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Abstract booklet

On-Line Optical Emission Spectrum Measurement in Control of Electric Arc Furnaces

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Abstract

Currently, one of the biggest challenges in electric arc furnace steelmaking (EAF) is the fluctuation of composition and size of the steel scrap. The fluctuations in the scrap charge results in significant fluctuations in EAF process, which are observed in high spread of overall heat characteristics like tapping temperature, energy efficiency and tapped melt weight. The problem is getting worse due to the need of using more and more external scrap in EAF charge and the overall trend of worsening market scrap quality. These changes could be compensated for example by modifying the arc voltage, bucket charging times and carbon blowing, but currently it is difficult since very little real-time data of process conditions inside EAFs is available.

A promising new method to measure the EAF process conditions is to gather and analyse the visible and near-infrared emissions of the electric arc and hot slag to gain information of the slag composition, scrap melting and slag surface temperatures. Optical emissions can be gathered with an optical fibre installed on the furnace roof. By using optical fibres it is possible situate the actual analysis equipment a safe distance away from the EAF making the measurement feasible in a practical sense.

The method has been tested previously in laboratory, pilot and industrial furnaces. Recently, the measurement system has been used in analysing the scrap melting and slag foaming phenomena in industrial furnaces. The analysis of slag composition from the arc optical emission spectrum has been tested in laboratory and pilot furnaces; promising results have been achieved especially in analysing the amount of chromium in slag.

Use of Biomass and Biogenic Carbonisates in EAF Steelmaking

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Abstract

Electric arc furnace (EAF) steelmaking is an important steel production route which constitutes approximately one third of the crude steel production. 12-15 kg of fossil coal per ton of steel is used process-related during the production. As the European Research Fund for Coal and Steel (RFCS) project GREENEAF showed, lots of biogenic materials have a high potential to substitute the anthracite coal that is currently used in steel mills.

A large number of biogenic materials from various production processes and residues from established industrial branches can be used as alternative carbon source. Beside the carbon content of the different materials, the reactivity is the main parameter to assess the possibility of application in an EAF. Problems occurred regarding the handling of some fine-grained carbonaceous material. In industrial scale, this causes the necessity of explosion prevention. In fact, the need for explosion prevention can prevent an economic substitution of fossil coal. Therefore, agglomerates from a fully biogenic blend were produced. These briquettes have a smaller specific surface which leads to a slower and more controlled combustion.

In July 2014, the follow-up project GREENEAF II was initiated. In this project, the application of biogenic materials as substitutes in EAF steel production is assessed in industrial scale. In this field campaigns more than 350 tons of biogenic material is needed to produce a statistic reliable amount of data.

The first two field campaigns already have been carried out and the data of more than 700 heats using biomass have been evaluated and compared to more than 350 reference heats. The results are promising.

The VALEAF RFCS Project

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Abstract

From 1991 up to now, in the context of the research programmes of the European Coal and Steel Community (ECSC) and Research Fund for Coal and Steel (RFCS) about 70 projects have been dedicated to EAF, 33 in the period 2001-2015. In the various projects all the most important players of European industry were involved (steel industry, engineering companies, suppliers, research centres). All the relevant technical issues of EAF process have been faced.

The VALEAF RFCS project is a dissemination project on Electric Arc Furnace technology. A dissemination project is a way to valorise and diffuse the most important results obtained in RFCS research with direct benefits for European steel industry. It intends to be also a basis for establishing a roadmap for future research work.

Objectives of the project are to promote the knowledge and various outputs derived from the European projects in this sector and 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 of the project are the collection and organisation of ECSC/RFCS projects of the last ten years, the organisation of seminars and workshops across Europe and the construction of a web site to publish the project results to the interested public.

