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Optimization Of Furnace Working Index

Optimization Based on Linear Programming, Usage of Principle of Linear Programing for Optimization of Parameters of EAF Work

Ilyasu Kayode Okediran[1*], Olayide Rasaq Adetunji[2], Adeboye Busayo[1], Idris Musibaudeen [1], Adefajo Abdulhafiz[1]
[1] Mechanical Engineering Department Osun State University, Osogbo Osun State
[2] Mechanical Engineering Department Federal University of Agriculture Abeokuta
*Coresponden auhtor: okedirani liyas@gmail.com

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Abstract
The need for high quality product has necessitated the scientists to put in more effort to produce metal of high quality at lower price. This job considered the possibility of optimizing the product and brings out the product at cheaper price. Nigeria as a developing country needs metal for different purpose like construction of roads, houses, bridges, and other infrastructure. Defined parameters of optimum work of EAF-50 comparing with the basic variant expenditure by limit has reduced by 33% (from 41,1 to 28,2 Ruble\ton) Relative usage of electric energy by 51% (from 0,5463 to 0,2669 mw Hour/ton) Hour productivity rose by 74% (from 71,17 to 123,61 ton/hour).

Keywords: Expenditure; heat loss; refinery; cost price; optimization; melting period; refinery period; useful energy.

Abstrak
Kebutuhan akan produk berkualitas tinggi menuntut para ilmuwan untuk lebih berupaya menghasilkan logam berkualitas tinggi dengan harga lebih murah. Pekerjaan ini mempertimbangkan kemungkinan untuk mengoptimalkan produk dan mengeluarkan produk dengan harga lebih murah. Nigeria sebagai negara berkembang membutuhkan logam untuk berbagai keperluan seperti pembangunan jalan, rumah, jembatan, dan infrastruktur lainnya. Parameter yang ditentukan dari kerja optimal EAF-50 dibandingkan dengan pengeluaran varian dasar berdasarkan batas telah berkurang sebesar 33% (dari 41,1 menjadi 28,2 Rubel\ton) Penggunaan energi listrik relatif sebesar 51% (dari 0,5463 menjadi 0 ,2669 mw Jam/ton) Produktivitas jam naik 74% (dari 71,17 menjadi 123,61 ton/jam).

Kata Kunci: Pengeluaran; kehilangan panas; kilang minyak; harga biaya; optimasi; periode pencairan; periode kilang; energi yang berguna.

1. Introduction

Approximately 65-90% of total refineries energy for heating is provided by furnaces. Chemical industries such as oil, gas and petrochemical comprise a set of diverse heating and cooling processes in many of them it is necessary that some of liquids to be heated to a certain temperature. This Processis generally done by furnaces, in essence are a kind of heat exchanger that transfer the thermal energy obtained from burning fossil fuels in a closed space to a process liquid which in coils or locked up Pipe flows.

Heaters are usually designed for uniform heat distribution. the average radiant heat flux specified is defined as the quotient of total heat absorbed by the radiant tubes divided by the total outside circumferential tube area inside the firebox, including any fitting inside the firebox. The rows of convection tubes exposed to direct radiant shall be considered as being in the radiant section and the maximum radiant heat absorption rate shall apply to these tubes, irrespective of whether extended surface elements are used or not. The maximum radiant heat flux density is defined as the maximum heart rate to any portion of any radiant tube (Alireza & Vuthaluru, 2010).

One of the most common furnaces in industry is the draft type which operates by high temperature difference between burner and stack. This means gases density inside furnace will be less the density of the air of surrounding area. This difference in the density causes that pressure inside furnace to be less than pressure of the air at each point of the same height outside furnace. Therefore, all points inside furnace have lower pressure relative to the pressure of surrounding area. This results in a relative negative pressure. This phenomenon is termed „chimney effect" or „natural draft". Under influence of this phenomenon, the air required for burning is naturally sucked in and after mixing with fuel and burning, resulted gasses from burning transfer their heat to process liquid and exit stack (Wildy, 2000).

Furnace designs vary as to its function, heating duty, type of fuel and method of introducing combustion air. Different typical furnace configurations for petroleum applications are shown in Fig. 1. The preferred design of furnaces is mostly of the radiation-convection type, since it uses the flue gas heat more effectively getting higher thermal efficiency and lower fuel consumption (lower operating costs) than the stand-alone convection or radiation types. Some types of process fired heaters presented in Figure 1 are: (a) radiant, shield, and convection sections of a box-type heater; (b) heater with a split convection section for preheating before and soaking after the radiant section as can be seen in Figure 1, furnaces have some common features, however. The main parts of a furnace are the radiation chamber, convection section, burners, tubes, and stack. The heat input is provided by burning fuel, usually oil or gas, in the combustion chamber. Fuel flows into the burner and is burnt with air provided from an air blower (Mussati et al., 2009).

Increase in thermal performance of furnaces, given increase of fuel price in recent years, is a very important issue. Correct design and optimally setting operational condition has impact enhancing performance of furnace. Thermal efficiency usually is defined as ratio of absorbed heat to total incoming energy (Ibrahim & Al-Qassimi, 2008).

