IOSUD - Polytechnic University of Timisoara
Doctoral School of Engineering Studies

"Research regarding the influence of the metallic charge upon reducing the specific consumption and the degree of pollution at electric mills"

PhD thesis – Summary

To obtain the title of PhD in

Politehnica Timișoara University

In Materials Engineering

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Introduction

Within the developed research program, a thorough study was carried out on the process of steel production according to the load structure, the degree of preparation and the chemical composition of the metal load. This study was conducted to optimize specific consumption, steel quality in the electric arc furnace, and the possibility of diminishing impacts on environmental factors and population health by reducing carbon emissions, airborne dust as well as noise produced during technological processes due to the complexity of the installations and raw materials used on the technological flow.

The steel industry faces the difficulty of being competitive on the market and continues to account for a significant share of carbon emissions in the atmosphere, and the need to continue to meet the increasingly demanding requirements of both steel and public consumers leads to the need to identify new technological improvements, but also the possibility of their implementation in production units aimed at reducing energy costs, raw material costs used in steel production, emissions of gases and dust released into the atmosphere, as well as recycling of dust resulting from to sewage plants.

In view of the above, the researches carried out within the doctoral thesis were oriented towards the improvement of the process of steel production in an electric arc furnace type EBT, following the structure of the metallic load the degree of its preparation and the influence of these factors on some specific consumption (metal consumption, removal of liquid steel, electrodes, electricity) removal of liquid steel, composition of dust deposited on the soil and noise generated by electric arcs formed between electrodes and the load.

On the occasion of finalizing the PhD thesis, I would like to thank all those who have guided, supported and shared professional knowledge.

Chapter 1

The European steel industry faces the simultaneous effects of low demand and overcapacity on a globalized steel market as well as high electricity prices, which means that the steel industry needs to invest in new technologies to adapt to the green economy and to produce innovative products.

With regard to steel demand, the construction of power plants, including wind farms built off land or offshore, energy transport, housing and transport will continue to provide new opportunities for innovative steel products. With regard to steel production, innovation is still a key element in the development of new products and the development of new markets.

The plan of experimentation and research, starting from the factors of influence, the quality of the metallic structure of the electric arc furnace, the degree of preparation of the metallic load, the structure of the additions, having as object of the research the reduction of the consumption of metal, electrodes and energy in the furnace electical arc and environmental pollution we obtained as response factors, liquid steel removal, specific electrode consumption, specific energy consumption, and environmental pollution parameters.

The aim of the doctoral thesis is closely related to the current needs in the steel industry, and this sector is continually changing today due to the global economic crisis, which has led to a decrease in production activity and of steel demand [1/13].

The theme of the doctoral thesis studies the influence of the structure and the quality of the electric arc furnace load on the extraction of liquid steel, the specific energy consumption and electrodes, the reduction of the pollution (chemical and sound) of the environment.

The researches foreseen in the PhD thesis plan were made at an electric steelwork equipped with an electric arc furnace type E.B.T with a capacity of 100 tons, steel processing plants outside the furnace, type L.F. and V.D, and the five-wire continuous MTC casting machine.

The research objectives are closely related to the theme of the PhD thesis, namely to develop processes for improving the quality of the steel produced in the electric arc furnace and to optimize the specific consumption on the entire technological flow.

The doctoral thesis is structured in 10 chapters, divided into three parts:

Chapter 1. Plan to conduct experiments and research.

Part I Synthesis of the literature on the electric arc furnace load.

Chapter 2. Study from the literature on the metallic load used in steel production.

Chapter 3. Preparing the metallic load.

Part II Research and experimental results on the influence of the structure (composition) of electric arc furnace load on specific metal, energy, electrodes and environmental pollution.

Chapter 4. Research on the influence of load structure on metal removal.

Chapter 5. Research on the influence of metallic structure on the specific consumption of electrodes.

Chapter 6. Research on the influence of metallic charge on specific electricity consumption.

Chapter 7. Soil Pollution in Electrical Installations and Analysis of Soil Deposition of Powders from Gas from Electric Arc Furnaces.

Chapter 8. Research on environmental noise pollution in the steelworks area.

Chapter 9. Industrial verification of research results.

Part III Final Conclusions. Original contributions. Dissemination of results.

Chapter 10. Final Conclusions. Original contributions. Directions for further research.

Annexes

In order to achieve the proposed theme, industrial experimentation studies and modeling and mathematical processing were carried out in order to determine the best structure of the metallic load and the most representative parameters of influence on the efficiency of the production process, decreasing specific metal consumption, energy, electrodes and environmental pollution. The aim was to determine how these parameters could be influenced in order to obtain a quality steel under the current market conditions for advanced technical, economic and ecological efficiency.

Chapter 2 presents a study of the literature on the structure and quality of the metallic load used in the production of steel in electric arc furnaces. The EBT furnace consists of a three-phase electric furnace that operates on the principle of direct heating of the metal bath via the electric arc.

The arc electric furnace as a result of constructively and technologically advanced improvements (EBT type) is preferred for the development of non-integrated flux steel to be continuously cast. It is thus envisaged that both ordinary carbon steels or low alloyed steels as well as highly alloyed steels can be produced, these ovens being built within very wide capacity limits. LV and VD or VAD and VOD streams are usually used for high alloy steels with an LF (Ladle furnace) furnace, VD (Vacuum degassing) and VAD (Vacuum Arc Gassing), VOD). In the picture you can see the EBT electric arc furnace and the bases it is made of.

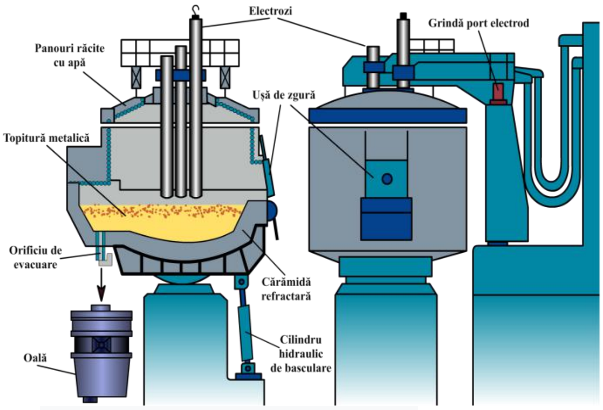


Figure 2.1 EBT electric arc furnace [2/43, 3/44]

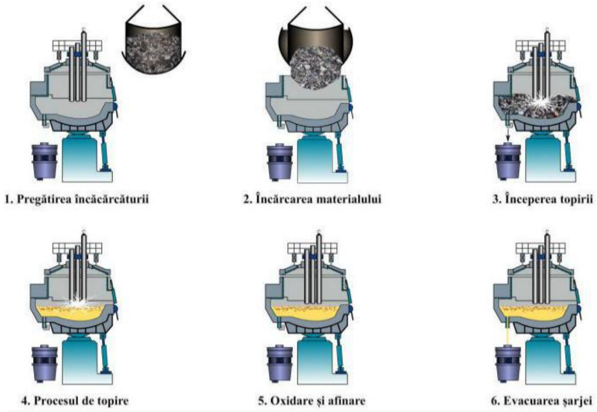


Figure 2.2. The processes of steel production in the arc furnace type E.B.T.

The stages of steel production are shown in figure 2.2: adjustment, loading, melting, oxidation, evacuation. The EBT electric arc furnace is powered at a voltage of 33.0 [kV] at SRA OE Station, being a pot-shaped melting furnace with a capacity of 100 [t] and an estimated electricity consumption of 500-610 [kWh / t of melted steel]. The furnace is lined with refractory brick (magnesite) and is therefore a basic furnace. In principle, the technological flow consists of preparing the metallic load of the electric arc furnace, which is composed mainly of pre-cooked old iron, the overhead furnace loading with a Greifer-type dump with a 125tf roller, cargo melting, oxidation, refining and evacuation .

The processes of elaboration in the electric furnace E.B.T. are the loading of the electric arc furnace with scrap metal mechanically. When preparing and building the load, account must be taken of the proposed purpose (the quality of the steel being developed) and, at the same time, depending on the economic situation, the momentary availability of raw materials. The duration of melting is determined by the degree of load preparation, load compaction, transformer power and meltdown. Burning is the period during which the oxidation process of the accompanying elements in the representative metal bath is continued, such as oxidation of carbon. Evacuation takes place as soon as the chemical composition and temperature are satisfactory by opening the molding hole. In the practice of steel production, there are frequently 2 steel production flows, one is the integrated flow and the flow in mini-factories.

The integrated flow is used in converters and non-integrated flow in mini-factories.

The integrated flow starts from the iron ore and coking coal, the coal is processed at the coking plant, where coke results as a thermal agent, the iron ore agglomerates and agglomerates as the raw material for the furnace, which is charged into the blast furnace, which is charged in the oxygen converter. On average 80% liquid iron is cast and the remaining scrap is the resultant liquid steel that is discharged into the pot which undergoes secondary treatment in LF (sometimes also VD) and then is continuously poured in the form of semifinished or laminated.