Development of a CFD Simulation Model of the Heat and Mass Transfer in an Electric Arc Furnace

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Abstract

Approximately 30% of the raw steel currently produced in Germany is produced in electric arc furnaces. During this energy intensive process with temperatures of more than 1500 °C, steel scrap is melted using the energy supplied mainly by either direct current (DC) or alternating current (AC) electric arcs. The extreme thermal conditions and electromagnetic interference within the furnace make it a challenge to monitor and control the transient steelmaking process. Therefore at the Department of Industrial Furnaces and Heat Engineering of the RWTH Aachen a numerical CFD model of the heat and mass transfer within the freeboard of an AC EAF during the flat bath phase is being developed. During this phase of the heat the AC arcs are generally used to superheat the melt, whereby the melt is decarburized by simultaneously injecting oxygen and carbon into the bath using lances. The long-term goal of the model development is to make it possible to qualitatively investigate the interrelationships between the flow field, the energy flows and the chemical reactions in the EAF vessel. The greatest challenge is to model the influence of the arc region on the heat and mass transport within the freeboard. The flow in this region for example also has an influence on the amount of turbulent mixing between ingress air and CO rising up out of the slag layer. The resulting post-combustion of CO to CO_2 has a direct influence on the amount of latent heat lost with the off-gas exiting through the 4th hole. The developed EAF simulation model makes it possible to better understand the 3D nature of the flow field conditions in the freeboard. At present the model can already be used to investigate the qualitative influence of process changes. Furthermore, during the model development important insights have been gained concerning the future development steps needed in order to achieve the long term goal.

New Control Concept for Post Combustion and EAF Off-Gas System on the Basis of NN and Measurements in Less Harsh Condition

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Abstract

We present an artificial neural network simulation, based on a set of data for prediction of off gas condition from electric arc furnace at the fourth hole. Input parameters and the outputs of neural network consist of off gas volume flow rate, temperature and composition extracted from simulated model in the literature. The presented approach facilitates the simulation of the dedusting system for special purpose like the control by using the experimental data. The error analysis in the neural network was performed by well-known back propagation error reduction method containing one hidden layer. The results showed good agreement with the available simulated data, indicating a suitable technique for simulation of the off gas condition. It is concluded that the established neural network system, in conjunction with the back propagation analysis, is able to determine the off gas condition at the fourth hole of the electric arc furnace for set of specified input parameters.

Spectrometric Measurements and Vibration Sensors at a 140 t DC Electric Arc Furnace for On-Line Evaluation of Scrap Meltdown Behaviour

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Abstract

Georgsmarienhuette GmbH, the Helmut-Schmidt-University Hamburg and other partners collaborate in a current EU-funded project to complement EAF process control by integrating novel sensor data and advanced process modelling tools. Object of demonstration is Georgsmarienhuette's 140 t DC Electric Arc Furnace.

First steps in the project focused on the revision of existing vibration sensors and the installation of additional measuring points at the furnace, aiming at reliable and significant measurement signals. Consequently, models for evaluating scrap meltdown behaviour are developed by correlating vibration signals with other relevant process data.

Moreover, an existing spectrometer system is developed further. This system has previously been used for detecting free-burning arc conditions and was installed in a water-cooled wall panel, thus providing a direct view into the furnace. Firstly, novel research focuses on an on-line temperature estimate based on Planck's Law. Secondly, methods for evaluating solid scrap amount and height inside the furnace are developed. As the spectrometers' view openings are prone to blockage by slag-caking, the main challenge with spectrometric measurement equipment is to render continuous data. Therefore, purging mechanisms are improved and analysis algorithms are refined to automatically detect blocked or impaired view conditions.

Ultimately, the above-mentioned new sensor data will be merged into an advanced on-line meltdown model as basis for optimized scrap charging as well as for detecting possible hot or cold spots, thus providing approaches for homogenizing meltdown behaviour.

EAF Steelmaking: Scuola Superiore Sant'Anna (Italy) Research Activities

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Abstract

Several research activities of Scuola Superiore Sant'Anna are mainly focused on European projects connected with steelmaking industry, both electric and integrated cycles. Electric steelmaking is an energy-intensive process and enhancement can be pursued for better process management, in order to reduce environmental impact and increase global benefits. Different European EAF steelmaking plants and research institutes cooperate in projects to develop materials and methods useful for this purpose.

For instance, "EIRES" project focuses on the development of an integrated decision support tool through metric device and process modelling of steelmaking route, from electric furnace to continuous casting. The process response to changes in operating conditions can be investigated according to the final steel grade. Prognostic evaluation of process emission and energy consumptions allows evaluating environmental impact in multiple scenarios by computation of ad hoc defined Key Performance Indicators. Practical guidelines can be extrapolated for management to be improved.