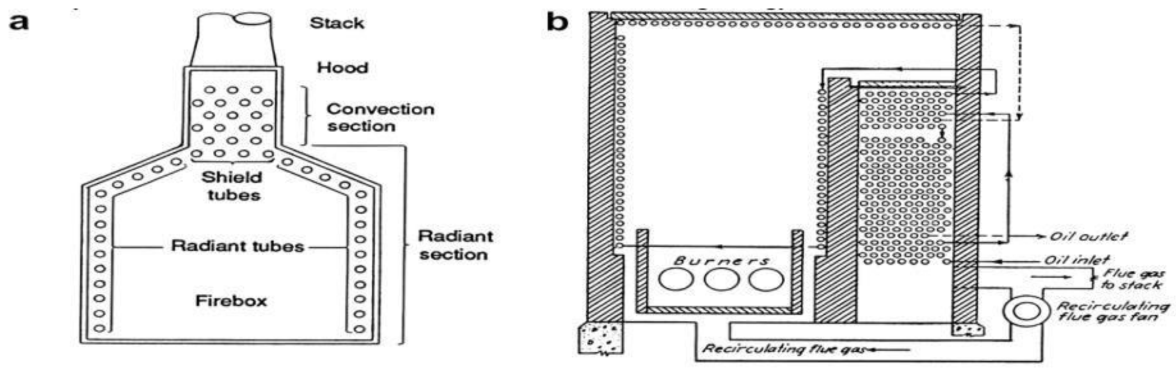

Fig. 1. Different box furnace configurations.

Jegla (2000) using optimization of stack temperature and air heating system registered a new method for furnace operation. This method is based on process integration using pinch technology and is for saving in energy consumption. This paper shows that using of gasses exiting stack energies for heating the air by a little change in operational parameters, could reduce annual energy costs of a refinery up to 20%.

Also in recent years, Jegla (2006) presented a method for design of furnaces burner which was based on models developed by Lobo-Evans, Bloken and by defining a target function based on minimizing annual costs of furnace, presented its optimum design.

There are different methods for increasing a draft type of furnace performance. The most common and effective ways are:

a. Reduction of thermal wasting in walls using insulation
b. Improvement of temperature condition in burner
c. Improvement in energy recycling in transport sector
d. Reduction of unburned carbon on internal and external surface of the furnaces.
e. Installation of pre-heater
f. Control of excess air.

Amongst the above-mentioned methods, pre-heating of air is normally applied possible for large furnaces and method of excess air control is one of the most common methods which are recommended for furnaces with low thermal performance. However, its effectiveness is and depended on operational conditions and can be studied (Jegla, 2006).

Burning process requires a certain amount of air that for its accurate calculation, fuel combination should be determined. If in burning process of hydrocarbons there is not enough oxygen available, compounds like carbon monoxide are created which have undesirable effects on bio-environment. Therefore, for obtaining full burning and ensuring polluting substances are not formed, a percentage of excess air is normally considered for the combustion process. Even though use of excess air, prevents production of compounds like carbon monoxide, but in practice, its amount cannot be more than an optimum level. Since any excess air which does not react with air will escape from the exitsstack, the more its amount is, the more thermal energy is wasted. Hence as a principle for design and operation of furnaces the amount of excess air is regulated in an optimal condition which prevents bothincomplete burning of the fuel and thermal energy losses. Two main parameters used in examining a furnace performance are temperature of exiting gasses from stack and amount of excess air (or oxygen), in stack gasses. As a rule of thumb, reduction of excess air of stack gasses to the amount of 10% orreduction of temperature stack gasses for 20ºC by pre-heater of the air, will cause 1% increase infurnace performance.

To enhance furnace or boiler's efficiency and improvement of its functioning condition, the first and most effective action is regulation of excess air. Now, in most furnaces and boilers, amount of excess oxygen and draft of stack gasses are measured which are proportional to excess air. Desirable amount of excess oxygen in furnaces and boilers gas fuel shown by analyzer in exiting gasses is 3% and suitable amount of draft is about - 0.3 (Marcel et al., 2003). If there is no sufficient air for burning of fuel, then diffusion of unburned hydrocarbons and monoxide will increase. However, a high level of excessive air in combustion process will produce NOx Fig.2 shows amount of diffusion of CO and NO with excess air in burning stoichiometric methane with the air in ambient temperature. Increasing the excess air, the amount of CO decreases but that of NOX decreases sharply before declining. It is crucial to have an optimum amount of excess air in the combustion process to control both CO and NOX. Burning efficiency depends on ratio of fuel to the air. In practice, use of 2 to 3% excess oxygen (about 15% excess air) indicates most suitable performance (Garg A, 1998).

Generally, solvable problems by linear programming are finding, by giving criteria, the maximum and minimum linear functions, with limited defined conditions. From here emerged the term "linear programming". From numerous variant possible solutions of problems, we choose the optimum which answers all conditions and maintains optimum value of giving chosen criteria (Solomahin & Portuova, 1972).

