hardware and soft sensors will be employed to develop, implement, and test innovative scrap mix optimisation and injection optimisation systems in dynamic process control.

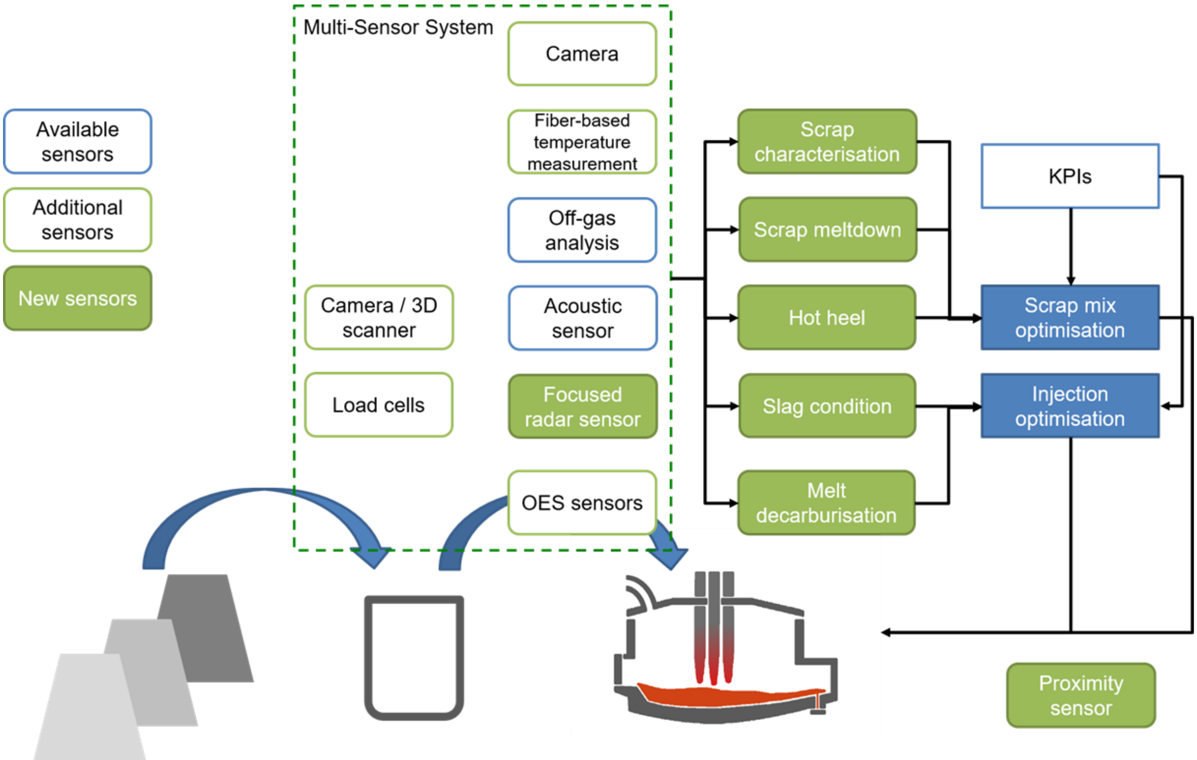

Figure 1. New and additional sensors and process control systems

Installation of proximity sensors

The main aim of having a proximity sensor inside an EAF is to understand the process of the scrap-melting process. Therefore, it would be imperative to install a proximity sensor near the injection modules to evaluate the presence of scrap. A sensor will have to be tested in an experimental rig, in the presence of hot scrap. Currently, it has been planned to install a sensor containing a protected camera with photodiodes including a cooling channel with a self-cleaning case. The protected camera should provide an internal view inside the furnace helping to verify the presence of scrap around the burners. Additionally, it would become easier to determine the moment when all scrap has been melted in order to begin with the supersonic injection of oxygen. This approach will increase the efficiency of chemical energy and minimize the melting time of the scrap, which will eventually result in increasing the overall efficiency of the furnace.

Hot Heel determination using focused radar measurement

A hot heel detection system using a focused radar will be developed and tested for the EAF. Since a focused, high frequency radar is not affected by optical visibility and emitted light, it is well suited for measurements in the conditions of an EAF melting process. The sensor will be designed keeping in mind the harsh conditions inside the furnace and the output signal of the measurement would need to appropriately calibrated and processed to account for uneven surface of molten steel. It is expected that the EAF roof design will be modified and free entry to the focused radar and its deflections will be ensured inside the EAF using a cooled tube with a slag cleaning system.