Another ongoing project to mention is "ENERGY DB", aimed at the application of a factory wide and product related energy database for energy reduction.

Other European project, which are concluded, related to electric steelmaking are linked to process control by introducing on-line determination of non-metallic inclusion characteristics with tests sampling and analytical methods (RAMSCI), process efficiency and optimisation in terms of nitrogen and carbon contents (LOWCNEAF) and scrap treatment and control, i.e. possibilities for simultaneous preheating and surface cleaning of zinc-coated steel scrap (PROTECT).

Gas Phase Modelling and Simulation in an Electric Arc Furnace Process Model

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As energy intensive process, the energetic optimization of the electric arc furnace (EAF) is in the focus of future developments to increase the energy and resource efficiency. Here, process models and simulations are able to contribute to a better understanding of energy and mass transfers during the melting process and can be applied to investigate new control strategies. The EAF off-gas thereby offers high research potentials due to its energy output of 20 – 30 % and the possibility of process control through off-gas measurements.

Within the presentation, the detailed modelling of the gas phase in an EAF process simulation model is described. Therefore, the process simulation model described by Logar et al., 2012, was re-implemented and the gas phase further developed. In the first step, hydrogen, water and methane are added to fulfil the energy and mass balance of the EAF process model. These gas components can reach high proportions in the gas phase and lead to high energy output of the EAF, especially when natural gas burners are used and the electrode cooling is operated excessively. Hydrogen and water are implemented by simple but dominant reaction mechanisms like water-gas reaction and post-combustion. Further development steps like improved calculation of the melting geometry, the view factors and the implementation of thermal radiation of the gas phase are carried out and will be described. With the help of detailed gas phase simulations, further research on control strategies is possible in combination with an EAF dedusting system model.

Development of a Cement Bonded Brick of Ladle Slag and Biochar for the Usage in Electric Arc Furnaces during Steel Production

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An innovative input material for the electric steelmaking was developed to increase the sustainability and resource efficiency of the process in the electric arc furnace (EAF). Therefore ladle slag, biochar and ferrous mill scale were agglomerated in a cement bonded brick.

The recycling of ladle slag leads to savings of CaO or MgO during the process and will reduce disposal costs. Biochar is a sustainable substitute of fossil coal and used as an additional source of chemical energy and contributes to foaming the process slag. Optionally, ferrous scale can be added to adjust the magnetic properties of the final brick. In order to ensure strength and durability of the agglomerates, cement was chosen as binder.

After analysing and determining the components, prototypes of the bricks with different compositions were developed. In the end, five different kinds of bricks have been configured and produced to run an experimental study in a 150 t EAF. Hence 2.6 - 5.6 tons of the bricks were charged additionally into the furnace in order to investigate the influence of the new input material on the process and the molten steel. These melting experiments in industrial scale were carried out and evaluated by analysing the produced steel, slag composition, off gas composition and the demand of electric energy.

From a technical point of view the usage of the developed bricks during electric steelmaking is possible and has neither any negative effect on the process nor on the final product steel.

Measuring the Scrap Level in an AC EAF by Using Vibrations and Harmonic Distortion

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Abstract

Knowing the molten state of the scrap in the electric arc furnace is very important for process control. But because of the harsh environment in and around the furnace new measurement techniques must be developed to measure the molten state during operation. This work looks at vibrations emitted from the arcs measured at the furnace walls and electrical disturbances in the form of current harmonization. Looking for correlations with the molten state, 254 heats were observed and the majority show increasing vibrations with time, while the power input is constant. This indicates that a high scrap level acts dampening on the emitted vibrations. There were however several heats that showed a very low vibration level throughout the heat. The electrical harmonisations were decreasing with time during the last basket. This is already used as a predictor of foaming slag but might show a possibility to indicate the presence of flat bath when operating without foaming slag. To be able to build a proper model for the scrap level, new measurements must be conducted while looking into more process variables. A designed melting scheme should be conducted to keep power constant over a longer time, while visually observing the scrap level by opening the roof. A better model of the scrap level in the furnace will decrease power on time and may help increase the understanding about what is influencing the energy losses during different parts of the EAF cycle.