Aim and objective of this work is generally solving problems by linear programming is finding, by giving criteria, the maximum and minimum linear functions, with limited defined conditions. From here emerged the term linear programming choosing the optimum which answers all conditions and maintains optimum value of giving chosen criteria from numerous variant possible solutions of problems. All the data used in this project were collected from active Metallurgic plant in Zerepaves, Russia.

2. Method and materials

Many Electric Water Heaters EWH. Models and control strategies have been proposed for optimizing and controlling the energy usage of the EWH (Booysen, J., & A, 2013; Lu & Katipamula, 2005). The performance of several different control strategies of an EWH under dynamic prices is analyzed in (Lu & Katipamula, 2005). Booysen et al. (2013) proposes a system for the time control of EWHs with wireless communications and machine networking. A two-node EWH model, proposed in Nei et al.(2018), can realize the control of an EWH in a computationally inexpensive and accurate way. Du & Lu (2011) introduces a systematic way to formulate an optimal load scheduling model of an EWH considering temperature constraints. However, the details of the cold-water mixing process in many research works are usually neglected. The cold -water mixing process includes two processes. In the first process, the cold water entering the tank is mixed with hot water inside the EWH tank. And in the second process when the heated water leaves the tank through the outlet pipe, it still needs to be fixed with cold water by the thermodynamically controlled automatic water mixer TCAWM, so that the tap water temperature can keep constant. Many works such as Nei et al. (2018), Du & Lu (2011) consider the cold -water mixing of the first process but neglect the second one. Belov et al.(2016) considers the equations of the EWHs for two processes of cold-water mixing. The flow rate of the output water is controlled by TCAWM to keep the tap water temperature constant. However, when considering TCAWM, the dynamics of the EWHs becomes complex and nonlinear, and cannot be solved using standard optimization algorithms such as mixed integer linear programing MILP. Heuristic algorithms, such as genetic algorithm GA and particle swarm optimization PSO, are common optimization algorithms for nonlinear relations. However, the heuristic algorithms are direct, and have problems such as this long calculation time, weak global search ability (Zbigniew et al.1992). To fill this gap, this paper detailly formulates the piecewise linear approximation functions of the nonlinear thermodynamic model and then adopts a MILP method to optimize the energy usage of an EWH with TCAWM. By this way, the electricity cost can be saved, and specific requests of users can be met.

3. Results And Discussion

In general form, problem of linear programming can be mathematically formed in the following ways, needed to define numbers of non-negative values of unknown $X_1, X_2 --- X_n$ that satisfies the system of linear equations :

$$a_{11x}x_1 + a_{12x}x_2 +\dots+ a_{1nx}X_n = b_1$$
$$a_{21x}x_1 + a_{22x}x_2 +\dots+ a_{2nx}X_n = b_2$$
$$\vdots$$
$$a_{m1x}x_1 + a_{m2x}x_2 +\dots+ a_{mnx}x_n = b_n \quad (1)$$

To get either maximum or minimum expression:

$$f = c_{1x}x_1 + c_{2x}x_2 +\dots+ C_{nx}x_n \quad (2)$$

Here, all the quantities symbolized with alphabets a, b, and c with corresponding indexes. Problems of linear programming in short form looks like the following.

Maximizing (or minimizing) $= \sum_j^n = 0\ C_j X_j$ with conditions:

H ><= taking non-equality :

$$a_{11x}x_1 + a_{12x}x_2 +\dots+ a_{1nx}X_n \le b_1 \quad (3)$$

Then it can be replaced by equation :

$$a_{11x}x_1 + a_{12x}x_2 +\dots+ a_{1nx}X_n = b_1 \quad (3a)$$

And if for example, in place of first equation is written non-equality:

$$a_{11x}x_1 + a_{12x}x_{2} + \cdots + a_{1nx}\, X_n \leq b_1 \tag{4}$$

Then it can be replaced by equation :

$$a_{11x}x_1 + a_{12x}x_{2} + \cdots + a_{1nx}\, X_n - X_n = 1 = b_1 \tag{4a}$$

Generally, it can happen that the system for (1) has non-negative solution, I.e., no one body is existing from non-negative number (X_1, $X_{2,}$ $X_{n,}$), that satisfies the given equation. Then it is clear, and problem of linear programming has no solution. Sometimes, equation system (1) contains non-negative solution. Then solution to the given problem is clear.

In real problem of linear programming tenth (hundreds) limit and hundreds (thousands) unknown, i.e., n˃m. In connection with that number of unknown higher than number of equations (limited) problem of linear programming, if only it is solved, it has no number of body solution. That in first instance, create known degree of freedom while choosing this or that variant of solution and secondly, many variants are not so great, that all the solutions were tied for that so as choose the best, impossible even using powerful electronic calculation machine. Here we show solutions of problem by linear programming

By plan or possible solutions, problem of linear programming is called any chosen non-negative value of variable (X_1, $X_{2,}$, $X_{n,}$), that satisfied the equation system (5).

Fixed plan or possible basic solution considered the contained equals to m positive variable (and therefore n-m variable equals to zero). Variable like (n-m), place equal to zero, can be named non-basic variable. The rest variable-based solution in quantity m, founded from the solution of system in equation with m unknown with the condition that this system has only one solution, is a basic variable.

