

# EAF Management Optimization

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**Abstract.** The article presents the main advantages of electric arc furnace (EAF): it has a great contribution to reintroduce significant quantities of reusable metallic materials in the economic circuit, it constitutes itself as an important part in the Primary Materials and Energy Recovery (PMER), good productivity, good quality / price ratio, the possibility of developing a wide variety of classes and types of steels, including special steels and high alloy. In this paper it is presented some important developments of electric arc furnace: vacuum electric arc furnace, artificial intelligence expert systems for pollution control Steelworks. Another important aspect presented in the article is an original block diagram for optimization the EAF management system. This scheme is based on the original objective function (criterion function) represented by the price / quality ratio. The article presents an original block diagram for optimization the control system of the EAF. For designing this concept of EAF management system, many principles were used.

## 1. Introduction

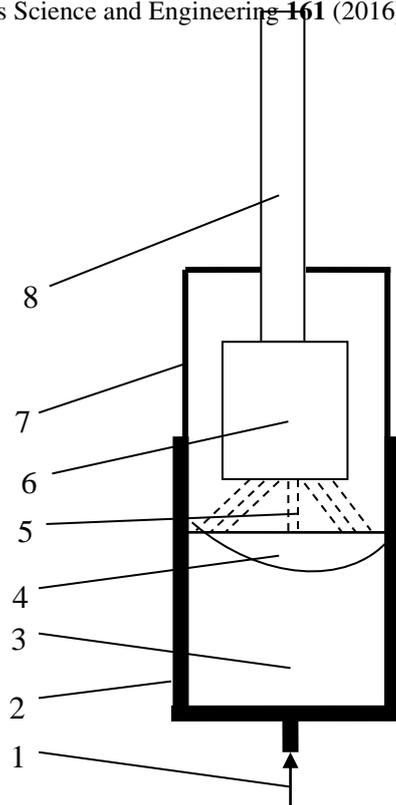
Electric Arc Furnace (EAF) is a complex and effective aggregate used in steels elaboration. The importance of this aggregate is the fact that it uses waste materials as base metal load. For this reason, EAF has a great contribution to the reintroduction of significant quantities of reusable metallic materials in the economic circuit.

EAF is considered an important part in the Primary Materials and Energy Recovery (PMER).

Other advantages of steel in EAF development are: good productivity, good quality / price ratio, the possibility of developing a variety of classes and types of steels, including special steels and high alloy.

As [1] „Steelmaking processes generate fume that must be captured and controlled to prevent emissions to atmosphere. This is done with large extraction fans and bag filter cleaning systems. The operation of these systems is critical to ensure good environmental performance of the steelmaking process and optimization is necessary to ensure that the fume extraction systems are run economically.”According to the National Strategy for Sustainable Development of Romania (SNDDR) the development of Romanian steel industry, with its primary segment, sets the product development rolled steels , as a main priority [3]. An important development of the electric arc furnace is represented by the EAF vacuum solution of this complex operation unit. In figure 1 such a variant is presented – Vacuum Arc Remelting (VAR), [2].

