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Some Aspects about Product Management of Electric Arc Furnace Elements

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Abstract. The methodology of establishing an Electric Arc Furnace (EAF) and technological plant's best management strategy is based on the "technological process – technological plant" interdependences. The paper presents the best management of a plant and consists of an assembly of operations, measures and decisions, established and applied in order to make the technological process more efficient from the technical – economical point of view. We present constructive and functional description of an Electric Arc Furnace such as: refractory masonry; metallic construction; electric installation. We also present the best management of a plant consisting of an assembly of operations, measures and decisions, established and applied in order to make the technological process more efficient from the technical–economical point of view, Electric Arc Furnace management included.

Introduction

The best management of Electric Arc Furnace (EAF) and plant consists of an assembly of operations, measures and decisions, established and applied in order to make the technological process more efficient from the technical–economical point of view [1].

To do this, the best management is a problem (technical, in this case) to study the operation that has a result that, compared to other possible outcomes, is the best, the most effective result and the one the technical-economical decision is based on.

EAF means "the bridge pass" of the electrical power (electricity), electrode between the end of the EAF and metal load of the EAF [2].

Generating, developing and maintaining electric arc to EAF depend on the phenomena and processes that take place both at the interface electrode - metal load, as well as in the space between them.

Electric arc generation is produced from the tip of the electrode CAE, where the power is concentrated in an area of very small ($\Phi = 10^{-3}$ mm). In this area the density of the current reaches high values (10^8 A/m^2) and by default form the point cathode ray tubes, due to very large electrons concentrations form the point cathode ray tubes [3].

It should be noted that punctual cathode ray tubes has a great mobility, and this happens due to the temperatures developed in this area (10^4 ^{0}C).

The generators of the arcing, the high concentration of very high temperature electrons, makes it possible that under the action of a potential difference (voltage), the emission of electrons from the metal cargo EAF electrodes, thus primes, the electrical arc. The speed of electron flow generation (v) related to arcing of the EAF is given by the Eq. 1:

$$v = \sqrt{\frac{2\cdot e\cdot U_a}{m_e}} = 5.9\cdot 10^7\cdot\sqrt{U_a} \qquad [\text{m/s}] \qquad (1)$$

where:
e – electrical charge (1.602 x 10 $^{-19}$ As);
m_e – the mass of the electron (0.9107 x 10 $^{-27}$ g);
U_a – is the voltage arcing (V).

The transformation of electrical energy into heat occurs in the largest unit of the electric arc, where the temperature overcomes by far 2500°C. Combustion heat transmission from the electric arc furnace cargo is done by conduction and radiation.

Constructive and Functional Description of EAF

The main component parts of the electric arc furnace with direct action are [3,4]:
- refractory masonry;
- metallic construction;
- electric installation.

In Fig. 1 we show the refractory masonry of an electric arc furnace of 20t capacity [1, 3].

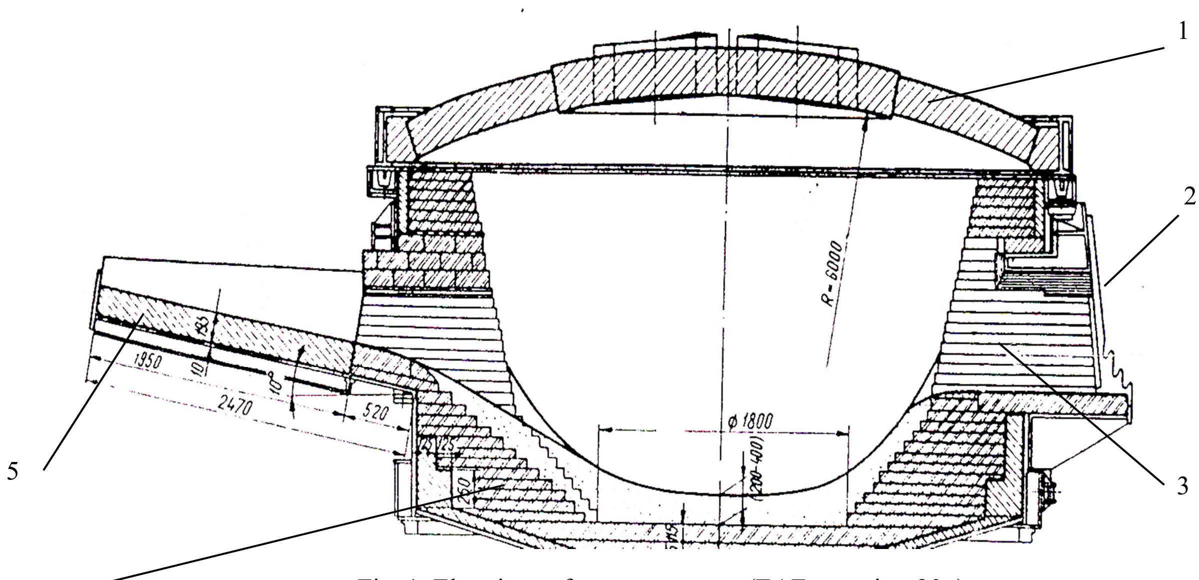

Fig. 1. Electric arc furnace masonry (EAF capacity: 20 t)
1 – Vault; 2 – Door; 3 – Vat walls; 4 – Hearth; 5 – Discharge chute.

