10th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

MATLAB-SIMULINK SIMULATION OF SLAG FOAMING CONDITIONS IN EAF PRACTICE

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ABSTRACT
The slag foaming practice in EAF process is very important. For a good slag foaming special conditions are necessary. Simulation with MatLab-Simulink program of slag foaming conditions and slag foam index are made and presented in this paper. It will be shown that in the case of slags with low iron oxide contents slag basicity strongly influences on foam index; increasing the slag basicities decrease foam index. Basicity of slag with high iron oxide contents has no affect on foam index.
Key words: slag foaming, MatLab-Simulink, foam index

1. INTRODUCTION

EAF process has been continuously improving for the last 30 years and has achieved spectacular performances in terms of productivity and electricity specific consumption. A general trend observed worldwide is an increase in oxygen and carbon injections [1].

The application of the foaming-slag practice to steel manufacture at the electric-arc furnace (EAF) brings benefits in terms of lower electric energy, electrode and refractory consumption etc. Control of slag foaming is very important in EAF process, because a large quantity of gas is evolved and the volume of the slag expands due to effect of foaming. The problems of efficient generation of foaming slag include chemical and physical conditions and control of foaming intensity.

MATLAB Simulink program

The MATLAB program provides a high-level programming language, an interactive technical computing environment, and functions for: algorithm development, data analysis and visualization as well as numeric computation. The Simulink product family is an extensible block diagram environment for simulation and model-based design. Its graphical tools enable: requirements capture and specification, design, implementation, test and verification.

The video and image processing blockset includes algorithms for designing and supports floating- and fixed-point data types for modeling, simulation, and C-code generation. It provides analysis and statistical functions to enable rapid optimization and debugging of models and its functions include video displays, scopes, and other techniques for visualizing image and video data and validating simulation results, Figure 1 [2].

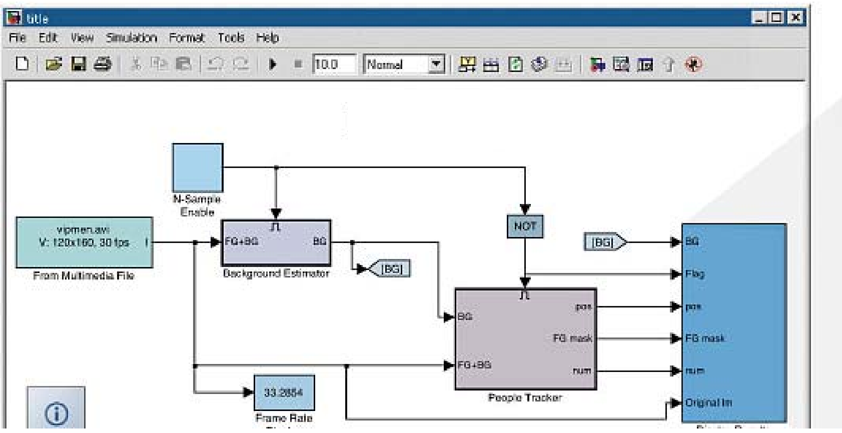

Figure 1: The video and image processing blockset – Matlab Simulink program [2]

2. MATLAB-SIMULINK SIMULATION OF SLAG FOAMING

Slag foaming is caused primarily by the generation of bubbles of carbon monoxide gas within the slag. In an electric arc furnace, slag foaming is caused by the deliberate introduction and combustion of large coke particles into the slag and is vital to modern EAF operations, as the foaming slag buries the arcs, shielding the walls and roof of the furnace from the radiant heat of the arcs and, as a result of this and of long-arc operation, transferring more of the arc's heat to the bath, making the furnace more efficient.

Due to the importance of slag foaming, foam index was developed, as a correlation among the foam index and viscosity, surface tension, density of slag and bubble diameter [3]:

$$\Sigma = \frac{\mu^{1.2}}{\rho + Db^{0.9} + \sigma^{0.2}} \qquad (1)$$

∑-foam index (s),
μ-viscosity (Ns/m^2),
ρ- density (kg/m^3),
σ- Surface tension, (N/m),
Db - bubble diameter (m).