It is worth mentioning that until the final phase-out of the Siemens Martin steelworks, most of them functioned in the integrated technological flow of OSM1 (100t) -5 furnaces and OSM2 (460t) Hd-8 furnaces, OSM Resita (250t) -5 furnaces.There is an integrated flow which in synthesis means that the raw material is the coking iron and coal ores and the finished product is laminated and semi-finished.

Lately, some cast iron producers have also become raw material for the electric arc furnace, which is typically mini-factories.

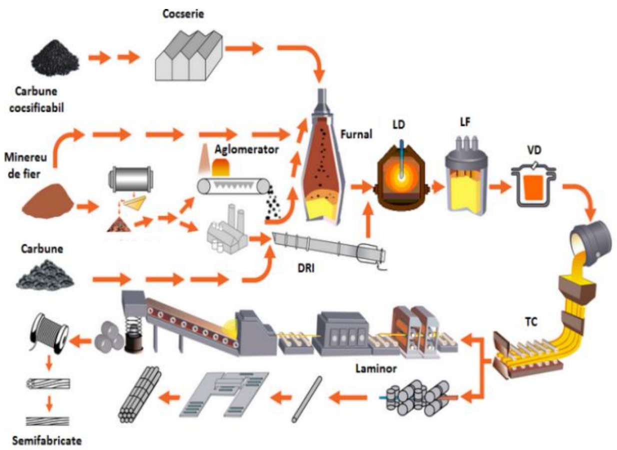


Figure 2.4. Integrated steel production flow [4/6]

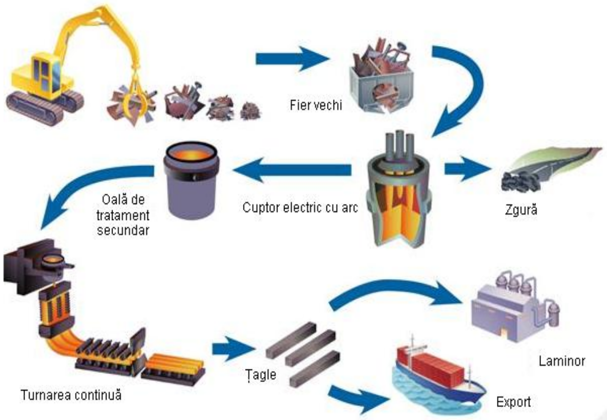


Figure 2.5. Technological flow in mini-factories for steel production [5/7]

Steel is entirely recyclable without a loss of quality. Derivatives resulting from the production of steel (eg slag) are almost fully utilized. Therefore, from the perspective of the Europe 2020 Resource Efficiency Flagship Initiative, the steel industry is well positioned to benefit from an orientation that favors the Life Cycle Analysis (ACV) approach, the increase in recycling rates and a more good use of derived products [6/9,7/18,8/19].

The production of steel from metal scrap compared to iron ore reduces energy demand by about 75% and saves about 90% of the raw materials needed in the production process [9/17].

Steel and cast iron, used as materials in so many industrial fields, have the property of being able to be recovered from the manufactured products after use, irrespective of the period of time corresponding to the lifetime of the products concerned.

Ferrous scrap therefore arises from the iron and steel industry in which iron and steel is being produced, passing through the whole range of industrial branches in which the steel products are processed (machine building, etc.) or used as such (in construction, railways, etc. .) and ending with the recovery of the ferrous part from the scrapped waste and household waste.

Chapter 3 includes the preparation of the metallic load.

Waste recycling is an industrial activity of major and useful importance for many economic sectors. Waste collection and recovery processes are an important step in the development of many highly industrialized countries, so many industrial sectors are adapting their technological lines and processes for introducing secondary raw materials resulting from the waste recycling process into the technological stream, thus optimizing raw material expense and obtaining an economical production cost.

Worldwide, countries with developed metallurgical industry provide their raw material in the proportion of 40 to 45% of waste and old metals. In order to carry out the preparation of the old iron and metal scrap, steel warehouses are sized and equipped with modern preparation / processing facilities (flame cutting machines, scissors, presses, crushers, shredder mills, cryogenic installations, etc.)[10/35,11/49].

The sorting operation is necessary because it allows the elimination of harmful non-ferrous metals (copper, tin, lead, zinc, etc.) as well as the sorting on types of steel assortments which, due to the content of elements, are useful in some assortments but can also be harmful others.

The dimensional preparation by cutting long or flat pieces of waste is achieved in order to obtain dimensions that allow either easier handling or adaptation of the dimensions to the needs imposed by their use (the diameter of the converter's bore or the bend diameter of the electric arc furnace).

Figure 3.5. Mechanical Guillotine Scissors

Figure 3.6. Hydraulic Scissors

Guillotine cutting can be grouped into several classes depending on the cutting force (3000 to 20,000kN). A major inconvenience to grind slightly iron scraper of scrap iron, for example, from car bodies, is the low volumetric weight obtained for chopped material (800-900 kg / m3).

Hydraulic shears are of high productivity and are designed for cutting thick sheet and large profile. There are clamping devices for the workpiece, the tipping dump, the cutting material processing box, all of which are component parts of the cutter.

Figure 3.8.Baler for preparing iron from light metal waste

Figure 3.9. Briquetting system for metal chips

The blasting of light ferrous waste is done with hydraulic presses. Frequently used are the 4000kN and 10,000kN presses with which packages / balls with a specific weight of 1000-3000kg / bale can be obtained, given the very low volume of this waste in unprepared condition, the hydraulic presses are provided with large dimensions.

Small metallic holes can be used as such or can be briquetted using hot pressing machines with outputs of 1.5-2.5 t / h. The briquettes thus obtained have a mass of 2-40 kg / pc, depending on the type of machine and a volume mass of approx. 5000 kg / m3 and can be used in good condition in the load of electric arc furnaces.

The transportation to the machining centers of the discarded vehicles and especially of their carcasses (bulky and light) requires transport vehicles in a non-economical way.

In this aspect, mobile presses were moved to the collection points and through a flattening operation, from the carcasses, large packs are made to allow more efficient loading in the transport vehicles, thus contributing to the reduction transport costs.

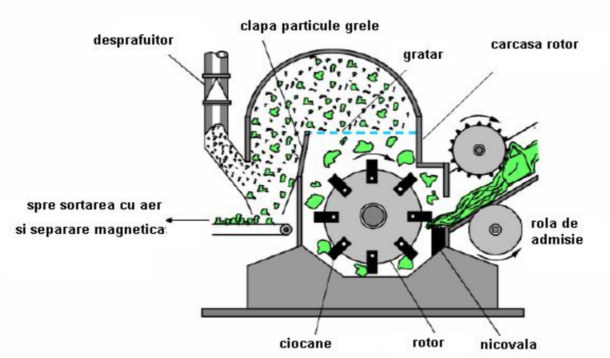


Figura 3.14. Moara tocătoare cu ciocane pentru vehicule scoase din uz [12/57,13/58]

Figura 3.13. Macara mobilă pentru reciclarea automobilelor care se deplasează lalocația beneficiarului

The Shredder method shown in Figure 3.14 - according to this technology, the car bodies resulting from the removal of the engine, radiator, tire, petrol tank and transmission are passed through a grinding mill. The fragments obtained pass over a magnetic separator, the parts of non-ferrous metals being collected separately. The steel fragments are further passed through a furnace in which the impurities of non-ferrous materials are burnt. From this plant, a ferrous material with a bulk density of up to 1500 kg / m3 can be obtained after processing and containing contaminants below the limits set by the rules for the use of steel waste. At the present stage, ferrous waste is advanced dimensionally prepared.

The preparation machines are highly productive, some are located in the ferrous material depots and some are mobile - especially those for VSU (end-of-life vehicles) processing. In Romania it is necessary to equip the processing bases with cryogenic installations for the processing of metallic materials. In the scrap iron deposits it is necessary to develop a complex stream for the advanced sorting of the old alloy iron.

Chapter 4 includes Research and experimentation on the structure's influence on metal removal. In view of the above, for the analysis of the structure of the load, a number of 98 steel batches of an electric steelworks equipped with an E.B.T electric arc furnace with a LF potting plant (Ladle- Furnace) and a 5-wire continuous casting plant, the blanks, billets and round profiles being molded.

The results are presented graphically, on the basis of which a technological analysis of the research was carried out.