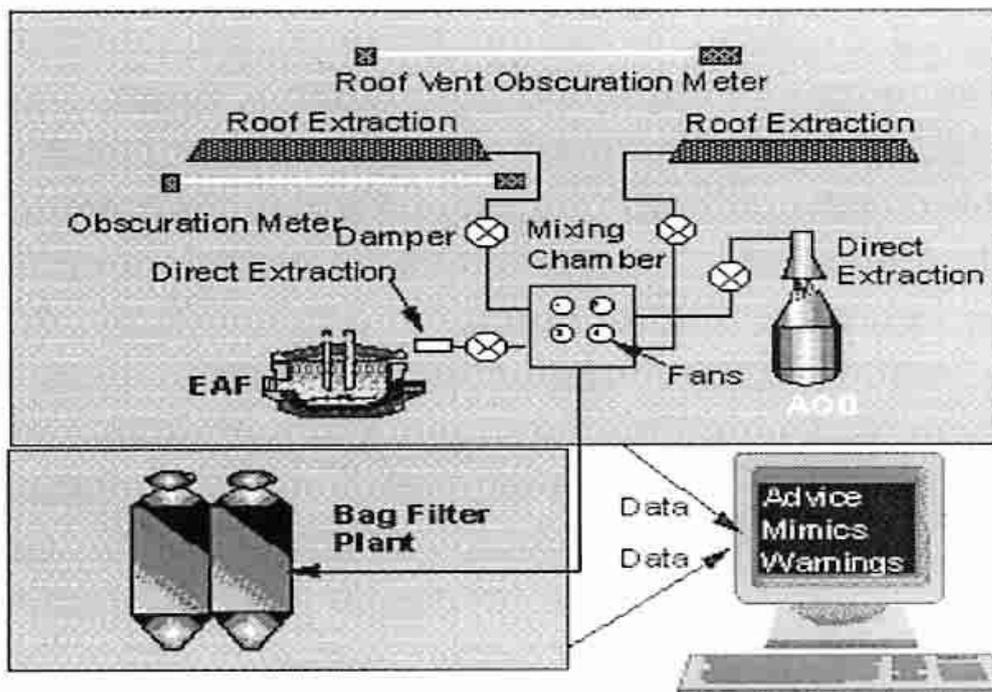




**Figure 1.** Vacuum Arc Remelting (VAR) Scheme

- 1 – Cooling water; 2 – Mold ingot; 3 – Ingot; 4 – Liquid metal; 5 – Electric arc; 6 – Electrode;
- 7 – Vacuum chamber; 8 – Driving rod electrode

Another development of the electric arc furnace is the artificial intelligence expert systems for steelworks pollution control (Brimacombe, Jackson and Schofield, 2001). Figure 2 presents the scheme of expert system.



**Figure 2.** Scheme of expert system of model for a EAF fume extraction (after [1])

## 2. Elements of EAF management optimization

In figure 3 it is presented an original block diagram for optimization the control system of the EAF [3, 4, 5].

For designing this concept of EAF management system, the following principles were used [6, 7]:

A. The principle of analogy - requires competent observation and analysis of the modelled reality using both analogy with other areas of research and logical homology.

According to this principle, for developing mathematical models, the following stages were taken:

- defining the modelled objective – this is the primary stage of the modelling analysis; This stage must satisfy both the aim and objectives of the system while ensuring their compatibility;
- defining criteria for efficiency - it is a step conditioned by the correct setting of the objectives of the system and it allows the optimization of modelling solutions;
- developing options - based on accessing realistic, effective and original solutions;
- evaluating alternatives – according to the criteria of efficiency previously set;
- determining the final solution - based on comparative analysis of different solutions to which modelling has led.

B. The Concepts Principle - is based on systems theory concepts including the concept of feed - back.

C. The Principle of Hierarchy - implies the need for designing a hierarchical models system, in order to structure decision and coordinate interactive subsystems.

D. The Uncertainty Principle - is generated mainly by the high complexity of the processes related to CAE. In addition, the existence of interaction between subsystems components - interaction that cannot always be exactly predetermined - and nonlinearities in the system, the subjectivity of choice and prescribing the objective function contributes to increasing uncertainty factors.

It is useful to note that, based on this modelling principle, as system complexity increases, requiring a hierarchical structure, the precision of developed models decreases but the degree of relevance increases.

