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UTILISATION OF NOISE LEVEL EMITTED BY THE ELECTRIC ARC FURNACE (EAF) FOR OPTIMISATION OF THE FEEDING PROCESS OF SLAG FOAMING MATERIALS

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The present paper reveals methodology of a research and the results of noise level measurements with respect to fluctuations of active power during EAF operation in one of the melt shops in Poland. In the current stage of experiment, the authors focused themselves on finding the optimum moment to start feeding of foaming material with the aim to obtain the most efficient slag foaming with the fastest coverage of electric arcs at the lowest losses of foaming material. Achieved results indicate that relation between the level of emitted noise and fluctuations of active power during melting can be utilised to define the moment to start feeding of slag foaming materials into the furnace.

Key words: steel, electric arc furnace, EAF active power, EAF noise emission, Poland

INTRODUCTION

Implementation of a ladle furnace into the melt shop has changed the steelmaking process completely. Today, the main role for the Electric Arc Furnace (EAF) is to melt scrap, remove carbon and other undesired elements from the liquid bath and superheating of steel to the temperature allowing for safe tapping, followed by addition of alloying and slag making materials. Before any heat, steel scrap is loaded into the charging baskets. Depending on the actual scrap density, the furnace is usually charged with two or three baskets per heat. Further refining of liquid steel takes place in a ladle furnace [1- 4].

Virtually all large steel mills in Europe using electric arc furnaces (EAF) for scrap melting, operate with foaming slag practice. This technology improves the thermal efficiency of the electric arcs and reduces active power fluctuations, leading to a decrease of the melting process duration. In order to take full advantage of the benefits of this technology, it is necessary to create a situation in which feeding of fine coal (foaming agent) into the liquid bath will ensure the fastest possible and complete covering of the electric arcs for the longest possible time.

It is necessary to find parameter, allowing to initiate the process of feeding slag foaming material at the most appropriate moment.

In this aspect, German researchers [5-8] conducted a research to find relationship between the level of noise emitted by the furnace, vibration of the furnace shell and FFT current analysis as well as the degree of slag foaming and other phenomena occurring in the furnace space. The aim of these studies was not only to improve the economic performance of steelworks, but also to increase the degree of automation of the metallurgical process. Such tests were carried out, among others, on furnace no. 1 in the melt shop of Lech Stahlwerke GmbH. A control algorithm for injection of slag foaming agent into the furnace was developed, which allowed to reduce the furnace power on time by 3,5 minutes. On the basis of these studies, systems for slag foaming quality control were developed [9].

Similar tests were also carried out in La Louviere steel plant in Belgium [10] on 100 t DC furnace operating with active power of 70 MW, where the only measured value was the noise level emitted by the furnace. Over 1 000 heats were made there, during which the slag foaming quality was evaluated by operators. This quality has been classified into four categories: no slag, presence of a thin layer of slag, presence of an emulsified amount of slag (arc almost covered), a large amount of foaming slag. The mean value of the noise level was determined for each of the categories. The nitrogen content in the liquid steel achieved immediately before tapping was adopted as a parameter allowing the verification of the slag foaming quality. It has been shown that with a graphically presented (on a computer monitor) measurement of the noise level in real time and assigning it to the appropriate position of the slag foaming quality, it was possible to reduce the nitrogen content in the liquid steel before tapping by about 20 ppm.

The authors of this paper also decided to assess the possibility of using the noise level emitted by the EAF

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and the fluctuations in active power consumption to determine the optimum moment to start feeding the slag foaming material to the working volume of the furnace.

The research described in this article was conducted for the purposes:

1 Evaluation the noise level of the furnace with which the slag foaming material needs to be fed.
2 Determination of the noise level emitted by the furnace reflecting the moment of complete melting of the scrap in the furnace. Measurements of noise levels and EAF active power were made in one of the Polish electric steelmaking shops plants. The obtained test results are presented on the figures showing the relationship between the noise emitted by the electric furnace and the active power consumption.

MEASURING INSTALLATION AND METHODOLOGY OF THE CONDUCTED RESEARCH

The tests were carried out during the operation of the EAF electric furnace (UHP type) with a capacity of 70 t, equipped with four oxygen-gas burners, of which three can also operate in the supersonic oxygen lance mode. The slag foaming material feeding lances are located under the oxygen-gas burners in the cold zones of the furnace. During melting, three baskets with scrap were charged into the furnace.

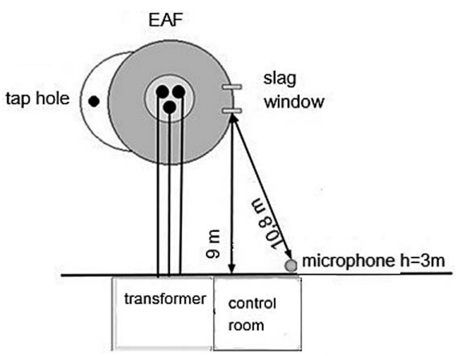

Figure 1 Location of the measuring microphone with regard to the furnace position.