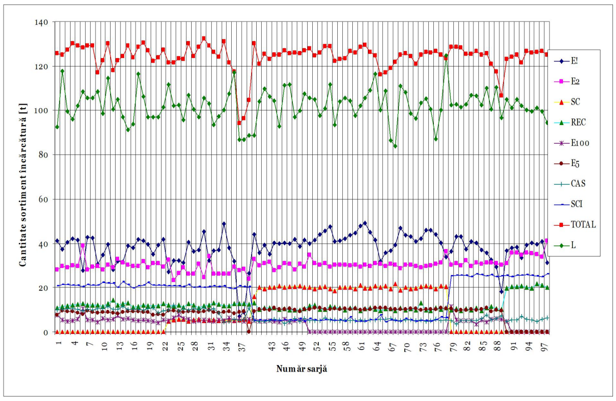


Figure 4.1. Variation in the composition of the electric furnace load (EBT type)

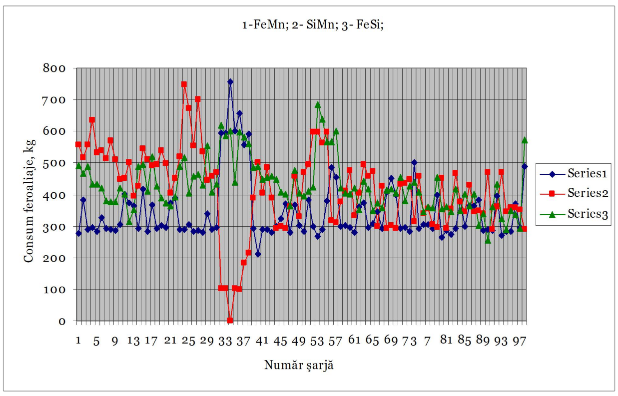


Figure 4.2.Variation of the quantities of ferro-alloys at furnace outlet

From the technological analysis of the diagrams presented, the following technological aspects arise:

- with regard to the composition of the metallic load, the large share of the total metallic load is the old iron quality E1 and E3 (Figure 4.1 and Figure 4.2), their average being 38% and 30%,

respectively; the variation of the quantities of iron in particular E1 and to a certain extent E3 is found in the variation of the total load and the removal;
- from the analysis of the data in Figure 4.7, it can be observed that there are real possibilities of reducing the duration of operation of the furnace under voltage, the maximum duration being 65 minutes, a minimum of 46 minutes and 56 minutes the average value; a reduction in lifetime, also leads to a reduction in the specific consumption of electricity and electrodes;
- the analysis of the lengths of the main technological steps (Figure 4.7) clearly highlights the possibility of reducing the duration of technological operations, and the increase in the degree of processing of the scrap iron allows the fulfillment of these requirements;

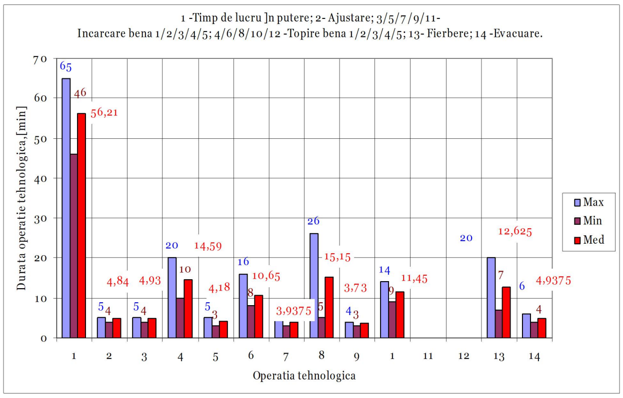


Figure 4. 7 Limits of variation of technological stages

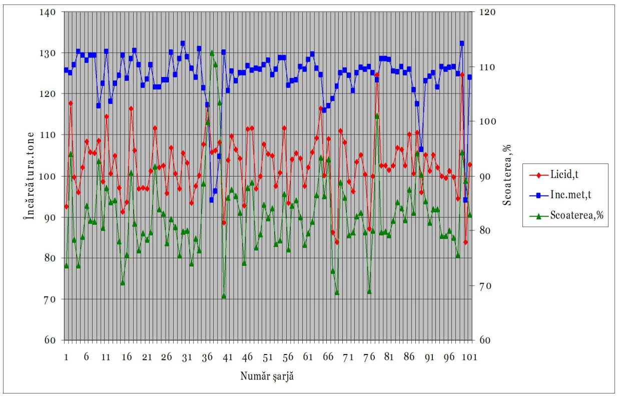
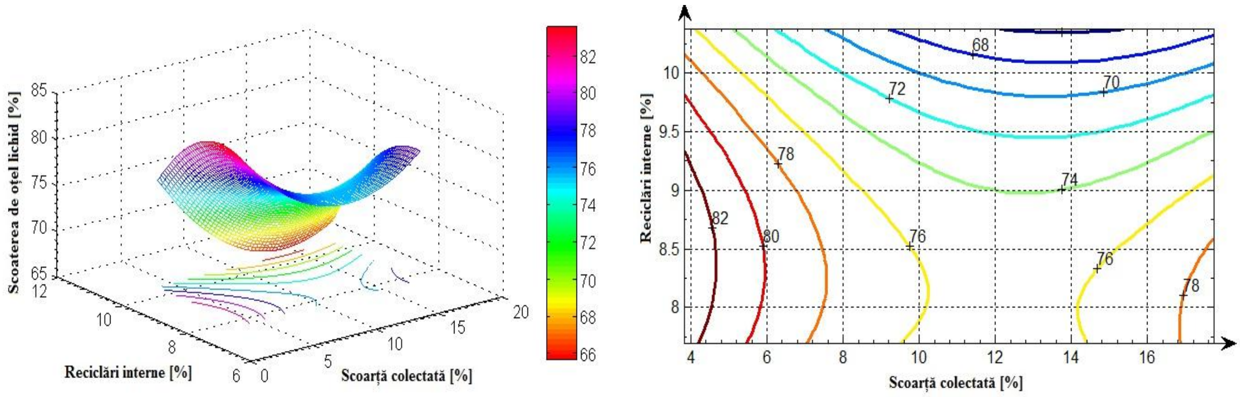


Figure 4.8. Variation in weight of metallic load, liquid steel and removal of liquid steel

- from the data presented in Figure 4.8, there are very large variations in the weight of the metallic load, the liquid steel and the removal of liquid steel, the main cause being the quality of the metallic charge, ie the proportion of the nonmetallic component in the metallic assortment of the load.

Data processing in the MATLAB program

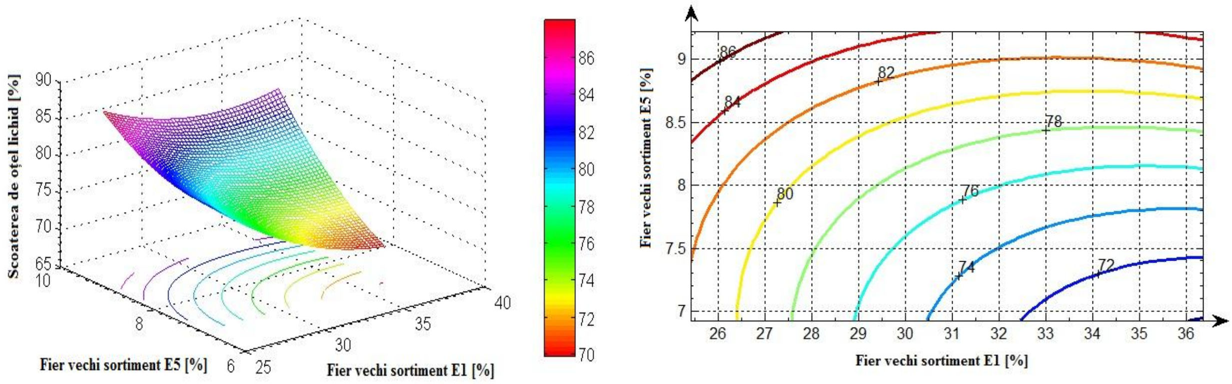
In the framework of the researches carried out, it was envisaged to establish simple correlations between the removal of liquid steel and the proportion of the different metallic batch types. In order to establish double correlations, the data were processed after 3 types of correlations.



a) the correlation surface   b) flat-level projection curves

a1=0.1104051; a2=-1.7666965; a3=-0.1475965; a4=-1.5058424; a5=30.243078; a6=-36.973579; D= -0.8019941; H= 0.22081024; R^2 = 0.5159873;

Figure 4.27.Removal correlation = f (collected / trade ferrous bark, internal recycling)



a) the correlation surface b) flat-level projection curves

a_1=0.0788109; a_2=1.269789; a_3=0.34081517; a_4=-8.3174359; a_5=-26.4914911; a_6=304.8916763; D= 0.28413797; H= 0.1576218; R^2 = 0.5272306;

Figure 4.28. Correlation: Removing liquid steel = f (scrap iron E1 assortment, scrap iron E5 assortment)

In Figure 4.28. it is presented that depending on the proportion of assortment E1 and E5 it is possible to determine the removal of liquid steel for example 33% E1 type and the old iron E5 assortment 8.5%, a removal of about 78% is obtained. A slight increase in E5 scrap may result in an increase in uptake of up to 80%.

E.B.T type electric arc furnaces, is the most suitable unit for the processing of steel scrap in order to obtain, both in terms of quality and the number of the load placed in the load ranges.

The structure of the load may vary widely in terms of assortment, provided it is advanced in preparation [14/69].

The great variation in the weight of the metallic load was determined by the variation in the weight of the different types of scrap iron. the scrap structure of the old iron does not result in the residual content being exceeded, leading to the downgrading of the batch.

The quality of the old iron, especially barking from both inside and outside, is reflected in the level of removal. In current practice, the quality of the load is also determined by economic considerations, these being made according to the developed steel brand, which obviously differs from one steel plant to another.

In chapter 5 researches on the influence of the structure of the metallic charge on the specific consumption of electrodes.