The foam index has the unit of the time and the measurement of foamability of slag. This index can be interpreted as the average traveling time of gas in the foamed slag. In this case the foam index ∑ is defined as the ratio of the foam height h to the superficial gas velocity Vco:

$$\Sigma = h / Vco \qquad (2)$$

A mathematical simulation for a slag containing the differently chemical compositions and the basicities were done with MatLab-Simulink program. A Simulation-model has been developed to describe the effect of foaming slag and to predict the foaming height considering the effect of slag composition, oxygen and carbon injection, temperature and the other characteristic important for the calculation of the foam index and the superficial gas velocity [4].

Figure 2 shows the simplified schema of MatLab-Simulink program to predict the foaming height.

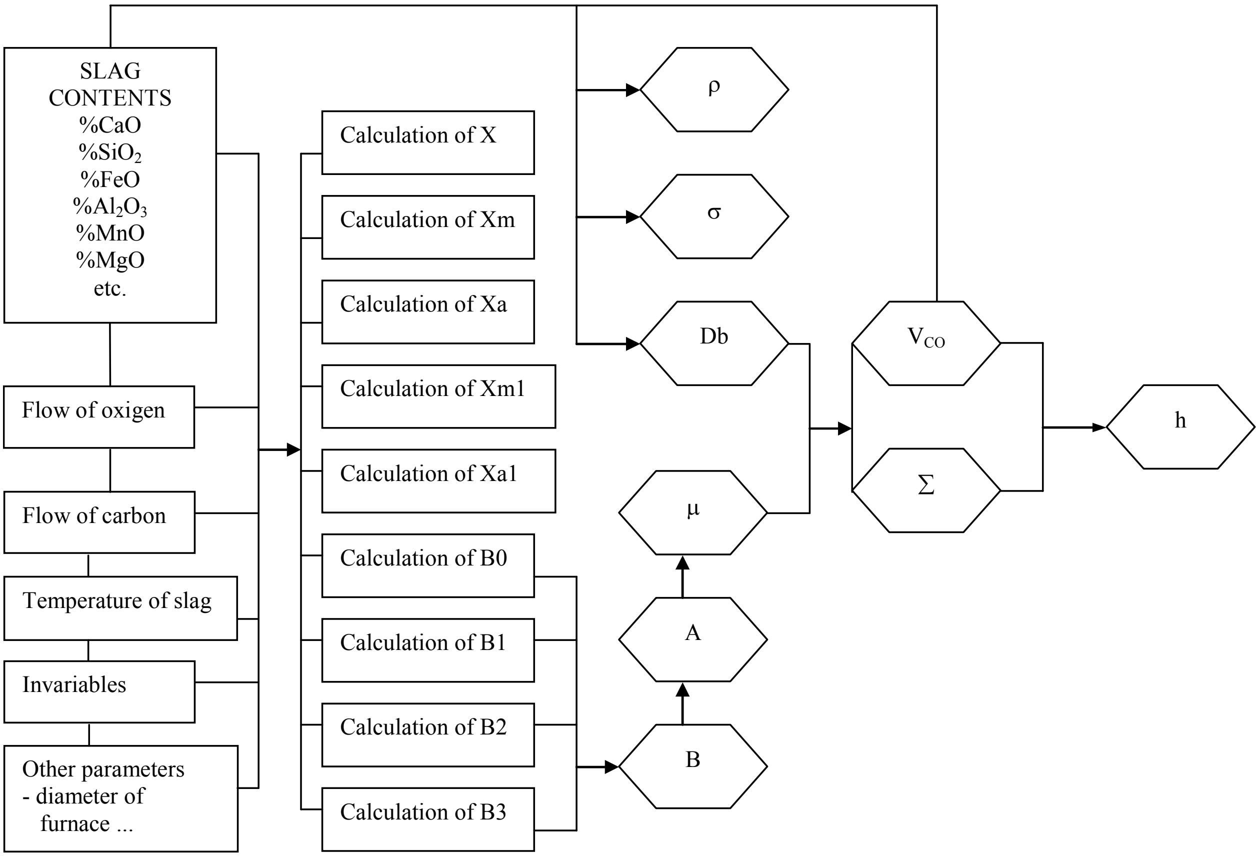

Figure 2: Schema of MatLab-Simulink program to predict the slag foaming height [4].

The program simulates the changes in the foam slag and the foaming height during the refining stage of the EAF process for the specified process conditions – that means for specified oxygen and carbon injection parameters as well as temperatures.

3. RESULTS

The Simulation can determine the change in foaming properties over the changes in slag composition and allows the evaluation of specific changes to the process which can influence foaming behavior.

