C. MATHY[*], P. NYSSEN[*], M. BRIMMEYER[**], D. GUALTIERI[**], D. RIGONI[***], J.C. BAUMERT[***]

INNOVATIVE TECHNIQUE FOR RELIABLE OPERATIONS AND BLOW-BACK PREVENTION OF EAF ANNULAR BURNERS, COMBINED BURNERS AND INJECTORS

NOWATORSKA TECHNIKA NIEZAWODNEGO STEROWANIA I ZAPOBIEGANIA PRZPŁYWOWI WSTECZNEMU PALNIKÓW PIERŚCIENIOWYCH I INŻEKTORÓW W EAF

In recent years, EAF process promoted the use of chemical energy for both enhancing productivity and reducing electricity consumption. Combined burners and sidewall oxygen lances are now currently operated in modern EAF. However, these tools are operated following pre-set patterns, without any feedback information from the process. This leads both to non-optimised operations and to occasional blow-back problems, resulting in damages to burners, lances, water-cooled panels and refractory lining.

CRM has developed an on-line "distance-to-scrap" measurement technique that can be fitted inside annular burners and provides a monitoring of the melting of scrap in front of each burner. This information allows controlling burner operation and detecting blow-back occurrences before any damage is created. This sensor was successfully tested in the ArcelorMittal Esch-Belval steel plant

This technology has been extended to combined burners. The size of the measuring beam has been reduced in order to allow the sight through narrow nozzle throats. The switch from the preheating to the lancing mode can be decided based on the distance information. First tests of the size-reduced sensor device have been carried out in the ArcelorMittal Esch-Belval steel plant.

Keywords: Electric Furnace, Burners, Lances, Control, Scrap, Distance, Blow-back, Energy optimisation

W poprzednich latach proces EAF lansował użycie energii chemicznej zarówno do podniesienia wydajności jak i do zmniejszenia zużycia energii elektrycznej. Aktualnie w nowoczesnych piecach EAF wykorzystuje się kombinacje palników i lanc tlenowych, umieszczonych na ścianie bocznej. Jakkolwiek te narzędzia są wstępnie ustawiane, bez jakiejkolwiek informacji zwrotnej z procesu. To nie umożliwia optymalizacji, a także problemów z przepływem wstecznym, doprowadzając do uszkodzeń palników, lanc, paneli chłodzących i wyłożenia ogniotrwałego.

CRM rozwinął technikę pomiaru on-line "odległość do złomu", gdzie czujniki pomiarowe są umieszczone wewnątrz palników pierścieniowych i zapewniają monitoring topionego złomu przed każdym palnikiem. Te informacje pozwalają na sterowanie działaniem palników i wykrywanie przypadków wstecznego dmuchu, zanim wywoła to uszkodzenia. Czujnik ten został z sukcesem przetestowany w stalowni ArcelorMittal Esch-Belval.

Ta technologia została rozszerzona o kombinacje palników. Wielkość wiązki pomiarowej została zredukowana, aby umożliwić obserwację przez wąskie przewężenie dyszy. O przełączaniu między podgrzewaniem, a trybem lancy decyduje informacja o odległości. Pierwsze próby ze zmniejszonymi wymiarami czujnika zostały przeprowadzone w ArcelorMittal Esch-Belval.

1. Introduction

The use of chemical energy (burners and oxygen lances) in the EAF has increased significantly in recent years, both for enhancing productivity and reducing electricity consumption. However, these tools are commonly operated following pre-set patterns, without any feedback information from the process. This leads both to non-optimised operations and to occasional blow-back problems, resulting in damages to burners, lances, water-cooled panels and refractory lining.

CRM has developed a "distance-to-scrap" laser sensor to be fitted inside burners, oxygen injectors and combined burners. As illustrated in Fig. 1, this sensor allows the on-line monitoring of scrap melting in front of each burner / injector. It should thus enable furnace opera-

[*] CENTRE DE RECHERCHES MÉTALLURGIQUES, LIČGE, BELGIUM
[**] ARCELORMITTAL BELVAL & DIFFERDANGE S.A., ESCH-BELVAL PLANT, LUXEMBOURG
[***] ARCELORMITTAL BELVAL & DIFFERDANGE S.A., RESEARCH CENTRE, LUXEMBOURG

tors to optimise burner / injector operation and to detect blow-back occurrences before any damage occurs.
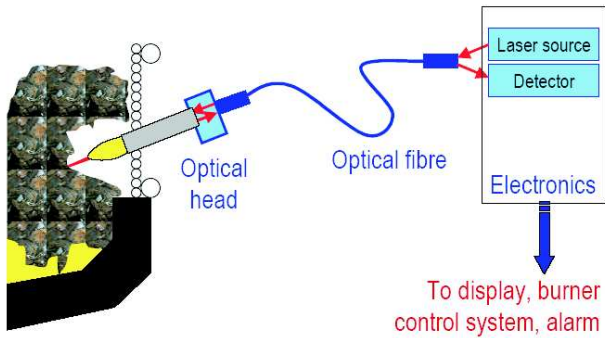