$a_{11x}x_1 + a_{12x}x_{2} + \cdots + a_{1nx}\, X_n \leq b_1$(3). Pivot plan called "borned", if he has number positive variable X_1, $X_{2,}$, ----- $X_{n,}$, that satisfies equation system (5) and so called linear function (maximum or minimum). For two variables, we can use simple geometric interpretation problem of linear programming leads to definition of compound non-negative values X_1, $X_{2,}$which satisfies the following non-equality system.

$4X_1 + 5X_2$	20;	(5)
$8X_1 + 4X_2$	32;	(6)
$X_1 + 3.7$		(7)
$X_1 + 2.5$		(8)

And approach in maximum expression.

$$f = 5.5X_1 + 4.5X_2 \tag{9}$$

Using rectangular system of coordinate on plane and we will search for a point on the plane, coordinate which satisfies the condition (6) and approach in maximum expression (9). On each point on the plane, linear form uses defined value i.e., f is the function of points on the plane. Consider equation with two unknown X_1 and. 4 X_1+ 5X_2 20; (5) If on the axis abscissa piled up random values of unknown x1 and on the axis ordinated values X_2. Calculate the formular.

$$X_2 = \frac{20-4X_1}{5} \tag{10}$$

Then we got graphical image of dependence between variable quantities X_2 in form of a straight-line AB (Fig. 2). the straight line divides the whole plane into two parts. Linear non-equality

4 X_1+ 5X_2 < 20 define points of plane lined in the lower part of the straight-line AB, while linear non-equality 4 X_1+ 5X_2 > 20 lined on the upper part of the line AB.

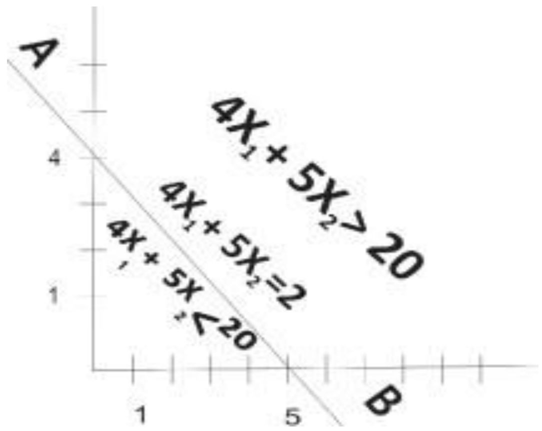

Fig.2 Graph of dependence between variable quantities X_2.

Geometrical interpretation non-negative 4 X_1+ 5X_2 >< 20. Clearly, non-negative system (6) will satisfy the point coordinates that fall within the hexagon OMNPKL (Fig. 3) in this hexagon we found all the points of optimum solution.

In this way, it is necessary to find needed point amongst all points that fall within the hexagon OMNPKL. It is known that coordinate point that gives the optimum solution should also satisfy straight line equation.

$$f_{max} = 5.5X_1 + 4.5X_2$$

Checking the straight form $f_{max} = 5.5X_1 + 4.5X_2 = a$, where a - some constants. Easily seen that in every point, its linear form has the same value i.e. $f = a$. If we take two straight lines type (9), different right-hand parts for example, a and B, then those straight lines will be parallel: on the first of them $f = a$, on the second $f = B$. However, we are interested only on points that fall within the hexagon OMNPKL. Through each of those points passed through only one straight type (9).

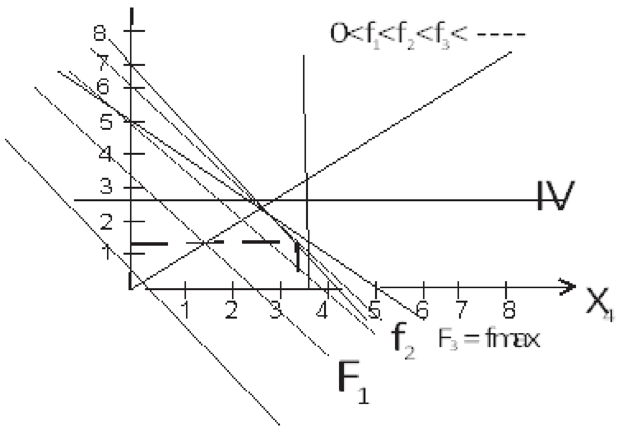

Fig. 3 Graphical interpretation of linear programming.

Changing the value of a, we received many parallel straight lines. The more the value of a, the farther the position of corresponding straight line from the beginning of the coordinates. If we begin with the type where $f = 0(5.5X_1 + 4.5X_2 = 0)$, and further move it along the direction shown by arrow (see Fig. 3). Then we will change to straight line with the bigger value of f, then the former straight line (type 9), which has no common points with hexagon OMNPKL are out of consideration.

So far, our interest is (on the condition of maximum solution) in the possible big values of f. Then we mix the straight line passing through point P. In that position, it will not have common point with the mentioned above hexagon apart from point P. If we mix straight lines in the same direction further, then we will come to that straight line which has non-common points at all with the hexagon.