The electrodes are the last component of the secondary circuit of the electric arc furnace, they lead the alternating electric current from the clamping ends to the load, which must be distributed evenly over the electrode section, which depends on the characteristics and its diameter.

The characteristics of the electrodes depend on the chemical and physical properties of the materials they are made of and the method of manufacture.

At that time, electrodes are used as raw materials as metallurgical coke, anthracite, petroleum coke, ash materials, which are prepared by crushing, heating at 120 ° C in a rotary kiln in a reducing atmosphere, grinding and granulometric sorting.

A significant influence on the specific consumption of electrodes has the structure of the metallic load, the quality and the degree of its preparation, as well as the way of conducting the technological process.

In this regard, a number of 98 batches of parameters have been tracked. By using a clean, rusty, low-scratch, low-grade scrap metal as well as an appropriate ratio of heavy, medium and light scrap quantities, it will increase the removal of liquid steel and reduce specific energy consumption electrical and electrodes.

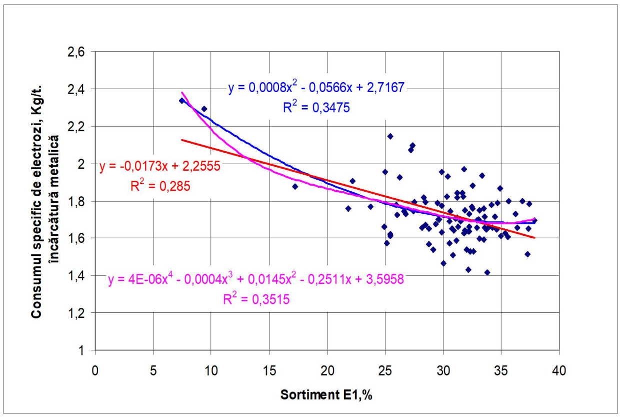


Figure 5.1.Correlation $C_{s.ez.} = f(\%E_1)$

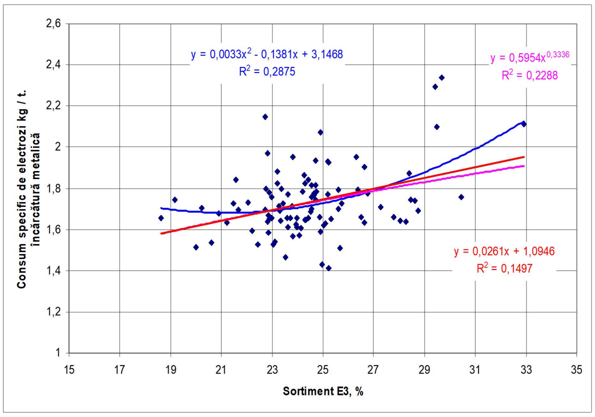


Figure 5.2.Correlation $C_{s.ez.} = f(\%E_3)$

Based on the analysis of the obtained results, expressed in both analytical and graphic form, the structure of the load, namely the proportion of ferrous products, influences the specific consumption of electrodes (kg / ton metallic charge). From Figure 5.1. there is a decrease in the specific consumption of electrodes with the increase of the ferrous E1 range reaching up to 1.4 kg / ton.

The decrease is well replayed after grade 2 and 3 polynomial correlations.

In the above-mentioned sense, the data obtained on the structure of the metallic load, were correlated with the specific consumption of electrodes and processed in the EXCEL and MATLAB calculus programs.

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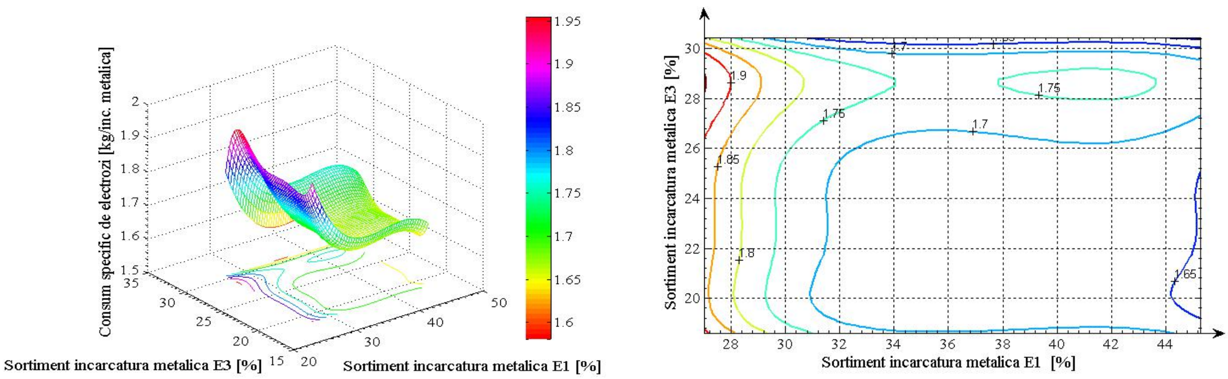


a) the correlation surface b) flat-level projection curves

D=-1012.93818; H=713.39064; **r2=0.39419;**a1=356.6953; a2=-0.70994; a3=0.01853; a4=-0.00016; a5=-73.74388; a6=6.25543;a7=-0.26397;a8=0.00554; a9=-4.6264e-05;

Figure 5.8.Correlation multiple $C_{s.ez.}$ = **f(%E₁ , % E₃);** **Equation tipe 1**

The correlations obtained represent a possibility of tracking the influence of the structure of the metallic charge on the specific consumption of the electrode. In each diagram are presented the level curves (plane projection), respectively the fields of variation for the specific consumption of electrodes (the surface between two level curves).

For example, by analyzing the data in Figure 5.8 it can be observed that in a proportion of 32-45% old iron E1 and 21-26% old iron E3 a specific consumption of electrodes below 1.7kg / t can be obtained, and at a increasing the proportion of scrap E3 to 30%, this parameter increases to 1.75kg / t metallic load.

Very close results are obtained also in the case of processing of the same data after the type 2 and 3 equations, which confirms the viability of these correlations.

From the analysis of the results of the researches carried out and of the observations obtained during the batch tracking follows a series of conclusions, namely:

The specific consumption of electrodes is largely influenced by the structure of the metallic loading and the state of presentation and preparation thereof.

Based on the graphical representations of the correlations obtained in the Excel and Matlab calculation programs, the proportions of the metal load components could be determined to achieve a specific consumption of electrodes below 1.75 kg / tonne of metallic charge (1.4-1.75) closer to the intended one.

After analyzing the graphical representations, to achieve a specific consumption of electrodes below 1.75kg / ton of metallic load, the following composition of the metal structure is recommended: E1 32-45%, E3 21-26%, E5 and E100 below 8%, bark below 20% and scratches below 10%.

Research can be improved by reporting the specific consumption of electrodes to liquid steel.

In the researches carried out in **chapter 6** there is presented a research on the influence of the metallic charge on the electric power consumption.

The analysis of the structure of the electric arc furnace load on the specific consumption of electricity (kWh / t of liquid steel) was considered.

The data tracked at a number of 98 batches considered the participation in the load of each "scrap iron" assortment, these being considered independent parameters and the consumption of electricity, considered a dependent parameter.

By processing the data in the EXCEL and MATLAB computational programs correlations were obtained between the analysis parameters, the results being presented analytically and graphically.

On the basis of the correlation analysis, the optimal load structure (under the given supply conditions) is chosen in order to obtain a technically-economically acceptable energy consumption [15 / 70,16 / 71].

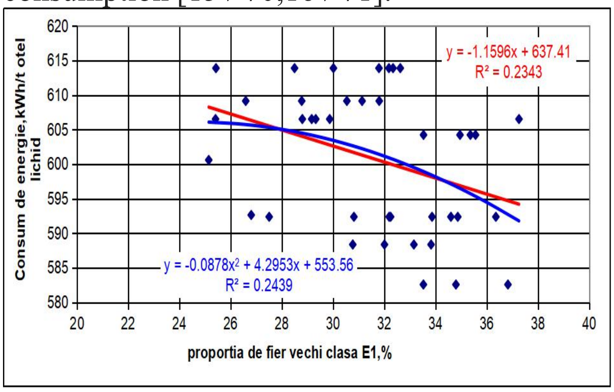


Figure 6.1. Variation of specific energy consumption according to the proportion of scrap iron E1

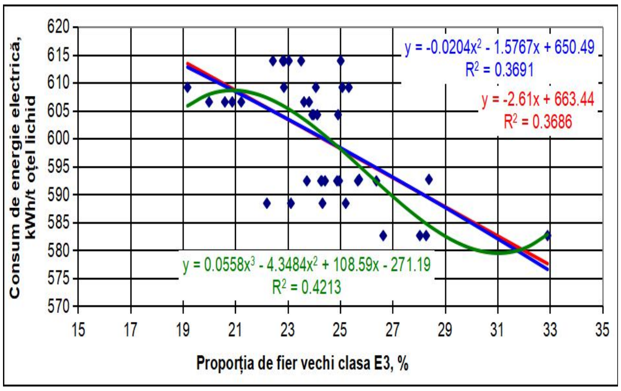


Figure 6.2. The variation of specific energy consumption according to the proportion of scrap iron E3

From the technological analysis of the correlations obtained in the EXCEL program and especially expressed in graphic form, the following conclusions can be drawn: - the main ferrous metal components, the E1 assortment, the E3 assortment, the commercial ferrous bark and the E5 ferrous assortment (Figures 6.1 and 6.2), which provide 65-87% of the total batch, by increasing their proportion, a reduction in consumption specific electricity [69,70,71].