Wiring of EAF with direct action mainly consists of (Fig. 2):
- high voltage triphase network (RST)
- separator (S) for disconnecting and connecting the equipment when the power switch of the voltage (I) is open;
- high-voltage breaker (I) to disconnect and connect the transformer furnace (TF) to any task;
- power adapter of the furnace (TF), with the connection of secondary voltage steps;
- the coil (coil shock) (CS) for limiting short-circuit currents at the interruption of electrical arches; electrodes (E).

The power transformer is determined by the ability of the furnace and the specific energy consumption for melting [5].

Electrical energy required (theoretically) for heating and melting of one ton of steel is about 340 kWh/t, and the loss of heat through the masonry oven, cooling water, through the door and other apertures are approx. 10...12% of total energy consumption.

Power transformer (Pt) from electric arc furnaces is calculated with the Eq. 2, [2]:

$$P_t = \frac{W}{t \cdot \eta \cdot \cos\varphi} \quad [\text{kVA}] \tag{2}$$

where:

W – is the total consumption of electric energy during the melting period (kWh);

t – is melting time (h);

η – is the yield (0.8...0.9);

cos φ – is the power factor (cca. 0.85).

The electrical equipment of the direct action electric arc furnace is composed by (Fig. 2):

- The three-phase (RST) high voltage network;
- The separator (S) to disconnect and connect the electrical equipment when the high voltage switch (I) is open;
- The high voltage switch (I) to disconnect and connect the furnace transformer (CT) to any task;
- The furnace power transformer (CT) with the system of connecting the secondary voltage stages;
- The choke reactor (BS) to limit the short circuit currents in arc interruption;
- The electrodes (E).

The transformer power is determined by the furnace capacity and the specific energy consumption for melting.

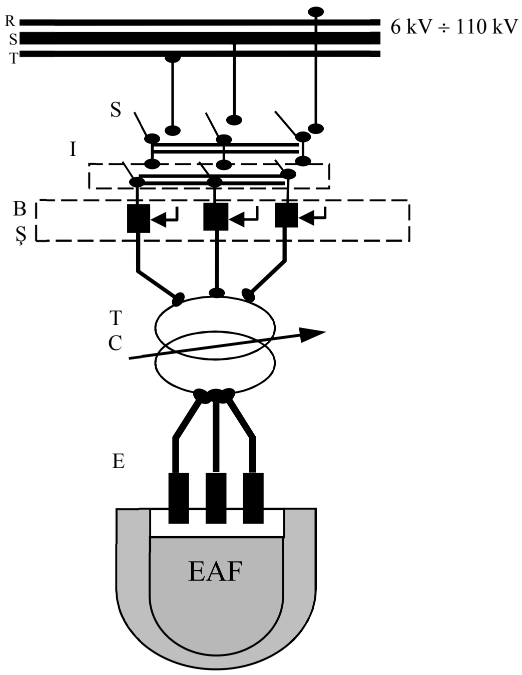

Fig. 2. EAF wiring

The electricity needed (in theory) to heat and melt one ton of steel is about. 340 kWh / t and the heat loss through masonry furnace, through cooling water, through the door and through other openings are approx. 10 ... 12% of total energy consumption.

The carbon electrodes are designed to conduct electricity from the grips to the metalic load of the arc furnace and to form the electric arc.

The graphite electrodes are most frequently used for electric arc furnaces.

The electrode diameter (d) is calculated using the formula:

$$d = \sqrt{\frac{4 \cdot I}{\pi \cdot \Delta}} \quad \text{(cm)} \qquad (3)$$

where:

I - is the phase current (A);

Δ - is the current density (A/cm^2) .

Management Elements

The methodology for establishing a EAF's best management strategy is based on the technological process-technological plant interdependences, briefly presented in Fig. 3.

Specific character of the EAF's best management consists of the rare complexity of the technological process, also proved by the high number of variables (parameters) which act independently or depend on one another in time (1, 2, 3,…,i,…).

From this point of view, the EAF' best management is based on efficient automatic calculus methods and techniques. Thus, the mathematical model represents the main element in the best management, [1]. Fig. 3 presents the steps of the algorithm for an original model of computer control the EAF steelmaking technological process.