In this way, the point for our problem - point P. That is the point that its coordinate satisfies system (6), in which linear form f has in it small value. Coordinates X_1 and X_2 of point P can be attained solving the joint equation of (I) and (II) system (6). In the result we found that $X_1 = 3.34$; $X_2 = 1.33$, but $f_{max} = 24.35$. That is the best solution possible for the given condition.

We remark that unknown number that entered with non-zero value in optimum solution, not more than number of limited given problem. In fact, practically often in most cases that number corresponds to number limited problem (II).

3.1 Usage Of Principle Of Linear Programming For Optimization Of Parameters Of Eaf Work.

If we strictly follow linear programming, then it is necessary to forward the system of linear equation:

$$a11 \times x_1 + a12 \times x_2 + \cdots + a1n \times X_n = b_1$$

$$a21 \times x_1 + a22 \times x_2 + \cdots. + a2n \times X_n = b_2$$
$$am1 \times x_1 + am2 \times x_2 + \cdots. + amn \times X_n = b_m \qquad (11)$$

Which for our condition could have been in the form:

$$a11 \times SH + a12 \times T2 + \cdots. \; + a2n \times GO_2 = B_1$$
$$a21 \times SH + a22 \times T2 + \cdots. \; + a2n \times GO_2 = B_2$$

.

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$$am1 \times SH + am2 \times T2 + \cdots. \; + amn \times GO_2 = B_m \qquad (11a)$$

As we see, the role of X_1, X_2,----X_n fulfill variable parameters of EAF work that is SH, Tm, GO2, pTП and so on. However, in the result of this project, we couldn't get equation system 1a. In its place we got equation of the type:

$$a11 \times t + a12 \times W = B_1$$
$$a21 \times t + a22 \times W = B_2$$

.

.

.

$$am1 \times t + am2 \times W = B_m \qquad (11b)$$

Variable parameter SH, Tm, GO2,--- show effect on t and W, therefore given value SH, Tm, GO2, and so on, we can get many equations of type (11b). In which their role Bm fulfill variable part of expenditure of limit i.e.:

CI = A' = Bm (12)

Really our basic equation Ci = n.ti + m.W + A'

Transformed to: n.ti + m.W = Ci – A'

For simplified variant of calculation, value of n and m remained unchanged and for system equation type 1b, we have parallel straight lines in coordinate t and W. The same as in the various paragraph of this chapter in coordinate X_1 and X_2.

Angle of slope straight lines to this axis abscissa (horizontal α) analytical can be defined through tgα. When W = 0, = $t_0 = \frac{C_1 - A^F}{n\,a}$

When, $W_0 = \frac{C_1 - A^F}{m}$

$$tg\alpha = \frac{t}{w} = \frac{t}{w} \qquad (13)$$

Drawn analytical straight lines for more difficult variant calculation are presented on Fig. 4.