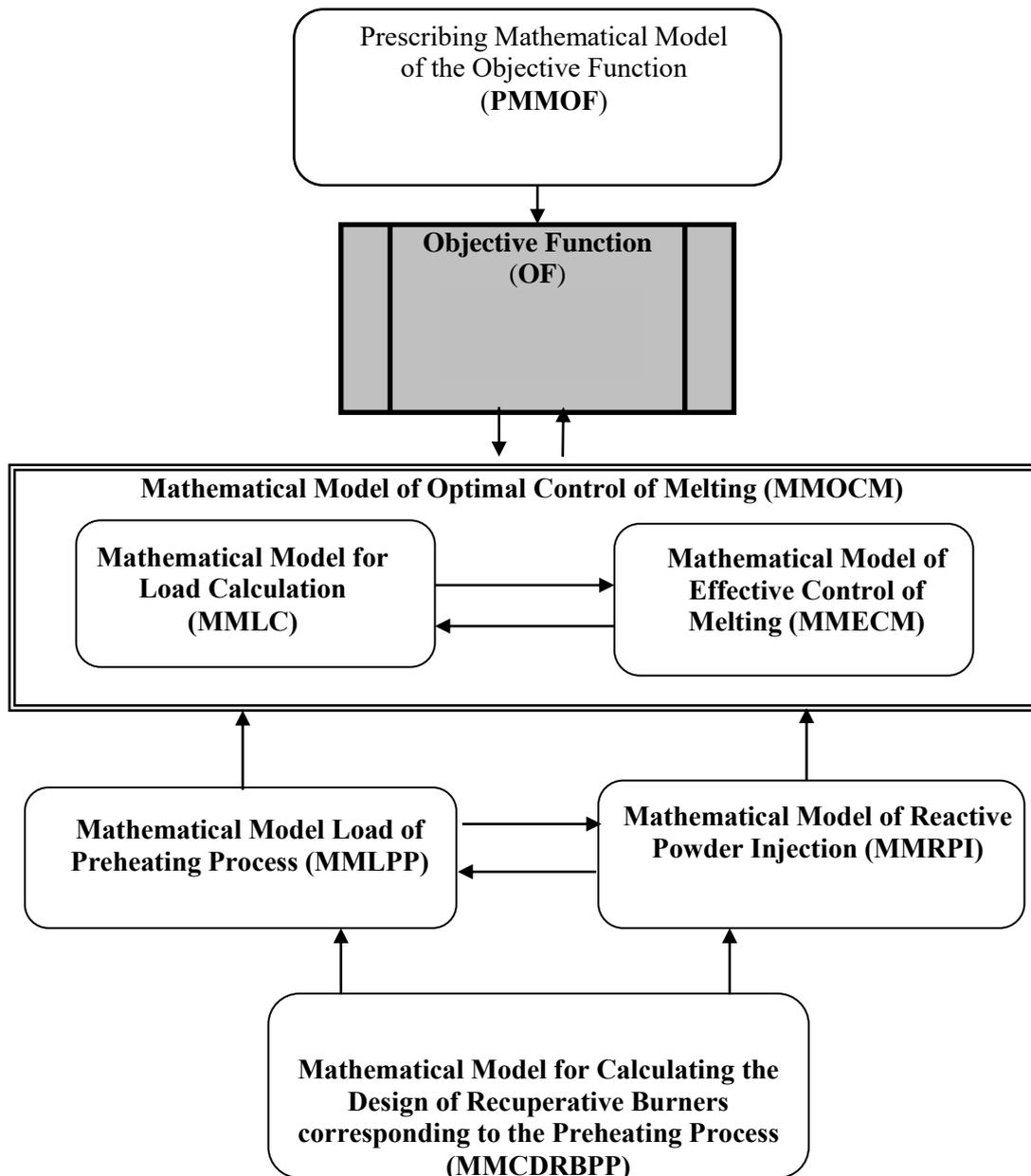
E. The Internal Model Principle - establishes that a dynamic system is structured in a stable way only if:

- it uses negative reaction of controlled sizes;
- it incorporates into a feedback loop a reduplicate model of the dynamic structure of exogenous signals; this internal model provides the signals meant to compensate asymptotically the disturbances of the considered CAE system.

The Modeling System designed for EAF processes consists of six subsystems represented by the following mathematical models:

- the Prescribing Mathematical Model of the Objective Function (PMMOF);
- the Mathematical Model for Load Calculation (MMLC.);
- the Mathematical Model of Effective Control of Melting (MMECM);
- the Mathematical Model Load of Preheating Process (MMLPP.);
- the Mathematical Model of Reactive Powder Injection (MMRPI);
- the Mathematical Model for Calculating the Design of Recuperative Burners corresponding to the Preheating Process (MMCDRBP).