Fig. 1. Principle of the burner control in the EAF

2. Principle of the measurement

The measurement sensor operates according to the principle of optical propagation time measurement: the distance to a target is determined by measuring the transit-time between transmission and reception of a short laser pulse.

The measuring system comprises an optical head and a separate electronics box, connected with a twin glass-fibre cable, allowing the installation of the sensible part far away from the furnace disturbances. The selected electronic allows to reach the required measurement time, less than 5 nsec ($5 \cdot 10^{-9}$ seconds), and the corresponding optical head enables a measure on a very hot target (up to 1650°C).

Unfortunately, for commercially available optical heads, the measuring beam diameter is too large to target through the burner free aperture. The optical head of the sensor has thus been completely re-designed.

3. Description of optical head for annular burners

An adapted optical head was first studied for application to annular burners. Optical bench tests have been used for design and optimisation. The head was then engineered, manufactured and tested in CRM laboratories.

Figure 2 shows its response signal as a function of distance; it can be seen that it covers the whole measurement range (from the burner tip to the electrode) with sufficient signal strength.

A high temperature laboratory furnace chamber has been used to test the sensor response on the high temperature measurement conditions, which prevails in the EAF. The measurement accuracy, reproducibility and drift, remain better than 10 mm even at temperature up to 1650°C.

This first sensor head was designed to be installed at the back of an annular burner (see Fig. 3). The laser signals are sent and received axially through a sighting tube purged with compressed air, to avoid any obstruction by slag or metal projections. Mechanical and thermal protecting devices have been carefully studied to cope with the harsh operating conditions prevailing in the vicinity of the furnace.
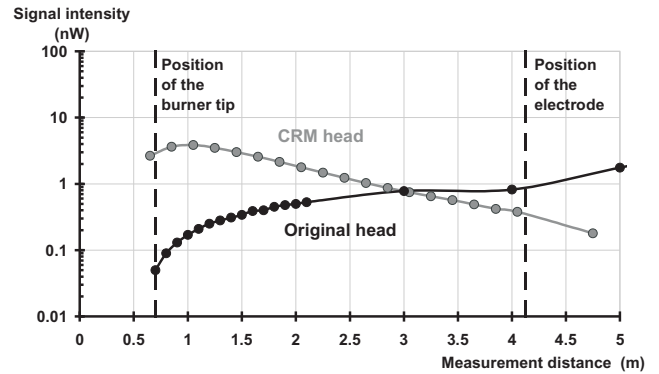

Fig. 2. Response of the optical head for annular burners
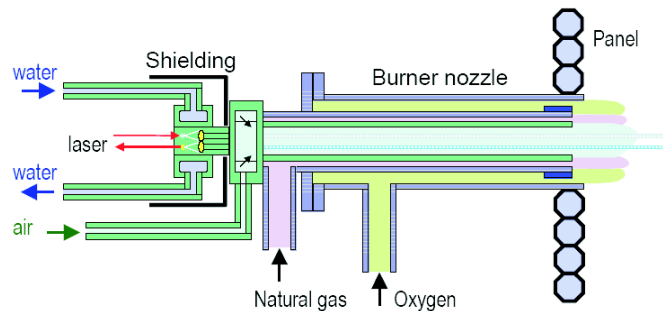

Fig. 3. Design of the new optical head mounted inside an annular burner

Optical signals to / from sensor head are transmitted by means of optical fibres to the electronics (laser emitter and detector), which can thus be installed in a safe location, away from the furnace shell.