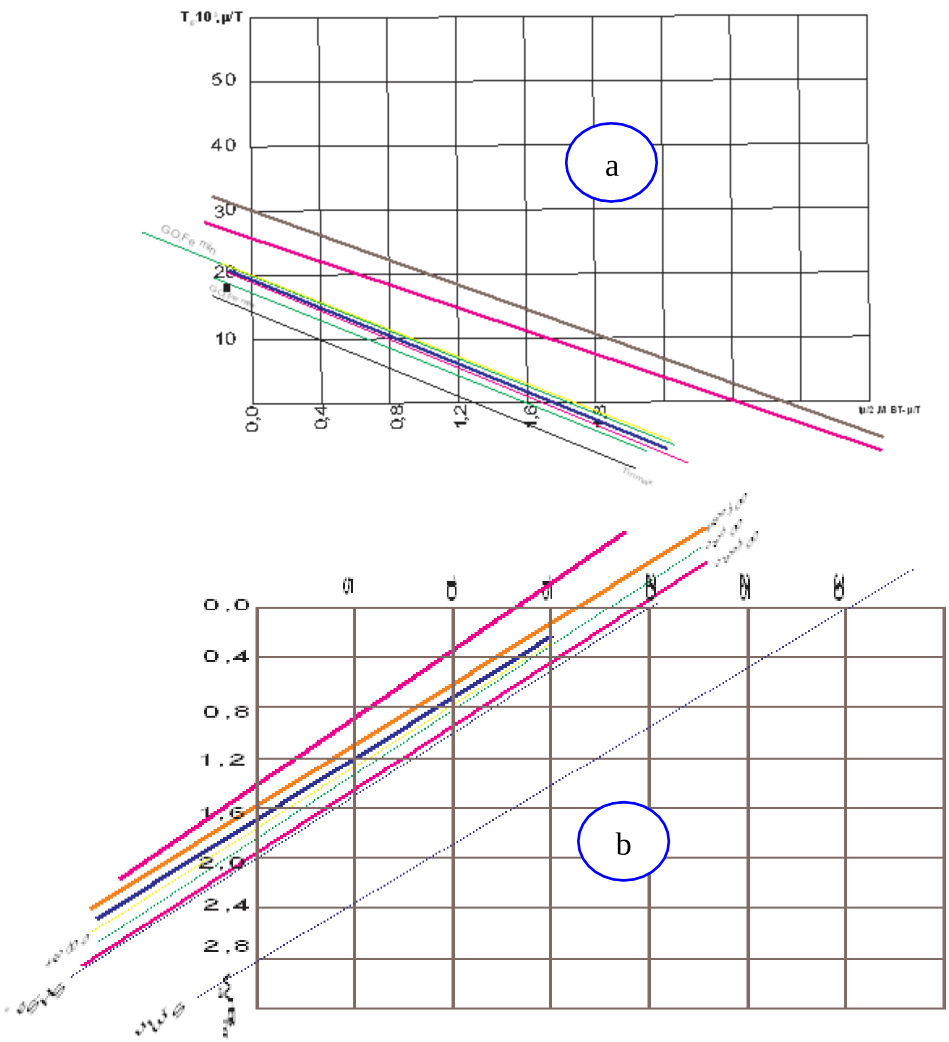

Fig. 4 Draw Analytical straight lines for more difficult variance calculations.

Separate straight line here not passing parallel to the other to the other. And that is understood so far, the values "m" and "n" in more difficult variant changed (see chapter 2). Angle of inclination of those curves easily defined by the known values n and m. On both figures is clearly seen the effect of value of the variable parameters SH, Tm, GO2, and others. On the mixed lines lies the increase of power of furnace transformer on the graph that leads to parallel displacement of straight lines in the direction of the beginning of coordinates, i.e. in the direction of minimization of value Ci – A' (free part of equation) straight line passing through the beginning of the coordinate when Ci – A' = 0.

Plotting a straight line on Fig. 5 is not giving solution to the question about optimization of parameters of EAF work. It is necessary to have 2 more equations from the previous paragraph.

$$f = C_1 \times X_1 + C_2 \times X_2 + \cdots + C_n \times X_n \quad (14)$$

Which for our condition must be presented in the form :

$$K_{SH} \times S_H + K_{TM2} \times T_M + \cdots + K_{G02} \times G_{02} = C_{MUH} \quad (15)$$

Where CMuH – Minimum cost by limit received from equation that gives us possibility during usage of rule of summation of vector quantity.

On fig. 5 were shown numbers of point characterizing working index (t and W) EAF – 50. Upper limit tΣ = 0.1Hour/ton proves that maximum efficiency of smelting under current in 50ton EAF accepted equal to 5Hour and minimum – 45minutes (tΣ = 0.015Hour/ton). Straight lines B1, B2, B3 connected many points characterized those indexes of EAF, by which the cost price by limit are the same. Line "Bδaz" drawn through point B, characterized working index in straight line plane basic variant. As seen, basic variant maintained lower level of usage by limit. We need the modern variant of smelting one-slag process. High powered transformer, water cooling lining shortened liquid (melting) period of smelting.

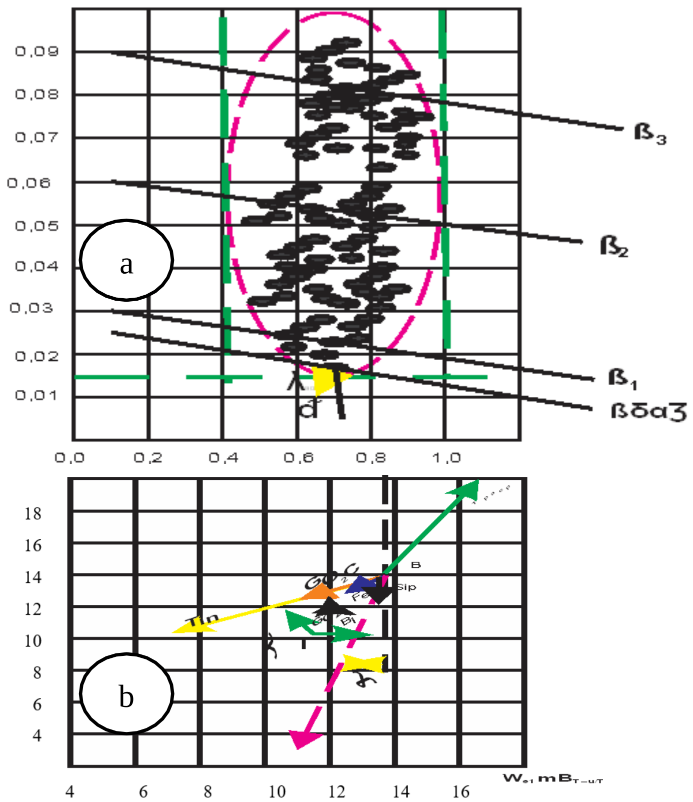

Fig. 5 Number of point characterizing working index (t and W) EAF – 50.

From Fig 5, it follows that the shortest (optimum) way of reducing expenditure by limit is movement from point B to the direction of vector d moving down perpendicular straight line "Bδaz". Angle of that vector with vertical equal angle α shows that for effective reduction of expenditure by limit, more profitable to reduce value of tΣ, i.e., increase productivity of the aggregate. In another economic situation when for example, sudden increase in cost of 1mW-Hour electric-energy and increase in value of m, angle α increases and possibly can be more profitably decreased in usage of electric-energy W.