Below it is presented the stages and computational algorithms related to the main models, as well as the modeling results including the validation experiments of the designed model.



**Figure 3.** The Block diagram of optimization the control system of the electric arc furnace

### 3. Mathematical model of establishment (prescription) of objective function (MMOFE)

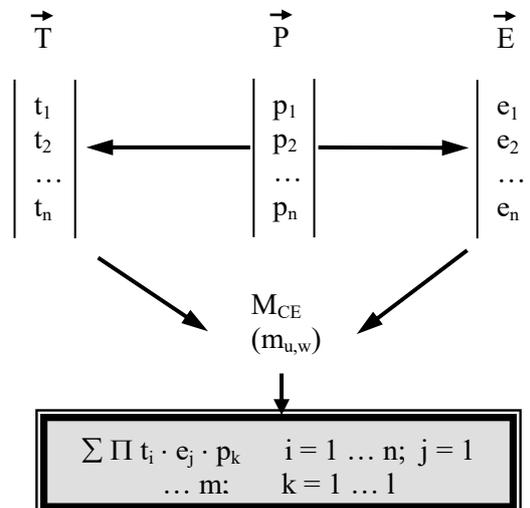
The Prescribing (establishing) of the objective function (OF) of modelling system related to EAF processes is based on a qualitative - economic analysis of these processes. In this respect, the developing of a new product (in this case a mark of quality steel) must equally provide both profitability and the ability to ensure quality conditions.

The Prescribing Mathematical Model design of objective function is based on quantification of the Objective Function (OF) as a qualitative - economic matrix  $M_{QE}$ , as in the diagram shown in Fig. 4.

The levels of prescribing the Objective Function are obtained by applying an algorithm relating three vectors:

- vector  $\bar{T}$  – the technical parameters vector ( $t_i$ );

- vector  $\vec{E}$  – the economic parameters vector ( $e_j$ );
- vector  $\vec{P}$  – the shares vector ( $p_k$ ).



**Figure 4.** The quantification of the objective function of the modeling system

The components of the two vectors  $\vec{T}$  and  $\vec{E}$  considered with significant shares in the quantification (prescription) of the objective function OF are:

- t1 - chemical composition of steel (precision fit trademark);
- t2 - steel purity (in gas);
- t3 - steel purity (the inclusions);
- e1 - the specific consumption of raw materials;
- e2 - the specific energy consumption;
- e3 - melting productivity of EAF.

The assignment of the values to the two vectors was made on a relative scale having as reference an Optimal Level (OL), as follows:

- OL = value 10
- OL  $\pm$  10 % = value 9
- OL  $\pm$  20% = value 8
- OL  $\pm$  30% = value 7
- OL  $\pm$  100% = value 0

The Optimal Level (OL) for each component of the two vectors is:

- for t1 – the arithmetic mean of the prescribed limits of variation of the steel composition mark;
- for t2 - the prescribed minimum gas content;
- for t3 - the prescribed minimum content of inclusions;
- for e1 - specific minimum standards consumption of raw materials;
- for e2 - the specific prescribed minimum consumption of energy;
- for e3 - the normal maximum productivity of the steel elaboration process.

#### 4. Conclusions

The electric arc furnace for steel elaboration is a complex and special utility aggregate. Therefore to optimize its control is of great importance.

The constructive and functional upgrades "suffered" by the electric arc furnace over time, objectively argues the importance of this complex aggregate. Among the upgrades, one can mention: the vacuum electric arc furnace, the DC electric arc furnace.

The original optimization scheme of EAF control is based on more specific correlations and mathematical models. We mention the main ones: the Prescribing Mathematical Model of the Objective Function (PMMOF); The Mathematical Model for Load Calculating (MMLC.); The Mathematical Model of Effective Control of Melting (MMECM); The Mathematical Model Load Preheating Process (MMLPP.), linked by dual correlation between them.

The objective function of the Modelling System (Control) is the price / quality ratio. The purpose of the component models of the control system is to maximize this ratio.

## References

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