The following parameters were taken into account when processing the data in the MATLAB program:

Dependent: - V - specific power consumption, kWh / t. liquid steel;

Independent: - x - proportion of ferrous product E1,%;

- y - the proportion of ferrous product E3,%;

- z - proportion of assortment recycling,%;

- t - proportion of assortment from internal cashings,%.

Triple correlation equations (general form relation 6.1) were obtained, out of which the double equations represented in the three-dimensional space were derived by means of the specifications mentioned in Chapter 4.

Triple correlation v=f(x,y,z), general form:

$$v=a_1x^2+a_2y^2+a_3z^2+a_4xy+a_5xz+ayz+a_7x+a_8y+a_9z+a_{10} \quad (6.1)$$

$$v=0.0649x^2-0.0070y^2-0.2979z^2-0.1385xy+0.7140xz+0.4754yz-7.2570x-1.5564y-23.1133z+839.8026 \quad (6.2.)$$

R^2 =0.7576

Double correlations:

$V=f(y,z,x_{med}=38{,}32\%) =-0.0070y^2 -0.2979z^2+0{,}4754yz-5{,}9156y-0{,}6399z+675.706;$ (6.3)

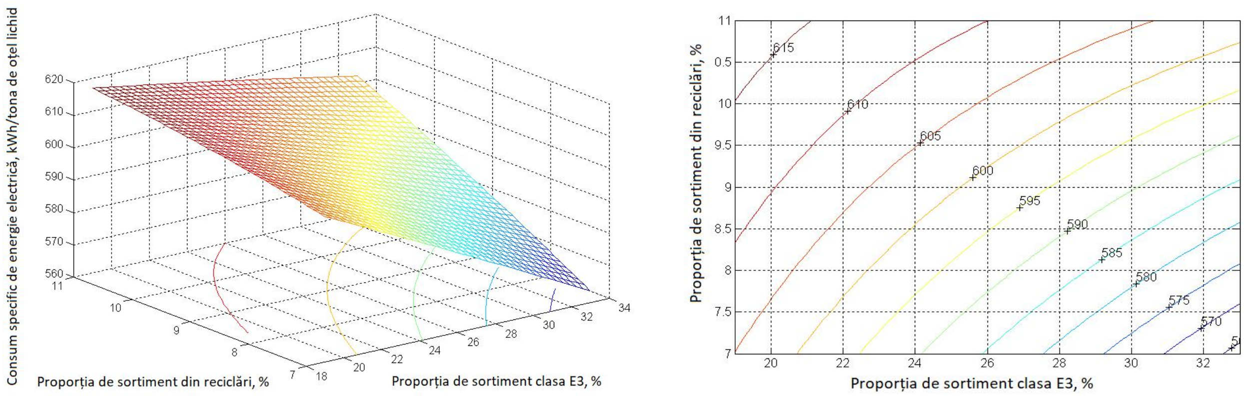
Correlation coefficient: R^2 =0.7015;

Stationary point, coordinate saddle point:

y=ferrous assortment E3=17.5943%

z=recycled ferrous assortment=12.9636

v= specific electricity consumption = 619.5180kWh/t liquid steel



a) the correlation surface; b) level-projection curves in the plan

Figure 6.11. Correlation of specific electricity consumption = F (E3 assortment, recycling)

$v= f(x,z,y=y_{med}=23{,}35\%) =0.0649x^2-0.2979z^2+0.7140xz-10.6121x-11.5972z +797.9796$ 6.4); (6.4)

Correlation coefficient: R^2 = 0.6003

Stationary point, coordinate saddle point:

x- ferrous assortment =E1=24,8709%;

z=recycled ferrous assortment=10.3399 %;

v=specific electricity consumption=606,0567kWh/t liquid steel;

The results obtained in the MATLAB calculation program are very well correlated with those obtained in EXCEL and allow for a better correlation / selection / better choice for the ferrous products in the load, for example: in figure 6.11 for determining the proportions of E1 and E3 in view obtaining a specific electricity consumption below 600kWh / ton of liquid steel, more precisely in the range of 590-595 kWh / ton of liquid steel.

In the same way other areas of the diagrams (correlations) can be analyzed.

Chapter 7 presents aspects of soil pollution in the electric steelworks and the analysis of the soil deposition of dust from gases from electric arc furnaces.

Environmental pollution is a reality of our day, meeting both in industrial areas and at urban level (to a lesser extent in rural areas). If natural pollution can not be foreseen and in this context, it can only be controlled to a limited extent, artificial pollution is induced by human activity (regardless of the type of activity undertaken) and it is up to us to limit the effects observed at the air - water level - ground.

Pollution is the contamination of the environment with materials that interfere with human health, the quality of life or the natural function of ecosystems (living organisms and the environment in which they live, biotope).

Depending on the nature of the pollutant, pollution may be physical, chemical or biological [17 / 74,18 / 75].

The modernization of the steel industry has always been aimed at reducing the pollution of the environment. Large quantities of dust discharged into the steel industry can be exemplified by the situation in the steelworks, where in the technological processes of steel production 10-15 kg of powder / t steel are formed at the oxygen converters and 15-25 kg / t of dust / t steel in electric arc furnaces (CAE).

In the case of steel production in electric arc furnaces, all metallurgical dust production mechanisms are met, as follows:

- volatilization in the form of very hot particles, such as electric arc contact
- melt or oxygen jet - melt;
- Mechanical metal melt projections at electric arc
- melt or oxygen jet - melt;
- liquid droplet projections by the carbon dioxide bubbles (CO), which as a result of the intense boiling of the metal bath rises from the hearth to the surface of it, exits in the atmosphere of the aggregate by drawing drops of steel;
- the direct emission of solid particles to the introduction of a solid load over the metal bath or to the contact of the metal bath with different jets of powdered materials.

It is worth mentioning that the modifications suffered by dust on the capture - purge - evacuation route must be added to the above: physical changes (phase transformations, agglomerations) and chemical transformations (reactions between the phases transported). As a result, it can be inferred that in the process of making steel (as in the case of other metal alloys), it is not only a "mechanical dust" but a complex dispersed system due to its provenance (a multitude of sources, including some due to operationalization technologies), compositions, sizes, mineralogical structures, granulometric structures, etc.

In such a context it can be considered that we are dealing with technological dust. In this chapter we analyze the composition of the powders deposited at different points in the area (in the vicinity) of the electrical capacity of 100 tons of EBT (EAF) arc furnace.

Deposits took place after the exhaust gas was removed, noting that there had been no instances of non-operation of the dusting facilities for more than 90 minutes, but there were instances of non-conforming operation and accidental pollution due to the ignition of the filter bags (dust bags).

These types of furnaces are equipped with very high power transformers, they are indicated for intensive use during melting, and the firing (reduction of carbon in the molten steel) usually has a short duration of 10-15 minutes.

To enhance the melting process, oxygen is used for both burners and lances. As a result of the blowing of oxygen into the metal bath, the temperature of the bath increases, which leads to the formation of brown smoke containing oxides of metals in the aggregate load (some of the metals are oxidized and pass into the brown smoke).

During the research, the dust deposits were collected at 7 sampling / sampling points located at different distances from the generator source (EBT electric arc furnace) table 7.1.

The research was conducted on the basis of the data obtained from the chemical analysis of the samples taken for a period of 9 years (2009-2017), taking into account for each component monitored and at each point of sampling of the annual values.

The graphical analysis of the content variation for each tracked item and collection point is presented in graphic form, accompanied by the technological analysis.