Multi-sensor systems

The project plans to combine existing sensors with additionally installed off-the-shelf and newly developed sensors in order to provide an overall picture of the EAF process. The data collected would further help in the development of soft sensors based on physical as well as AI-based models. In order to provide the necessary data, the project will create multi-sensor systems by combining the following physical sensors:

- Acoustic sensors to monitor scrap melting evolution and arc coverage by foaming slag
- OES sensors installed in the EAF roof to monitor scrap meltdown
- Off-gas composition detected at the fourth hole coupled with virtual sensors for estimation of flowrate and temperature to evaluate energy losses and quantity of C present
- OES sensors to analyse slag composition and temperature in the refining phase
- Cameras providing a view inside the EAF when the roof is opened for charging
- Cameras/3D scanner delivering information on scrap volume in the scrap basket
- Load cells to deliver the scrap basket weight
- Hot heel sensor based on focused radar measurement
- Optical fibre for continuous measurement of the steel temperature

Soft sensors

The combination of historical data already available and collected by the multi-sensor system will form the basis for the development of a series of soft sensors. The soft sensors and their purpose are described below.

Scrap characterization

The implementation of new scrap optimization concepts will be carried out with the data provided by the multi-sensor systems to characterize scrap based on scrap volume, density and meltdown behaviour. In combination with the conventional operational data a comprehensive new scrap characterization model will be developed, featuring data from the following sources:

- Tracking of the charged scrap mix and total scrap weight
- Determination of the scrap volume in the basket obtained by 3D scanner or camera and dedicated image processing for volume and subsequent density calculation
- Determination of the meltdown behaviour of the specific heat and scrap mix
- Collection of conventional heat data like tapped steel weight and composition

Camera-based hot heel determination using Machine Learning

In the process of understanding the effectiveness of the chemical injectors with regards to different approaches in terms of setting the process parameters in different geometric positions, EAF configurations will require a system which can correlate several parameters in accordance with both input and output parameters of the process. Acquired data from the sensors and cameras can be used for the determination of Hot Heel inside the EAF. Using image classification techniques like Convolutional Neural Networks (CNN)[26] and many optimized architectures from the same family as Mobilenet-SSDv2[27], Faster-RCNN Inception Resnet v2[28] may prove beneficial for the task in hand. All required libraries are open source and can be upscaled according to our needs.

The development of the online application by incorporating the above-mentioned techniques will empower the system to detect hot heel quantity present at the end of the heat. The knowledge of the real steel weight available in the EAF can improve the melting results at the end of each heat.

Scrap meltdown evolution and slag characterization

Optical emission spectrometry (OES) analysis on the light emitted within the furnace has been previously helpful in the measurement of temperature of the emitting material and the excitation of alkali metals often occurring in combustion reactions. Similarly, OES measurements can used to understand the overall melting state of the furnace. For instance, the optical emission spectrum can be used to assess the slag surface behaviour or the combustion reactions occurring in the freeboard. Within the project models will be developed and implemented to monitor the overall scrap meltdown evolution and to characterize the slag based on composition, temperature.

Decarburization rate determination

During the refining phase of the EAF process, the injection of oxygen enables the oxidation of the various element present in steel batch with the formation of oxides like FeO, MnO, SiO_2, etc. Furthermore, the decarburization of the steel bath generates carbon monoxide and carbon dioxide inside the EAF, whose composition is measured via the off-gas analysis. On performing an overall component balance for carbon, the total decarburization rate can be determined to evaluate the influence of bath oxidation on carbon removal. Another parameter to be determined is the post-combustion rate to evaluate the efficiency of post-combustion occurring on the off-gas prior to the off-gas leaving the EAF.

Decarburization rates have been evaluated in other processes (like AOD) characterized by more process stability. In the EAF this approach could give beneficial results but the instability of the process and variability make its application and validation more difficult. Nevertheless, the project will attempt to evaluate the decarburization rate in this project using all possible soft sensors.

Online control and optimization concepts

Scrap mix optimisation

Using the data and information collected by the physical sensor and the scrap characterization soft sensor, a scrap mix optimization will be developed and tested. The scrap mix optimization will be based not only on an extended scrap characterization including density and meltdown behaviour, but also on process KPIs and steel grade requirements. An

[26] O'Shea, Keiron & Nash, Ryan. (2015). An Introduction to Convolutional Neural Networks. ArXiv e-prints.
[27] Chiu, Yu-Chen & Tsai, Chi-Yi & Ruan, Mind-Da & Shen, Guan-Yu & Lee, Tsu-Tian. (2020). Mobilenet-SSDv2: An Improved Object Detection Model for Embedded Systems. 1-5. 10.1109/ICSSE50014.2020.9219319.
[28] Anthony, Adole & Edirisinghe, Eran & Li, Baihua & Bearchell, Chris. (2020). Investigation of Faster-RCNN Inception Resnet V2 on Offline Kanji Handwriting Characters. 1-5. 10.1145/3415048.3416104.

online OES system application will be developed which will detect the conditions on the reacting volume, slag thermal status, slag bath conditions like composition to have online feedback about the entire process evolution in the EAF. The application of the scrap mix optimisation systems will enable the EAF operators to predict the eventual time and energy necessary for melting which will assist in appropriate process optimization.