The main steps for the process of optimal leading of the EAF, [3, 6] are presented in Fig. 3.

These steps have the following meanings:

1) GFOL – Goal (aim) Formulating of the Optimal Leading.

2) EOF – Establishing the Objective Function (performance criteria, function).

3) IQPOF – Identifying and Quantifying the Parameters (variables) which influence the Objective Function.

4) SVTOFP – Studying the Variation Theories of Objective Function Parameters (variables).

5) DREAFP – Defining the Restrictions for EAF Parameters.

6) CMMOL – Conceiving the Mathematical Model for the Optimal Leading.

7) FBSL – Finding the Best Solution of Leading.

8) RVCMM –Results Validation of the Conceived Mathematical Model (through implementing the optimal leading of the technological plant, in different stages of functioning).

We emphasize the importance of the first step of the technological EAF management, Goal (aim) Formulating of the Optimal Leading (GFOL), [7,8,9,10].

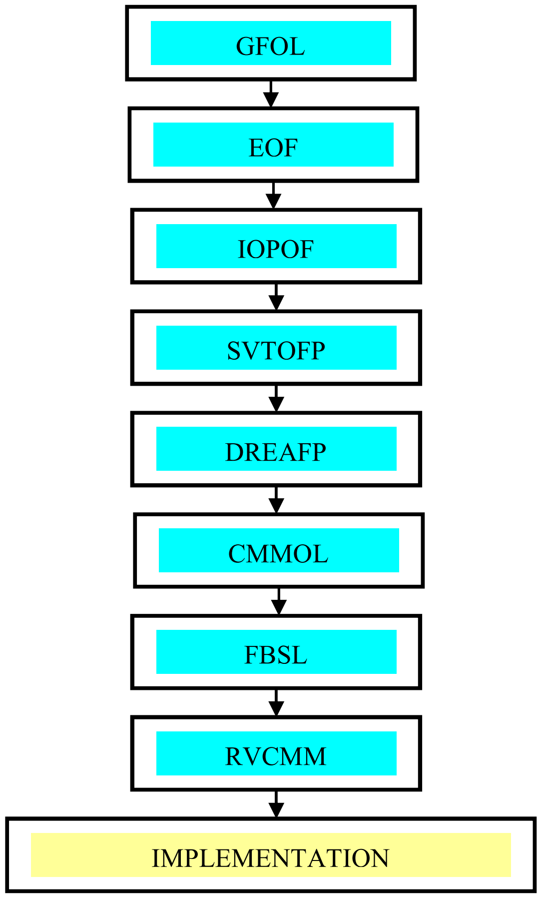

Fig. 3. The steps of the technological EAF' management

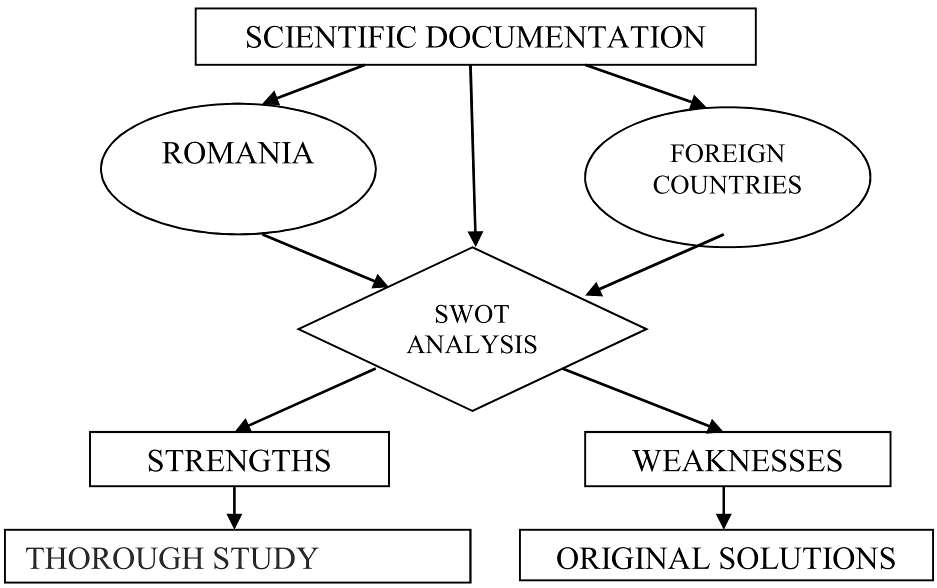

Fig. 4. The algorithm of scientific research methodology

The Scientific Research Methodology and Original Contributions

The scientific research methodology used is based on the algorithm depicted in Fig. 4.