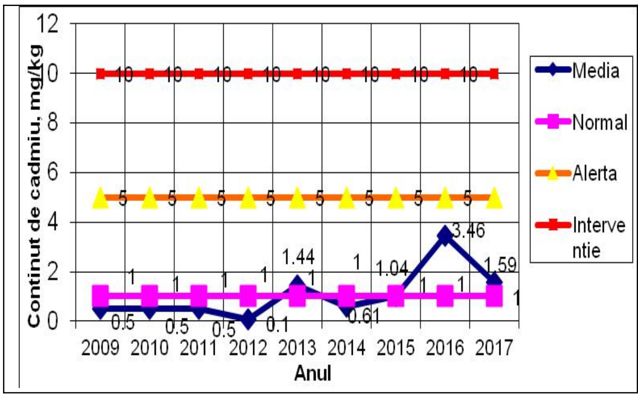
Table 7.1 Position of the ground sampling points pollution source

Nr.crt	Position post sampling	The distance from the source of pollution, [m]
1-S6	The enclosure limit carries OE2 entry	150 m NV
2-S7	South of the old iron warehouse discovered	100 m
3-S8	North of OE2 near GA-TC	100 m
4-S9	To the east of OE2 in the vicinity of LS3(wire)	150 m
5- S10	To the east of the LPU (lightweight)	2000 m
6- S11	On the west of the Laminor LPG platform	1500 m
7- S12	The limit on the Laminore gate	500 m S

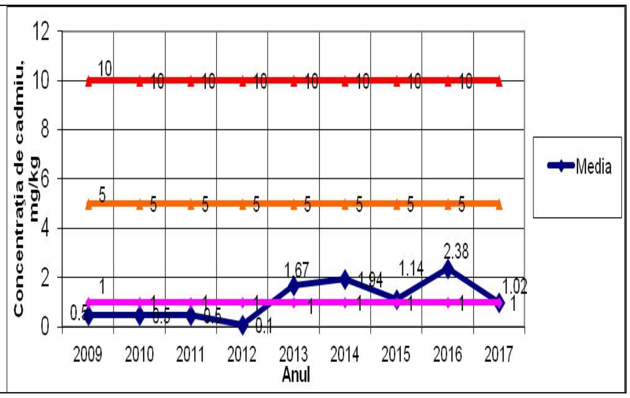
Table 7.2 Limit values of soil pollutants content

	Concentration mg/kg							
Elements	Cd	Cr	Cu	Zn	Pb	Mn	Ni	HCP
Normal value	1	30	20	100	20	900	20	-
Alert value	5	300	250	700	250	2000	200	1000
Intervention value	10	600	500	1500	1000	4000	500	2000

The following metals (Cd, Cr, Cu, Zn, Mn, Ni) and HCP petroleum hydrocarbons have been monitored for the following metals (from soil deposited dusts from certain points). The points from which or samples are taken are located at different distances from the generating source.



Sampling Point S6-Cadmium Parameter



Sampling Point S10-Cadmium Parameter

Regarding the cadmium content the alert value was not exceeded, only in four cases were values above the normal ones (1mg / kg), namely: in 2013 the value was 1.44mg / kg, in 2015 the value was 1 , 04mg / kg, in 2016 the value of 3.46mgkg was registered, and in 2017 the value of 1.59mg / kg was recorded.

Regarding this parameter, the situation is similar to the one presented for sampling point S6.

Analyzing the results of the research results the following conclusions:

- sampling and sampling points have been well chosen in view of the location of the source of pollution, the distances from the source and their orientation from the point of view of the air currents;
- the analyzed components were well established taking into account the structure of the furnace load (the metallic and non-metallic parts), as well as the intense use of oxygen for both the burners and the metal bath (intensification of the oxidation processes);
- there is a correlation between the metallic elements in the analyzed samples and those in the metallic load structure eg for chromium, manganese, zinc, etc .;
- it can be considered that there is a preoccupation for a good preparation of the metallic load in the sense that it is advanced recovered from copper waste (very high economic benefits) and, to a large extent, lead (it may increase recovery);
- there was also a good sorting of old iron in terms of alloying (explained by the low chromium and nickel content);
- Zinc can be considered to have greatly improved the preparation of the metal loading (sorting-dosing), but the sorting process should be continued;
- regarding oil pollution (HCP), it was very little influenced by technological processes, and more so by economic restructuring processes (especially by the complete decommissioning of technological flows) of the former steel mill;
- it should be noted that from the visual observations regarding the structure of the load the aluminum wastes are recovered in the proportion of 98-100%.

Chapter 8 includes Research on environmental noise pollution in the area of electrical steelworks.

Acoustic pollution, also called noise pollution or noise pollution, is a component of environmental pollution caused by noise [65,66,67].

Noise is defined as a complex of sounds of a non-regular nature with random disagreeable insurgency that affects the psychological and biological state of humans and other organisms in nature. The physical or objective characteristics of the noise concern strength or sound intensity, duration and frequency. Intensity is the most important feature that depends on the features of the source, the distance, and the possibilities of transmission or multiplication.

It is measured in decibels (dB) or foni [19/65].

It was admitted that the figure 80 on the scale of decibels, or on the scale of foni, represents the threshold at which the intensity of the sound becomes harmful. Excessive exposure to intense noise over long periods of time causes deafness [19/65].

In acoustic pollution studies, sonometers that measure the sound pressure level are used to determine almost any type of noise, especially for industrial, environmental and airport noise. With these, with repeated measurements, a noise map of a locality or area [65, 66, 67] can be obtained.

The sources of acoustic pollution in the industrial environment are: compressors and turbochargers, fans and turbochargers, ventilation systems, high velocity fluid piping, pumps and electric pumps, thermoelectric power stations, fans, power generators, piston compressors for supply compressed air, steam boilers, industrial furnaces, electric arc furnaces, plastic deforming machines, metal scrap processing machines (sons, crushers, dynamite breakers, hammer mills), metallic clothing manufacturing equipment, etc.

Table 8.1 Position of the noise detection locations

Nr. crt.	Position Post Noise Determination	Distance from source of pollution, position in m,N,S,E,V,NV.Sv…..
1	The enclosure limit carries OE2 steel	150 m
4	The limit is within the dusting area	150 m
5	The boundary of the entrance gate laminae	500 m
6	The enclosure limit next to the gas pressure control station	750 m SE
7	The limit includes the PETAC stream	2500 m S
8	Limit the enclosure to the Cylinders Reconditioning Workshop	2000 m SE
Noise Maximum value Admissible 65 dB (A)		

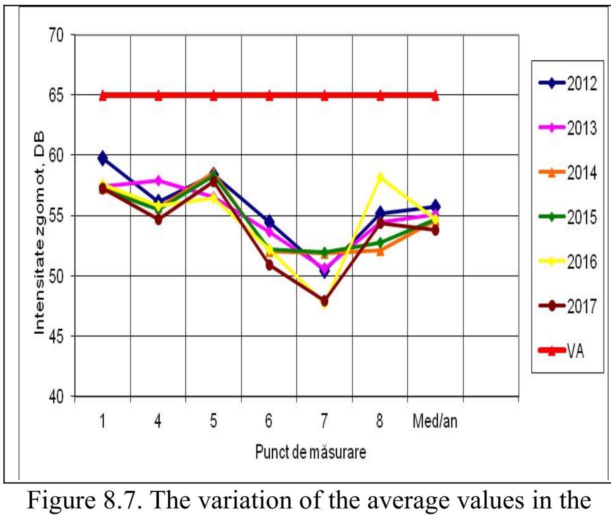


Figure 8.7. The variation of the average values in the measuring points for the period 2012-2017

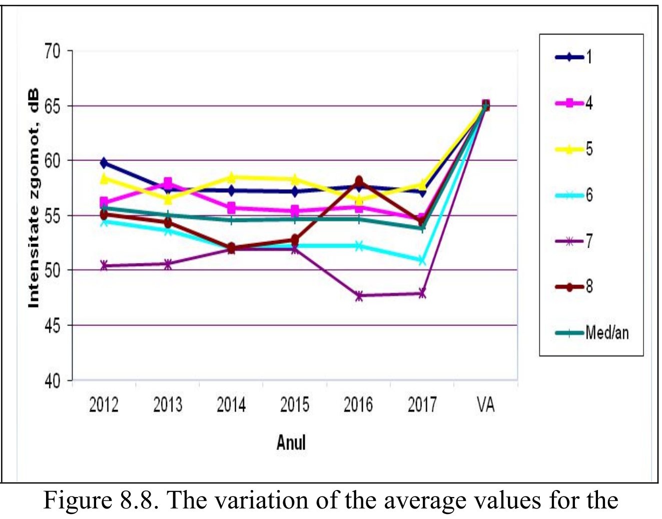
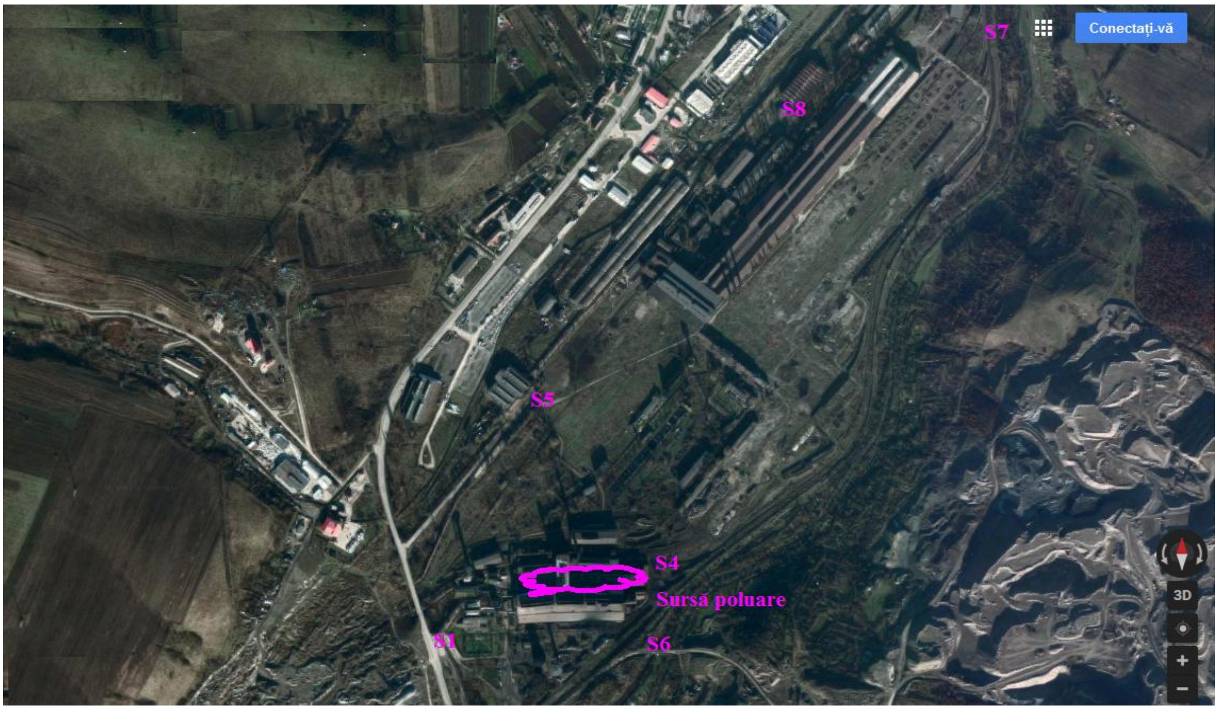