Injection optimization

The available control system realizes dynamically in real time the mass and energy balance of EAF process considering charged masses and energies by electrical source and chemical oxidations as well as considering energies losses which enable the estimation of compositions and temperatures of steel, slag and off gas. It is necessary to collect data coming from distinct positions and support the distinction of effectiveness in reacting areas related to motion with respect to other positions.

Furthermore, the modelling of the deep interaction between steel and slag in liquid phase will be improved in the modelling approach including specific dynamic kinetics of the reactions occurring.

Combining the historical data acquired by relative sensors will provide the base for acquiring the following indications relevant for management of chemical injections in EAF:

- Evaluation of scrap presence in front of the injection modules
- Slag foaming efficiency and necessity of Carbon and Lime injections for each sector
- Evaluation of melting evolution and reactions status to manage electrical and chemical parameters.
- Evaluation of decarburization rate
- Evaluation of thermal status of liquid steel/slag bath
- Evaluation of kinetic evolution of the reactions in the process

Using this approach, guidelines for eventual future management of these rules in the management of injection modules automatically will be defined.

Industrial trials and performance evaluation

Evaluations of the refining phase will also be considered to determine the following aspects:

- Evaluation of chemical reactions occurring due to interaction between steel, slag, Carbon (C), Calcium Oxide (CaO) injected.
- Evaluation of chemical energies generated will be compared with bath thermal status detected with OES.
- Evaluation of bath decarburization by off-gas composition and evaluation of high percentage of carbon in the steel.

Expected impacts

Optimization of the charged scrap mix to reduce energy and resource consumption

One of the main goals of the project is the investigation of the melting evolution in correlation with the properties of the charged scrap. In this regard, properties such as type, weight, density as well as size of the scrap shall be examined using the technology presented in the proposed approach. Following the proposed approach, a better understanding of the meltdown behaviour of different scrap types and compositions can be achieved. In addition, an optimized scrap mix will be determined in order to minimize energy and resource consumption by ensuring a favourable melting behaviour of the scrap.

The MultiSensEAF project results will benefit different target groups including EAF operators, EAF steelmaking companies and EAF equipment suppliers. The following outcomes are expected to be reached:

- Better understanding of the melting evolution within the arc furnace
- Optimization of the charging schedule and reduction of the electric energy and fossil fuel consumption
- Reduction of the overall CO_2 emission connected with the steel production
- Increased profits due to improved plant productivity

Increasing process efficiency by online-monitoring and adaptive process control

Another aim of the project is the forefront optimization of the charged scrap. It is aimed to be complemented by application of a multi-sensor system in combination with historical data from already existing equipment. The aggregated data will be used to develop a series of soft sensors covering multiple aspects of the process including meltdown evolution, slag characterization and hot heel determination. Existing process control systems can be improved by the incorporation of new data. In this regard, the overall objective is to identify disadvantageous process conditions and develop new control strategies to react on them. As a result, the energy distribution as well as the distribution of reactant in the steel bath can be homogenized, with the goal of increasing process efficiency and metallic yield.

These results will mainly benefit the EAF operators and steelmaking companies as well as EAF equipment suppliers. The following outcomes are expected to be reached:

- Improved reliability and stability of the EAF process by optimization of control strategies and model-based decision support systems
- Improved chemical composition of the scrap by achieving a more homogeneous energy distribution and oxidization
- Improved safety and working conditions by advanced monitoring of the process
- Increased metallic yield and energy efficiency
- Reduction of the overall CO_2 emission connected with the steel production

Wider impacts

All the technologies mentioned in the proposed approach aim towards improving the stability and safety of the EAF process by upgrading the current state of the art and exploiting the large amounts of data collected to identify previously hidden correlations. The described measures can be combined and their impact will contribute to the common goal of modernization of the EAF process and to a smaller extend to the decarburization of the European steel making by decreasing energy and resource consumption and increasing the metallic yield. Due to the advancements in efforts to decrease the carbon footprint of the steel industry in Europe, the share of steel production via the EAF route is likely to increase and the increase in energy efficiency in the EAF route is expected to maintain profitable production despite the current situation of the energy markets.