The noise level measurements were made during three heats of the same steel grade (S235JR). The scrap structure of the charge of each of the melts consisted of the following types of scrap: light scrap 52 %, medium scrap 17 %, heavy scrap 31 %. The noise level measurements were made using the SVAN948 sound level meter by Svantek with the SV12L preamplifier and the SV22 microphone (Figure 1). The measurement results recorded in the measuring device memory were processed with the SvanPC ++ software.

The apparatus was calibrated before and after each measurement using an acoustic calibrator type 4231 manufactured by Bruel & Kjaer.

RESULTS AND DISCUSSION

The test results are presented in the graphic form on Figures 2 and 3. The tests described below were carried out with the furnace operating during three heats.

1 Determination of the Noise Level Emitted By the Furnace Indicating Complete Melting of the Scrap.

During the first heat, the noise level at which stabilization of the electric arcs takes place without feeding the slag foaming material into the furnace was determined. The analysis of the recorded noise level and active power consumption values presented in Figure 2 shows that even without feeding the foaming agent into the furnace, the electric arcs become stable and the fluctuations in active power consumption are reduced after reaching a certain noise level (in that case it was the value of 104 dB). This value was taken as the value indicating the complete melting of the scrap (with no scrap found on the furnace walls).

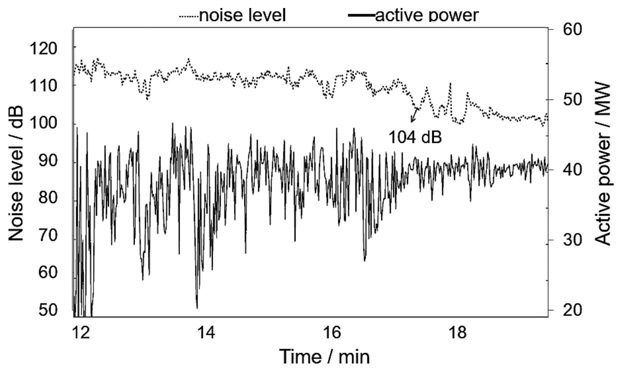

Figure 2 Noise level and active power consumption without feeding foaming agent in function of the heat No.1 duration

2 Determination of the Noise Level Emitted By the Furnace at which the foaming agent should be fed.

The present tests were carried out in the manual mode of feeding the slag foaming agent into the furnace during the heat No. 2.

The feeding of the slag foaming material used to be started only when the power consumption fluctuations

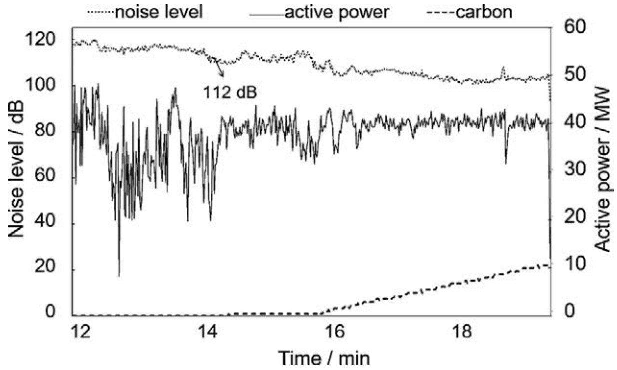

Figure 3 Noise level and power consumption in the initial phase of slag foaming material feeding as a function of the heat No.2 duration

were decreasing in the moment when the furnace operation of the furnace was getting stable as a result of scrap melting. This made it possible to indicate a specific noise level value at which the feeding of slag foaming agent should be started. It is the value of 112 dB, which was determined by the researchers on the basis of the obtained measurement results and observation of the phenomena occurring in the furnace, e.g. degree of scrap melting (with very little scrap quantity attached to the furnace walls with practically no further movement down the furnace). This is graphically presented on the Figure 3.

VERIFICATION OF THE OBTAINED TEST RESULTS

In order to confirm the reliability of the obtained noise level values, they were verified on the basis of standard industrial heat carried out in automatic control mode (Heat No.3) and a statistical analysis was performed. The achieved consumption and melting time are in the range of average values achieved in the melt shop.

Based on the obtained data, a graph presented on the Figure 4 was constructed showing changes in the noise level, active power consumption and carbon level.

Then, a time period (from approx. 37 minutes to approx. 50 minutes) to be analysed in further statistical analysis was selected. The smoothing of the time series of the noise level and the active power level was carried out using the moving average method.