Figure 8.8. The variation of the average values for the period 2012-2017 at the points of determination

Processes in the steel industry, such as steel casting and casting, in addition to generating intense pollution with solid suspensions and gases, also generate noise. Under these circumstances, steel units equipped with electric arc furnaces, especially those equipped with high power transformers (working under UHP and SHP), generate the greatest noise pollution.



The researches related to the elaboration of the present doctoral thesis were aimed at determining the noise intensity analysis in the area of an electrical steel equipped with electric arc furnace (type EBT) of 100 tons capacity and pot processors (LF and VD). The cast steel was cast in semifinished form on a five-wire continuous casting plant.

The investigations carried out aimed to determine the noise intensity at different locations (locations) of 6 in the steelworks area (some corresponding to those for determining chemical pollution at ground level). The positioning of these locations with reference to noise source is presented in Table 8.1

Analyzing the data in Figure 8.7 it is observed that the highest mean values for the period under review were obtained in the case of point S1 and the lowest for S7 point, which are between 48-60dB. The smallest annual averages were in 2017 and the highest in 2012, the situation being technologically explicable by improving both the degree of load preparation and the better functioning of the electrical arc furnace housing.

From Figure 8.8. it is noticed that in any year and at any point the average annual value over 60dB was not exceeded and they were over 50 dB with the exception of point 7 where it was 47.5dB in the years 2016 and 2017.

From the analysis of the values of the noise intensity determined at different points (8) of the metallic load structure and of the degree of preparation of the load and the distance from the generator source, the following conclusions can be drawn:

- the degree of preparation and the structure of the metallic loading, the order of insertion and distribution of the metallic and non-metallic loading in the dump, the electric regime of the furnace, especially during the melting, influences the noise intensity;
- the higher the noise level measurement source than the source of the noise, the noise intensity is reduced;
- EBT electric arc furnaces with soundproofing systems, good operation (primarily continuous) substantially reduce the noise intensity;
- the noise intensity is also influenced by the existing constructions between the measuring point and the source of generation, especially if they are not noise generating (situation existing in the analyzed case, these are in fact decommissioned industrial plants, some partially or completely others) of "vegetal curtains" (on different surfaces and different heights).

Chapter 9 presents the industrial verification of the results of the research carried out.

The industrial verification of the research results was followed by the use of a good quality load both in terms of composition, content of non-metallic materials, non-ferrous metals and advanced prepared in terms of batching (brought to size suitable for batching: medium cut, and slightly bundled). The check was done for 6 batches, out of which 5 with an improved quality load, the proportion of bark, especially domestic, the range of crushing and internal recycling, decreased the share of the E1 and E3 assortments. For lot 6 a load with a significantly lower proportion of E1 and E3 was used for comparison, the E5 and E100 assortments remained constant and the proportion for the other components increased.

The composition of the load, with reference to both metallic and nonmetallic (materials for slag forming, bathing, bathroom deoxidation, etc.), the duration of the technological operations are presented in table 9.1.

Table 9.1. Structure of the metallic and non-metallic load of the electric arc furnace

Nr. Charge Exper.	Structure of metallic load																		Liquid steel	Removal of liquid steel
	E1		E3		E5		E100		SC.C		SC.I		REC. int.		Casări		TOTAL			
	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	39,5	29,04	36,4	31,14	6,1	5,22	5,4	4,62	6,4	5,47	7,5	6,42	9,3	7,96	5,5	4,71	116,9	100	106,7	91,22
2	40,3	33,75	35,2	29,48	6,4	5,36	5,3	4,44	7.8	6,53	8,4	7,04	10,6	8,91	6,4	5,36	119,4	100	108,7	91,04
3	38,7	31,13	37,7	30,48	6,1	4,93	5,6	4,53	8,2	6,63	8.2	6,63	10,4	8,41	6,8	5,50	123,7	100	111,2	89,89
4	37,8	30,78	40,3	32,80	6,3	5,15	5,2	4,15	8,7	7,11	8,1	6,42	9,8	8,01	7,2	5,58	122,4	100	109,7	89,63
5	41,6	34,35	34,5	28,49	6,2	5,12	5,1	4,21	9,3	7,68	8,2	6,77	8,5	7,02	7,7	6,36	121,1	100	110,1	90,92
6	28,8	22,62	28,7	22,62	7,9	6,21	6,5	5,11	10,1	7,87	21,6	16,91	11,9	9,34	11,8	9,34	127,3	100	108,6	85,32

SC.C –commercial bark; SC.I - internal bark; Internal recycling

Nr. charge Exper.	Metallic load			Auxiliary materials										Technological operations				
	Ferro-alloys			Flux agents				Fuel			Gas Injector / Lance			C_{SEE}	Duration of operation. Tec.			
	FeMn	SiMn	FeSi	Var	TopexCa	Topex	MS	Cocs	Gra.L	C.inj.L	O_2 .ij	O_2 L	CH_4	.	A+Î	T .	A+E	Tot
0	21	22	23	34	25	26	27	28	29	30	31	32	33	34	35	36	37	38
	kg	kg	kg	kg	kg	kg	kg	kg	kg	Kg	m..c.	m.c.	m.c.	kWh/t	min	min	min	min
1	354	435	356	3100	480	220	615	900	125	675	2535	426	435	552	11	41	25	67
2	376	427	423	3250	462	235	586	900	136	634	2450	438	413	561	13	44	23	80
3	492	465	457	3650	415	325	564	900	156	765	2765	469	498	573	12	46	24	82
4	465	438	412	3545	480	345	548	890	138	754	3258	523	476	586	12	45	25	82
5	376	476	464	3780	445	310	574	900	138	675	3125	512	465	574	11	43	24	68
6	546	542	512	4250	510	395	664	920	150	858	3565	652	564	602	15	48	25	88

Gra.L- graphite injected into the bathroom through the lance; L-carbon injected in the bath via the lance; O2. ij. Oxygen consumption in injectors; O2 L-oxygen consumption at the lance; CH4 - consumption of methane gas injector; A + H - adjustable + charge; T-melting time; A + E Duration of extinction + evacuation; T - total duration of the batch; CSEE - specific electricity consumption kWh / tonne liquid steel;

As with the 98 batches analyzed in chapters 4-8, casting and casting were made at the same steelwork, the same aggregate, more precisely respecting the same technological flow and the same technological instructions.

In order to carry out the above mentioned experiments, the preparation of the load for the 6 batches was prepared in advance, and all 6 batches were programmed with the same steel mark, which was feasible because the experiments had not only the verification of the results but also the concern of the steel plant for improving the technological, economic and environmental development process (in the direction of increased metal removal, electricity and electricity consumption, pollution, and manufacturing costs).

Analyzing the data from table 9.1 regarding the structure of the metallic load, we can see the following:

- for batches 1-5, in which the load is composed of good quality and very good quality, well-prepared, the removal of metal was between 89-95%;
- for the same batches the specific electricity consumption ranged between 550-590 kWh / t of liquid steel, the technological explanations being similar to the ones described above, and the fact that the load was advanced, allowed the furnace to be loaded from 3 bene, which reduced the heat loss caused by the rebate of the vault, on the one hand, and on the other hand the reduction of the duration of the melting, so of the batch;
- by working with an advanced load ready for charging, the transformer can be used to the maximum power limit, which leads to shortening the duration of the batch, respectively increasing the productivity;
- in the case of the batch No.6 where the load was of good quality / acceptable, the removal was 80.52% and the specific electricity consumption of 602kWh / t of liquid steel;
- for the other technological parameters there are no significant differences;
- in conclusion the results of the researches are confirmed.

Chapter 10 presents final conclusions, original contributions, directions for further research and dissemination of results.