For safety reasons, the laser beam is switched off automatically during furnace maintenance works.
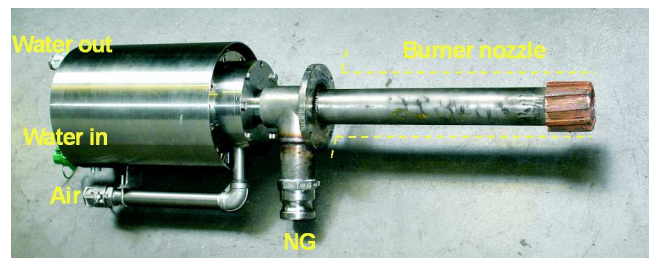

Fig. 4. Picture of the new optical head ready to be installed

Figure 4 shows a view of the sensor and the burner nozzle tube ready to be installed in the furnace. The mechanical protection, thermal shielding and cooling have

been carefully studied. a stainless steel cylinder fixed directly on the flange protect the aluminium body of the sensor from possible impact. The aim of the cooling of the optical head is only to cope with the possible presence of flames at the back of the burner in case of its malfunction, mainly due to blow-back phenomenon.

4. Industrial tests inside a burner at ArcelorMittal Esch-Belval

The first industrial tests were performed in the EAF plant of ArcelorMittal Esch-Belval. For those tests, the distance sensor has been installed in an annular burner located close to the hot spot area of the furnace. In this location, the scrap disappearance could be faster compared to the cold spot where scrap remain unmelted late in the process. Consequently, the burner may have to be stopped earlier in this vessel zone.

The first test campaign was carried-out continuously during three weeks, without any damage to the system.
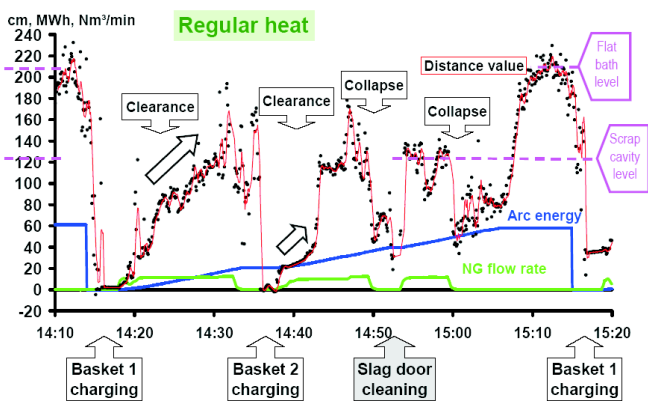
Fig. 5. Response of the distance sensor - example of one regular heat (ArcelorMittal Esch-Belval)

Figure 5 shows an example of recording during one regular heat. Electrical energy input and burner gas flow are given as reference. The distance is expressed in cm, relative to the burner tip. At furnace charging, scrap is present in front of the burner (low distance measured). As burner operates, the distance increases as a free cavity is formed in the scrap pile. This cavity may collapse during melting, as shown by some fast decreases in the measured value. On flat bath, the distance finally reaches a maximum at about 2m (distance between burner tip and liquid bath).

For some abnormal heats, the measured distance remains at a low constant value during the whole preheating process, thus showing that some scrap is unmelted in front of the burner. This behaviour allows anticipating burner damage due to blow-back phenomenon. In the example shown in Fig. 6, the burner mantel has quickly

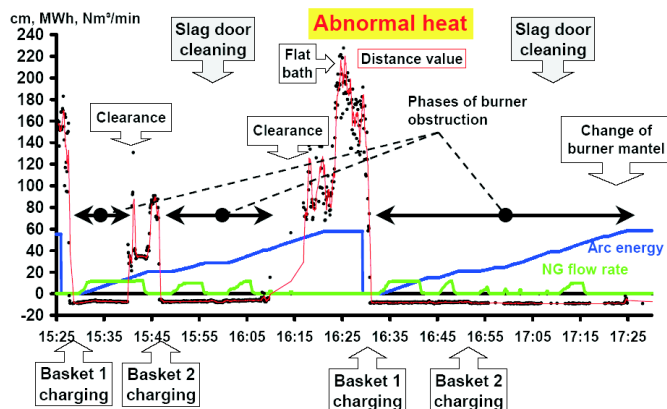damaged by the blown-back flame, and has to be replaced.

Fig. 6. Response of the distance sensor - example of one abnormal heat (ArcelorMittal Esch-Belval)

A supplementary industrial test has been carried out in the ArcelorMittal Esch-Belval plant. The aims of this test were to enhance the industrial character of the sensor and to confirm blow-back detection by an independent measurement.

The Esch-Belval plant uses burner holding tiles, which are highly sensitive to overheating and equipped with thermocouples on the water supply ducts. The temperature variation is thus measurable and can be related to a blow-back occurring on the panel. This measurement has a long response time but can be compared to the distance information.