We define α for the chosen economic situation 1982 of values of n and m. For definition of angle on the graph, it is more necessary to show in expression tgα scale coefficients from calculation 1mW-

Hour/ton = 10cm 1Hour/ton = 200cm, i.e. kW = 10 and kt = 200. tgα = $\frac{m.kt}{n.k_w} = \frac{13.58 \times 200}{1329.27 \times 10} = 0.2043$; from where α = 11.55

On Fig.6 also sows point "B" and optimization vector d. There also vector expression possibly mixing points "B" when changing this or that variables of factors of smelting. (SH, Tm, $GO2^{Fe}$, $GO2^{c}$ pT П, Trpa ф) in those maximum limits which checked in this project. For construction of factorial vectors formulas were used calculations considered in the previous chapter. In comparison with Fig. 6 a and Fig. 6b, we changed scale:

kW = 40cm (cmW-Hour/ton). Where α also changed tgα = $\frac{m.kt}{n.k_w} = \frac{13.58 \times 1000}{1329.27 \times 40} = 0.2554$. Denoting angle of vertical variable parameter I as αi; for example, for Tm like αTm, angle βi is angle between vector variable parameters and vector optimization (d); βi = αi – α.

Angle αi can be found through tgαi which for example, for vector Tm is defined from the relation

$$\frac{\Delta t_{\Sigma i}}{\Delta W_{\Sigma i}} \text{ or } \frac{(t_{\Sigma \delta az} - t_{\Sigma imax})}{(W_{\Sigma \delta az} - W_{\Sigma imax})} \quad (16)$$

With consideration of corresponding scale coefficients:

$$\text{tg}\alpha i = \frac{W_{\Sigma i}.\ KW}{\Delta t_{\Sigma i}.K_W} \quad (17)$$

Defined for each from vector angles αi and βi, we can project vector variables parameters on optimization vector, summing up those projections allows construction of equations. CΣ = Kc . SH + KTm . Tm + ---- + KTpaф . Tpaф). Value of KsH, KTm K can be defined from division of project corresponding vectors (on optimizing vector) on different values of variable parameters.

$$\text{Ki} = \frac{L_{i}.\ Cosa_{i}}{\Pi\Pi_{imax} - \Pi\Pi_{i\delta az}} \quad (18)$$

For example, when i ⇒ SH.

$$\text{KSH} = \frac{L_{SH}.COSa_{SH}}{S_{Hmax} - S_{H\delta az}}\text{, mm/Mwa} \quad (19)$$

Coefficient Kc is convertible. It is known as projection vector in mm and Ruble/ton. Dimension Kc Ruble/ton mm. So far vector SH practically fall to the same direction with optimum vector, then, we define also the numerical value of Kc by known cost price by limit when the furnace work by the basic variant (CSh45) and maximum regime (CSH55). ∆CSH = CSH55 − CSH45 = 38.34 - 41.17 = - 2.83Rouble/ton. Kc $= \frac{\Delta CSH}{L_{SH} \times COS\beta_{SH}} = \frac{-2.83}{19.5 \times 1}$ = -0.145 Rouble/ton mm.

All data and preliminary calculations are presented in the previous discussion. This discussion can show the equation of optimization as follows:

$$\Delta C\Sigma = -0.283 \times \Delta SH - 0.011 \times Tm - 0.265 \times \Delta G^{Fe}_{O2} - 0.140 \times \Delta G^{C}_{O2} + 0.473 \times \Delta Tраф + 0.075 \times \Delta РТП. \quad (20)$$

Reminding that in this equation.

△CΣ – Reduction of expenditure by limit in relation to basic variant (Rouble/ton).

△SH – increase in relation to basic power of furnace transformer (mV.A);

△T – Temperature of heating the budding material k.

$\triangle G_{O2}^{Fe}$ – Oxygen usage going to oxidation of iron (m3/ton)

$\triangle G_{O2}^{C}$ – Oxygen usage going to oxidation of iron (up to 8m3/ton)

△Tраф – Refinery continuity in relation to basic variant (min).

△PТП – Change in power of heat loss (PТПmin – △PТПδaz) mW.

Numerical coefficients for the used scale has unit correspondingly Rouble/ton mV.A; Rouble/ton.k); Rouble/m^3_{O2}; Rouble/m^3_{O2}; Rouble/ton.min; Rouble/ton.mW.

For optimization working index of EAF-50 accepted value of the factors under consideration, namely:

△SH = 10mV.A

△T = 702k.

$\triangle G_{O2}^{Fe}$ = 0

$\triangle G_{O2}^{C}$ = 24m3/ton.

△Tраф = 0

△PТП = -3.083 mW.

Then:

$$\Delta C = -2.83 \times 10 + 0.11 \times 702 - 0.140 \times 24 - 0.075 \times 3.083$$
$$= -2.83 - 7.22 - 3.36 - 0.23 = -13.64 \text{ Rouble/ton.}$$

Expenditure by limit can be reduced by 13.64 Rouble/ton.

3.2 Working Index Of EAF – 50-Ton Optimum Parameters

Using the above changes in parameters of basic variant to initial given for calculation of electric and working characteristics.