The simulation quantifies the change in the slag foaming as the foam index with consideration of FeO content in slag and temperature; basicity of slag is included. The simulation was run for a slag with basicity of 1.5 for two temperatures. Examples of the results reported graphically. Figure 3 illustrates the influence of temperature and FeO content on the foam index of slag with basicity of 1.5. Generally decreasing temperature favor the increase of the foam index, because the temperature coefficient for surface tension is positive and that for viscosity is negative [5].

The foam index and the volume of slag increases dependently of slag basicity. In order to explain the effect of slag basicity and compositions on foaming process, slag foaming was studied for CaO-SiO_2-FeO- slags in the basicity ranging of 1, 1.5 and 2. The effect of basicity on the foam index dominates relative to iron oxide content, Figure 4. Foam index decreases with increasing FeO up to about 20% FeO content. In the case when the basicity is lower than is the carbon-gas reaction faster and strongly increases the foam index. The slag with high iron oxide contents up to 20%FeO the effect of basicity has no effect on foam index.

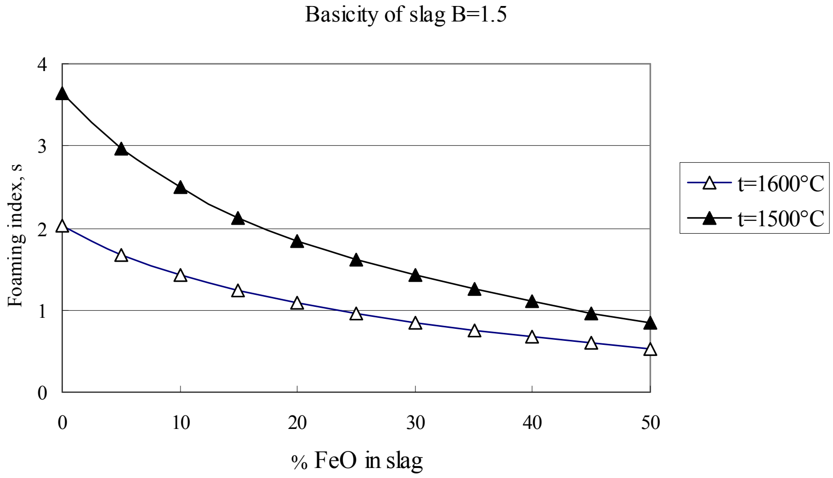

Figure 3: The foam index of the slag as a function of temperature

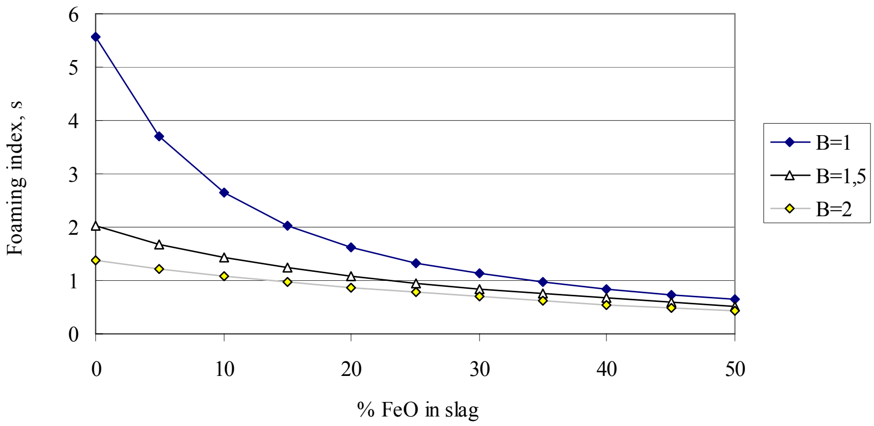

Figure 4: The foam index of the slag as a function of basicity and %FeO in slag, t=1600°C

4. CONCLUSIONS

As more and more oxygen and carbon are injected in EAF; control of these inputs as well as the control of slag foaming is becoming a critical target for most EAF in order to improve their global efficiency. A mathematical model to predict the foaming heigh considering the effects of bubble size, viscosity, slag basicity, surface tension was developed. Simulation with MatLab-Simulink program of slag foaming shown that the effect of foaming strongly dependent on the slag chemistry. In the case of slags with low iron oxide contents slag basicity strongly influences on foam index; increasing the slag basicities decrease foam index. Basicity of slag with high iron oxide contents up to 20%FeO content has no effect on foam index.

5. REFERENCES

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