Figure 7 gives an example of a typical result during a heat. During this heat, a panel overheating occurred, at the beginning of the pre-heating of the first scrap basket.
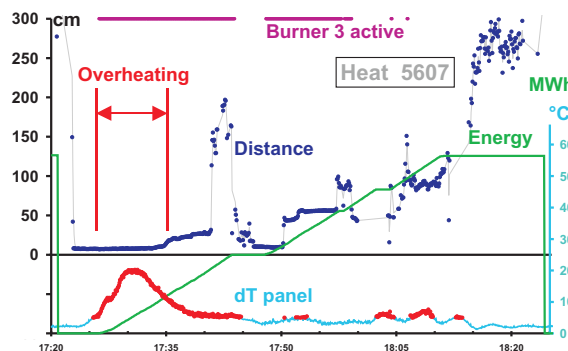
Fig. 7. Concluding test - example of panel overheating (ArcelorMittal Esch-Belval)

It can be clearly seen that when burner is operating and distance is low, a strong overheating of the burner tile is produced. Later, the temperature decreases as the distance starts to grow. a persistence of a low distance value must be interpreted as a blow-back tendency.

Compiling the whole measurement campaign, that represents more than 230 heats, all the distance measurement points have been plotted as a function of the temperature difference of the panel tile. Figure 8 shows the results of this exercise.
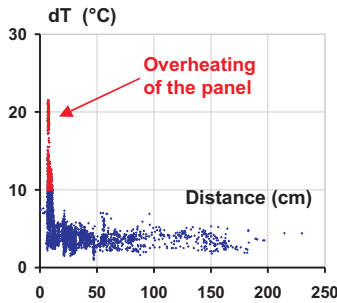

Fig. 8. Concluding test – panel temperature as a function of distance value (ArcelorMittal Esch-Belval)

A clear relationship appears, the following rules may be deduced:

- a low distance value leads to an overheating of the panel tile, a value of 10 cm seems typical of the phenomenon,
- high distance values (greater than 10 cm) induce a safe preheating process.

Development of this first sensor has been carried out in the frame of an RFCS project.

5. Application to oxygen lances and combined burners

Regarding those results, plant operators of both ArcelorMittal and Corus have asked for the full industrial implementation of the sensor, as well inside oxygen lances, as inside combined burners. This new development was made in the frame of an internal project.

This implementation required first further reducing the size of the measuring beam from 40 mm down to 20 mm in order to fit inside the nozzle throat of industrial oxygen lances. This called for a complete re-design of the optical head. Both laser paths overlay now each other, thanks to a deviating special mirror. Optical bench tests have been carried out in order to optimise the new configuration and to check its efficiency. Those laboratory measurements have proven that the same reflecting energy level can be guaranteed to the detector (see Fig. 9).

The additional goal of the new optical head design was to enhance the industrial character and to minimise the manufacturing cost. The new configuration uses standard optical components for cost reasons and allows some optical adjustments. Several technical improvements have also been provided: fast release connectors, self-cleaning of the window, no more cooling requirement, simplified mechanical junction to the lance, etc.

To connect the sensor, the oxygen lance has been modified to ensure a free sighting axis for the sensor and an efficient cleaning of the window, while guarantying the achievement of the oxygen flow rate value.

Those modifications resulted in the system presented in Fig. 10, the modified lance being connected to the new sensor.
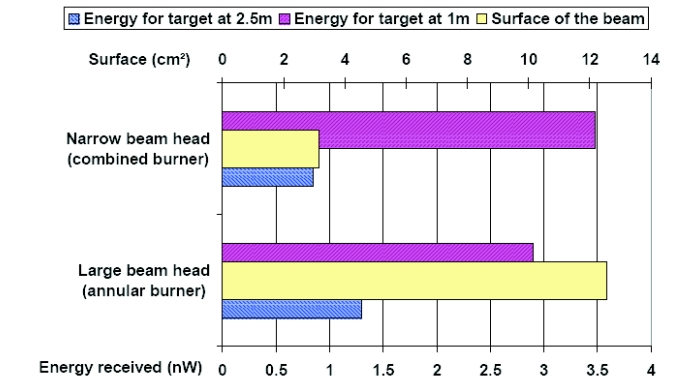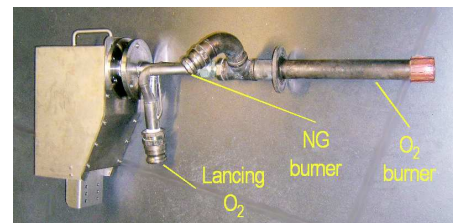