New initial data will have the following values:

Melting period

uфПʌ = 368.3V.

UП ʌ = 0.000611Ω .

XПʌ = 0.00367Ω.

Refinery period

uфраф = 368.3V .

uраф = 0.000564Ω .

Xраф = 0.0029Ω .

РТП.Пʌ = 4737kW.

WП0ʌ.Пʌabʌ = 175.4kW-Hour/ton.

РТП.раф = 4624kW.

WП0ʌ.раф = 15.2kW.

TTex = 0.003975 Hour/ton.

The calculations given to the computer as an example for the optimal variance were shown in the previous chapter and coordinates of optimum point (0) on Fig.6.

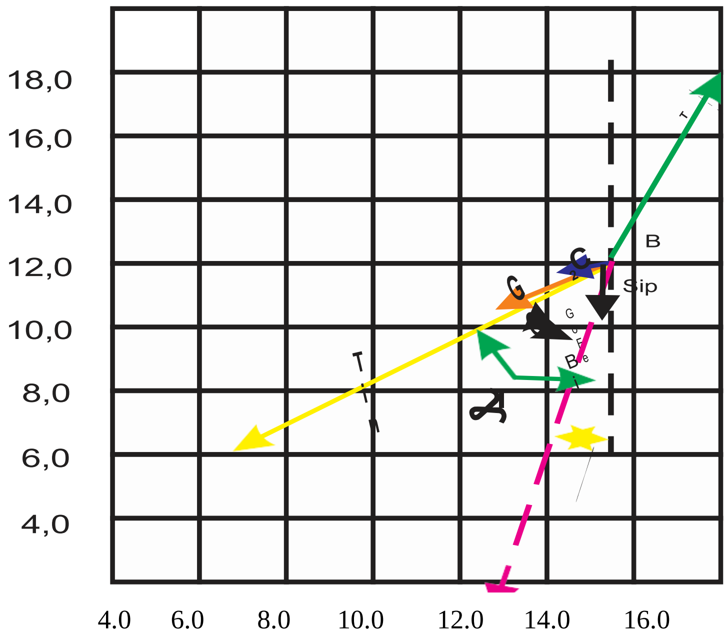

Fig . 6 Calculation for the most optimal variant.

Optimum cost by price limit can be presented as follows:

$C_{\Sigma\delta ag} - C_{\Sigma onT} = \Delta C$

Where $C\Sigma\delta ag$ - Expenditure by limit, by the basic variant of each of the factors under consideration.

C_{onT} - Expenditure by limit, by optimum value of factor.

By this, we define for each factor ΔC expenditure by limit, they have the following form:

$C_{\delta aZ.SH45} - C_{SHmax\ 55} = \Delta C_{SH}$.

$C_{\delta aZ.PTn} - C_{TMmax(100)} = \Delta C_{TM}$

$C_{\delta aZ.GO2} - C_{GO2C(24)} = \Delta C_{GO22C}$

$\Delta C_{\delta aZ.PTn} - C_{PTn} = \Delta C_{PTn}$.

Then we can show them in general form: $\Delta C = \sum_{i}^{n} \Delta C_{i} = \sum_{i}^{n} [C_{\delta aZi} - \Delta C_{i}]$.

We symbolize through $A_{C\delta az.i}$, a Ci through x. So far in general form of our equation, it has the above shown form, then, we can simplify:

(A - X1) + (A - X2) + (A - X3) + (A - X4)

A – [(A – X1) + (A – X2) + (A – X3) + (A – X4)] $= C_{onT}$

A – A + X1 + X2 + X3 + X4) $= C_{onT}$

Expenditures by limit will be defined by formula =

$$\text{A (1 – n) } C_{SH55} + C_{TM100} + C_{G02C24} + C_{PTn100}\ C_{onT\ min} C_{onT} = C_{onT} \quad (21)$$

Value of cost of limit is taken from calculation. See from the previous chapters.

C_{onT}= 41.05 (1 - 4) + 38.34 + 33.63 + 38.67 + 40.86 = 28.24Rouble/ton

4. Conclusion

By observing the above values and chosen factors, we can reduce the expenditure by limit up to 12.845 Rouble per ton value which is very closed to the calculated value of basic usage by limit is not absolutely these condition. On that we were convinced that affectivity of furnace work, 50ton capacity can be realized if we use the value of power of furnace transformer equal Snequal to 55m V. A Syg equal to 1.1mV.Aper ton . Temperature of heating budding material Tm equal to 100K, oxygen usage on carbon combustion, Go2c equal to 24m3 per ton and power of heat loss PTnequal to 4.624mW. Under these conditions, continuity of refinery qÉ equal to 71.17 ton per Hour. Usage of electric energy WEbas equal to 0.5463mW-Hourper ton, and WE of heat loss equal to 0.2669 mW-Hour per ton. Changes during the process are as follows.

Xt_E equal to 0.01405– 0.00809 equal to 0.00596 Hour per ton(42%).

Xq_E equal to 123.6090– 71.17 equal to 52.439 ton per Hour (74%).

XW_E equal to 0. 5463–0.02669 equal to 0.27946 mW-Hour per ton.

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