From the analysis of the studies and researches carried out at the industrial level, a series of final conclusions stand out as follows:

1) At the national level, steel companies are equipped with oxygen converters, electric arc furnaces, potting plants (LF and VD), continuous casting plants and, where appropriate, different types of rolling mills, deforming plants hot and cold plastic;

2) Oxygen-powered steelworks are only one, namely SC ARCELORMITTAL Galaţi, and steel arc furnaces equipped with electric arc furnaces in the following companies: SC ARCELORMITTAL Hunedoara, S.C. TMK Resita; COS Targoviste;

3) Well-documented presentation of ferrous products that make up the batch, both in qualitative terms and in processing technologies, the load being composed of a relatively large number of components, depending on the possibilities of supply, the cost price, the condition preparation for batching, non-ferrous metal content and non-metallic materials;

4) References to the recovery of waste from electrical and electronic components as well as end-of-life vehicles are well documented, especially as the development of techniques has led and leads in the future to the quantitative increase of metallic (ferrous) scrap from these sources;

5) Regarding the use of pre-treated materials (RDI and HBI iron sponge, metallic pellets, metallic agglomerate), these are well presented, both technically and economically;

6) Also, in synthesis, there are well presented the metal scrap processing machines and technologies for batching;

7) From the analysis of the structure of the metallic load for a number of 98 batches elaborated in the EBT electric arc furnace, it resulted that it consisted of a number of 8 metallic groups, with a large participation but acceptable from the point of view technologically and economically;

8) Large weight in the load had E1 and E3 assortments; fairly close was also the share of high quality external ferrous bark (commercially available) (severe conditions at reception);

9) A significant contribution was also the proportion of internal bark, both in the case of the frequently occurring fluxes on the technological process of casting-casting, as well as those resulting from the slag processing on the dump, with the observation that the first batch of bark is (on average small amounts of non-metallic material) compared to the other (with high

proportions of slag, refractory, earth, etc.) which sometimes has less than 50% Fe (confirmed by several tests);

10) There have been no particular problems with the E5 and E100 iron assortments;

11) With regard to the types of recycling and scrapping, even if they are in relatively small proportions, special attention is paid, in particular, to scraps (non-ferrous metals and alloying elements);

12) Ferroalloys are used within technological limits;

13) As regards auxiliary materials (fluxes and fluidifiers) it should be mentioned that lime, dolomite, topex, topexCa are used, within the usual limits applicable to current technologies;

14) The use of oxigaz burners led to the reduction in the duration of the batch, and the addition of carbon (coal dust) and oxygen led to a good foaming of the slag, with well-known effects;

15) The removal of metal varied within very large limits, the reasons being: the large number of ferrous products, the variation of their proportions in the composition of the batch, their quality, the degree of preparation for batching;

16) Data processing in the EXCEL and MATLAB computation program allowed the establishment of correlations expressed both analytically and graphically: simple (polynomials of 1-4, exponential and power) in the first case and doubles, analyzed analytically by three types of equations (polynomial grade 2 and 5, respectively polynomial-logarithmic combination) and graph (regression surfaces and level curves) for the second case;

17) On the basis of the correlations obtained, the optimum load structure was established and can be corrected at any time, depending on the availability of ferrous material;

18) Specific consumption of electrodes is one of the main indicators for the process of making steel in electric arc furnaces, in this case it is correlated with the structure of the metallic load; the obtained data were processed in the EXCEL and MATLAB calculation programs, obtaining simple and double correlations, analytically and graphically, based on the analyzed indicator;

19) For any technological process, specific energy consumption is taken into account, with careful consideration of the possibilities of reducing it; as a result, and within the doctoral thesis, the possibility of reducing the specific consumption of electricity (kWh / t of liquid steel) was pursued;

20) In the analysis carried out, factors of influence on specific electricity consumption were taken into account: load structure (ferrous load), batch weight and number of loads / bene, the latter factor being well correlated with the degree of preparation the old iron for charging;

21) The data collected for the technological analysis were processed in the EXCEL and MATLAB computational programs, the simple and double correlated analytics and graphs, based on the possibilities of reducing the specific consumption of electricity;

22) In view of the pollution generated by industrial activities, and especially those in the iron and steel industry, the pollution of the soil with electric steel dust was analyzed in its area;

23) The assessment of the pollution was assessed on the basis of the chemical composition, the composition of the components being expressed in mg / kg of dust; the content for each component is related to the structure of the load, the location of the collection points, the "barriers" between the collection points and the source of the pollution, the weather conditions, etc .

24) Normal, alert and intervention values were considered in the analysis; it is worth mentioning that in a few cases the alert values and far less intervention values were exceeded and could be considered as isolated cases;

25) Determinations were performed for samples collected at 7 points, for each collected material being determined the content for 8 components deposited over 7 years;

26) In addition to chemical pollution, many industrial branches frequently produce environmental noise, as is the case with electric steel equipped with electric arc furnaces (type EBT in SHP mode); the noise measurement was performed at 6 points in the steelworks area for a period of 5 years, the permissible limit being 65dB, not exceeded in any case;

27) The results obtained during the verification / industrial valorisation of the results of the researches confirmed their validity.

Original contributions

Based on the study of the specialized literature, referring to the topic of the PhD thesis, the experiments carried out at the industrial phase, the technological analysis, the results obtained and their industrial verification, the following can be considered as personal contributions:

1) Based on the study of the literature on the topic of PhD thesis of syntheses:

-procedures and current technologies for steel production and casting;

- ferrous materials used in the steel production process, provenance, qualitative characteristics, classification, methods of preparation, etc .;

-technologies and machinery for mechanical processing of metallic waste;

-expanding the range of raw materials and auxiliaries used in metallurgy / ironmongery;

2) Analysis of the structure of the 100-tonne EBT electric arc furnace load in terms of ferrous products, used ferroalloys, fuel and oxygen used (for 98 batches);

3) Establishing, on the basis of the processing of industrial data in the EXCEL and MATLAB calculation programs, the optimal structure of metallic loading (function and supply conditions) in order to increase metal removal;

4) Recommendation of the correlation of the structure of the metallic load with the availability of ferrous material (depending on the conditions of supply, cost price, possibilities for preparation for charging, etc.);

5) Analysis of the specific consumption of electrodes according to the structure of the load (comparison with the optimal one);

6) Determination of correlations of dependence between the specific electricity consumption, the metal load types, the batch weight and the number of loads (compared to the optimal load);

7) Motivating / justifying the use in the metallic load of a lower metal product range by correlating with environmental norms and cost price;

8) Motivating the need for advanced load preparation in terms of non-metallic components, sorting by alloying degree, size and degree of alloying;

9) Determination of the chemical composition (8 components) of the steel powder deposited in 7 collection points (2012-2017) and its correlation with the structure of the metal load, technological factors / parameters, positioning of the collection / deposition points / sources from the source the weather conditions, obstacles between the two positions; In the analysis performed, the normal, alert and intervention limits were considered;

10) Determination in 6 points of the noise level and its correlation with the load, the degree of preparation, location, obstacles / obstruction, furnace charging (admissible value for noise intensity 65dB);

11) Industrial verification of the results of the research, namely the load structure, which confirmed their validity, namely: E100 - 4-6% assortment; commercial bark 10-20%; internal bark 10-20%; internal recycling 8-10%; cents 4-6%.

Based on the results obtained in the research conducted on the topic of the PhD thesis, it can be considered as of particular interest to the metallurgical / steel industry and not only the continuation of the researches in the following directions:

1.Processing in the steel companies, steel products, slag by-products and steel slag (ferrous fraction) in the form of agglomerated metallic briquettes and pellets, depending on the quantities available and their incorporation metallic loads (blast furnaces, oxygen converters, electric arc furnaces etc);

2. Valorisation of reducing slags (LF and VD) in:

- agglomeration, briquetting and pelletizing processes (founder and binder);
- the cement and refractory industry;
- Basic amendment to agriculture.

3.Recycling in metallurgy waste resulting from the dismantling of WEEE (electrical and electronic waste);

4. Higher utilization of materials resulting from the dismantling of end-of-life vehicles (VSUs) in the metallurgical industry (with special attention to their sorting by degree of alloying), chemical, building materials;

5. Advanced utilization of tailings from the metallurgical (ferrous and non-ferrous) industry, mining (coal, ores, minerals, etc.), chemical, energetic etc., deposited in heaps and ponds.

DISSIMINATION RESULTS

- **C. D. Păcurar**, T. Heput, E. Crișan, "The influence of the structure of the metal load removal from liquid steel in electric arc furnaces", International Conference on Numerical Analysis and Applied Mathematics ICNAAM 2015, SEP 23-29, Rhodes, Grece, AIP Conference Proceedings, Volume 1738, Article Number 080007, 2016 indexat ISI, (DOI: 10.1063/1.4951842, WOS:000380803300092).
- **C. D. Păcurar**, T. Heput, M. Ardelean, "Optimizing the structure of metal load in order to reduce electricity consumption in the production of steel", International Conference on Numerical Analysis and Applied Mathematics ICNAAM 2015, SEP 23-29, Rhodes, Grece, AIP Conference Proceedings, Volume 1738, Article Number 080006, 2016 indexat ISI, (DOI: 10.1063/1.4951841, WOS:000380803300091).
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