Fig. 9. Enhancement of the sensor design

Fig. 10. View of the lance distance sensor

6. Industrial tests inside a combined burner at ArcelorMittal Esch-Belval

The first tests of the system in a combined burner (oxygen lance in burner axis) have been carried out at ArcelorMittal Esch-Belval. The whole installed system can be seen on Fig. 11.
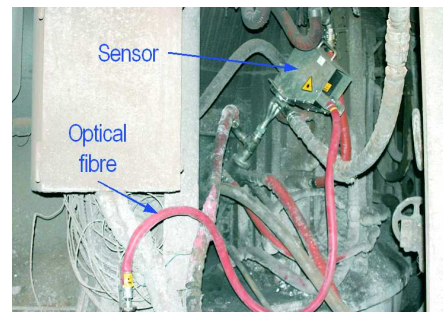

Fig. 11. Installation of the sensor on the back of the combined burner (ArcelorMittal Esch-Belval)

The sensor head is very compact with only one connection cable. The system can be easily removed (a simple flange closing the lance back aperture).
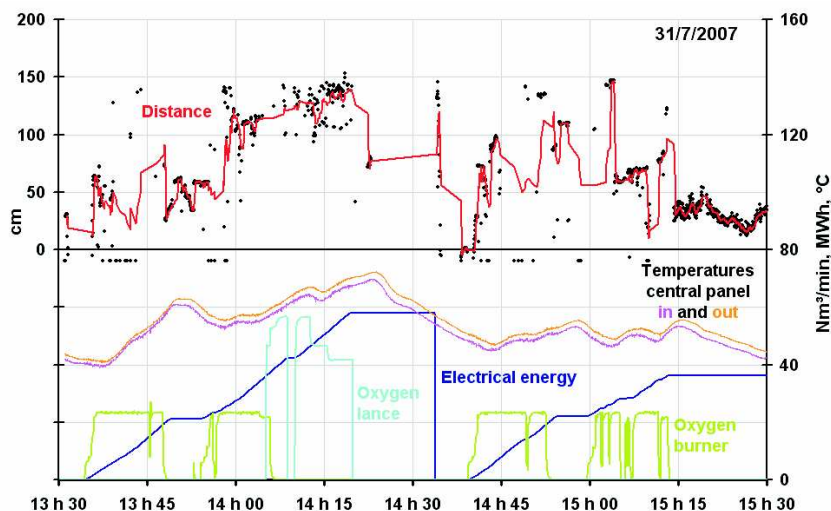
Fig. 12. Sensor signal and process values

The sensor operated two working days, providing correct measurements, especially during lancing operation as illustrated in Fig. 12.

During this first industrial campaign in a combined burner, no overheating of panels has been observed but the interesting result is the achievement of a valid measurement even during the oxygen-blowing phase when liquid metal is present.

Using the sensor signal, operators are thus able to follow the evolution of the scrap pile in front of the combined burner. This distance information can be used to control the two injectors and to aim at:

- optimisation of the burner pattern,
- switch from preheating mode to oxygen lancing when distance to scrap increases according to a pre-set value,
- set of oxygen lancing to high supersonic flow rate only when distance to scrap reaches a minimum pre-set value,
- in any case, warning if any sudden decrease of the recorded distance.

The next step (currently in progress) will be the use of optical switch boxes in order to have only one laser source and detector per furnace for controlling all burners and lances.

Automatic regulation (switching between operation modes / flow adjustments) is forecast in a final step.

7. Conclusions

CRM has developed an on-line "distance-to-scrap" measurement technique that can be fitted inside annular burners, combined burners or oxygen lances. This measurement allows monitoring the melting of scrap in front of each injector, and thus optimising its operation and detecting blow-back occurrences before any damage is created. Those sensors were successfully tested in the ArcelorMittal Esch-Belval steel. The comparison made with the panel overheating proves their ability to predict blow-back proclivity.

CRM is now preparing the full industrial application, including switch boxes and automatic regulation.

REFERENCES

[1] "Production of steels at lower operating cost in EAF", Final Report to ECSC contract 7210-PR-075, Report EUR 20895 EN, (2003).
[2] P. N y s s e n, C. M a t h y, J. L. J u n q u é, N. P é t r é, J. C. B a u m e r t, J. H o f f m a n n, Innovative Visualisation Technique at the Electric Arc Furnace, Proceedings, 8th European Electric Steelmaking Conference, Birmingham, p. 165-172 (2005).