According to this scientific research methodology , the authors of this article have had original contributions in the specific field of EAF on :

- Concept, design and prototype implementation of a self-recuperative combustion installation for preheating the charge of the EAF (patent No 98852/1989, OSIM, Bucharest)
- Industrial experimentation of the preheating system for the charge of the EAF, with beneficial effects for environmental protection.
- Other patents of authors: "Preheater for scrap iron in steel-making electric arc furnace-includes metal support with main and pilot burners, and has combusted gas heat recuperation", Patent number: Ro105114-A, Derwent primary accession no.1993-326131, ISI Web of Knowledge; "Specially profiled hydraulic tipper-consists of track mounted mobile platform of controlled trajectory archimedean spiral shape", Patent number: Ro103874-A, Derwent primary accession no.1993-173455, ISI Web of Knowledge; "Preheater for steel-making electric arc furnace charge-includes metal shell with refractory material, and regenerative flame-type combustion unit for fuel-feed reversal", Patent number: Ro105113-A, Derwent primary accession no.1993-326130, ISI Web of Knowledge; "Combustion gas trap increasing metal melting economy-includes heat recuperation assembly and combustor for metal charge treatment", Patent number: Ro110865-B1, Derwent primary accession no.1997-040972, ISI Web of Knowledge.

Conclusions

The optimal leading of the technological plants may progress either in an off-line working system (which requires the active participation of the operators) or in an on-line working system, which involves the level of performance.

The optimal leading in on-line working system requires the technological plant to be equipped with both measuring, control adjustment devices and computerization in leading the technological process, including the necessary process interfaces.

Electric arc furnace was imposed as the base aggregate of electric process, facilitated by the benefits, among which we mention:

- Top level of quality and competitiveness of electrical steel.
- Possibility of re-introduction of industrial circuit increasing the amount of reused raw material (waste, consisting mainly of scrap collected).
- Secure operation, management and restoration.

Construction and functional analysis of the variables of the electric arc furnace, is the objective to study the technical premises of evolution of this aggregate (in constructive and functional terms) for the purpose of enhancing its performance.

The best management of a plant consist of an assembly of operations, measures and decisions, established and applied in order to make the technological process more efficient from the technical–economical point of view, Electric Arc Furnace management included.

Generating, developing and maintaining electric arc to EAF are dependent on the phenomena and processes which take place both at the interface electrode - metal load, as well as in the space between them.

Electrical energy required for EAF heating and melting is the most important chapter of total energy consumption.

The methodology for establishing a EAF's best management strategy is based on the technological process-technological plant interdependences.

The innovations and originality shown in the article consist mainly in designing several stages of management specific for the technological process in EAF steelmaking. An original specific EAF management scheme was also built based on this concept.

In our future scientific research we consider designing models for applying the concepts of ERP and ES in the EAF .

References

[1] A. Ioana, Management Elements of the Metallurgical Technological Plants, Annals of Oradea University, Fascicle of Management and Technological Engineering. IV, XIV (2005) 124-127.

[2] A. Ioana, A. Marinică, Electric Arc Furnace (EAF) – Application In Efficiency of the Energy, Advances in Energy Research and Development, ORIC Publications, USA, 2014.

[3] A. Ioana, A. Semenescu, C.F. Preda, Elements of Quality Analysis in Metallic Materials Industry Production, Proceedings of Engineering Solution and Technologies in Manufacturing, Applied Mechanics and Materials. 657 (2014) 881-885.

[4] A. Ioana, A. Nicolae, Cr. Predescu, I.F. Sandu, M. Sohaciu, G.G. Calea, Optimal management of electric arc furnaces, Fair Partners Publishing, Bucureşti, 2002.

[5] A. Ioana, Metallurgy's Impact on Public Health, Review of Research and Social Intervention. 43 (2013) 169-179.

[6] A. Ioana, A., Semenescu, Technological, Economic, and Environmental Optimization of Aluminum Recycling, Journal of the Minerals, Metals & Materials Society, JOM. 65, 8 (2013) 951-957.

[7] A. Ioana, V. Mirea, C. Bălescu, Economic Processes Study through Fuzzy Logic, Journal of Economic Computation and Economic Cybernetics Studies and Research. 2 (2010) 129-137.

[8] A. Ioana, C. Bălescu, Environmental Study of the Formation of Evacuated Burnt Gases from a Steels Making Plant, Chemical Journal. 5 (2009) 468-471.

[9] L. Brimacombe, C. Jackson, N. Schofield, Artificial intelligence expert systems for steelworks pollution control, La Revue de Métallurgie-CIT. 1 (2001) 111-116.

[10] P. Chapelle, J.P. Bellot, A. Jardy, T. Czerwiec, X. Robbe, B. Champin, D. Ablitzer, Behaviour of the electric arc in the VAR process, La Revue de Métallurgie-CIT. 12 (2001) 1129-1138.