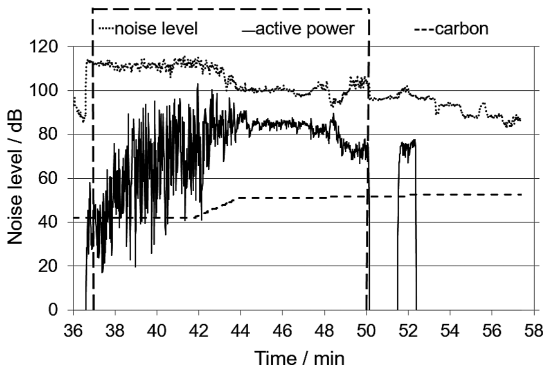

Figure 4 Graph showing changes in the noise level, active power consumption and carbon addition level in function of the heat No. 3 duration

After a detailed analysis of the obtained data, the value equal to 30 was adopted as the smoothing constant k, what in practice meant the estimation of successive values of these variables for 30 values of empirical variables. On the other hand, Figure5 shows the graph of the smoothed time series of the active power level. Additionally, in the case of analysing the statistical variability of the active power level, the coefficient of variation Vz was determined, as being the quotient of the standard deviation to the mean of the next thirty empirical values of this variable.

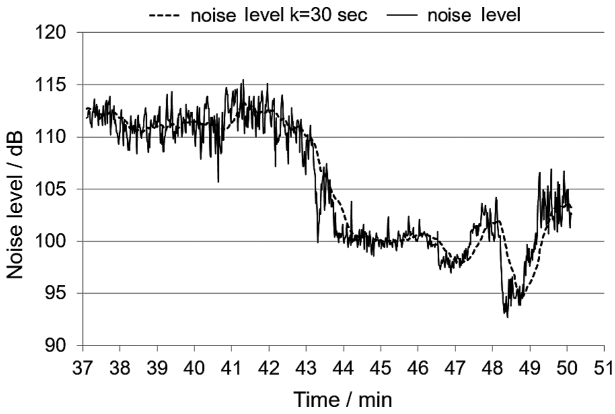

Figure 5 Smoothed time series of the noise level using the moving average method for the smoothing constant k = 30, as a function of the duration of the heat No. 3

The graph showing the coefficient of variation clearly indicates status of stabilization (with low variability and low amplitude of the level variation), starting at 44 minute of the heat, i.e. at the moment when very intense slag foaming took place.

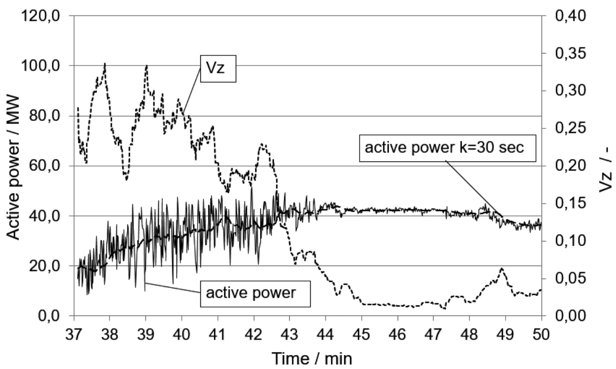

Figure 6 The smoothed active power level by the moving average method for the smoothing constant k = 30 along with the time series of the variation coefficient Vz

In the final stage of the statistical analysis, the mutual correlation between the smoothed average values of the noise level and the corresponding average smoothed values of the active power level was assessed. In all analysed cases, the regression and correlation analysis based on the linear Pearson model allowed to conclude that the correlation coefficient ranges from -0,6911 to -0,9143, which proves a high negative correlation between the examined variables. This was also confirmed by the results of statistical verification of the regression coefficients ($p < 0,0001$ in each case)-Figure 6.

SUMMARY AND CONCLUSIONS

The necessity to reduce costs in steel mills forces the search for new methods of optimizing the operation of the electric arc furnace. In order to optimize this process, the proper moment to start feeding of the slag foaming agent should be selected. In order to define the optimum moment to start feeding of the foaming material, the authors of the present paper utilized the level of noise emitted by the electric arcs and the fluctuations in the active power consumption.

Measurements were recorded with the use of equipment specially designed for testing, involving sound level meter, a pre-amplifier and a microphone. The obtained results were then correlated with the selected parameters of the furnace operation and the phenomena occurring in the furnace. Then, attempts were made to find out the relationships between changes in the noise level and the parameters of the furnace operation.

Based on the tests results and performed measurements, it was found that:

- the beginning of feeding the slag foaming material to the furnace described in the paper should start at a noise level of 112 dB,
- a decrease in the noise level to 104 dB, achieved without feeding the slag foaming material indicates the moment when practically all the scrap is melted,
- the research shows that there is a clear correlation between the way of feeding the slag foaming agent and the level of noise emitted by the active electric arcs in the furnace and the fluctuations in active power consumption and this occurrence can be used to determine the start and end times of feeding slag foaming material into the furnace,
- on the basis of the obtained results of their statistical evaluation, it can be clearly stated that there is a significant negative correlation between the active power and the noise levels, what means that in case noise level drop below a certain threshold, the active power level increases significantly and becomes stable (with low amplitude of changes).

Acknowledgements

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Note: The responsible for English language is Adam Partyka.