(RESEARCH ARTICLE)

Effect of continuity of refinery on the working index of electric arc furnace

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Abstract

The need for metal usage is indispensable in the daily activities of human life. Metal is needed for the construction of different infrastructures such as houses, roads, bridges etc but despite the fact there is huge amount of metal available, it does not meet the global demand. Thus this paper investigated continuity of refinery as a measure to improve the efficiency of Electric Arc Furnace. In order to achieve maximum precision during production, getting the product at relatively reduced price has remained a major problem to Scientists. The experiment was conducted at industrial scale whereby the time was varied from 20 to 40 minutes while energy consumption rose from 0.0542 to 0.1103 mW-Hour/ton and productivity fell from 253.0 to 99.2 ton/Hour .The data were collected from active furnace in Zerepaves Metallurgical plant, Russia and analyzed with software package for accuracy. It can be concluded that increasing refinery continuity reduces working productivity of the electric arc furnace.

Keywords: EAF; Steel; Efficiency; Productivity

1. Introduction

Total continuity of melting period can be defined not only by the time of its location under current in the furnace, but also time used on auxiliary technological operation, fulfilled while the furnace was switched off ordinarily on the on-loading of second or the next budding scrap [1-3]. In metallurgical plant firm Vallurek in Anzene France already in 1972, judging by the result of self-chronometry, 60 ton EAF stopped on each pot 3-4 minutes. Continuity of smelting on that furnace was 2 hours in February 1984. Stop time of furnace on each pot in 100 ton furnace plant in Haisewide was averagely 3 minutes, and interval between smelting conducted with ruminants in the furnace 15-25 ton liquid steel – 9.1 minutes. End of smelting here lasted for 3minutes when total cycle of smelting 80.9 minutes. Interval pause when poring each of the pots by scrap was 3mins /0.05hour/and became typical so also for other high productivity furnace can be explained by the fast mechanisms of mixing pots by over-heading cranes, electrodes(0.35-0.75)kW-Hour electric energy [4-7]. Theoretically, by the total energy usage of arc, for that it is necessary $0.86MJ/T^0$ C/ about 0.24KW-Hour/T^0C/.

Judging by these data, in 100ton furnaces relative power 750KV.A/ton and oxygen usage 1000m^3/Hour when 100%of its assimilation, speed of heating metal in the melting oxidizing period of smelting while using high degree, secondary voltage can attain $(12-14)^0$C/minutes. By increasing temperature from 1550 to 1670^{0}C and oxidizing 0.2%of carbon, as it is accepted in energy balance , continuity of melting period can be reduced to 9-10 min, in average up to 15-20 minutes, with consideration of stop-over to furnace to take the specimen of metal and its temperature record [1]. Metal is needed for the construction of different infrastructures such as houses, roads, bridges etc .but despite the fact there is huge

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amount of metal available, it does not meet the global demand. Thus this paper investigated continuity of refinery as a measure to improve the efficiency of Electric Arc Furnace.

2. Methodology

The experiment was conducted at industrial scale whereby the time was varied from 20 to 40 minutes while energy consumption rose from 0.0542 to 0.1103 mW-Hour/ton and productivity fell from 253.0 to 99.2 ton/Hour .The data were collected from active furnace in Zerepaves Metallurgical plant, Russia and analyzed with software package for accuracy.

Table 1 Time for Furnace Operation.

S/N	Operation	Time(s)
1	-Filling the furnace on-loading the first scrap, put on and charge of electrode	20
2	- Melting the budding materials including internal operation pause	55
3	-Oxidation period; Heating and de-carbonation of the metal	15
4	-Delivery of metal from the furnace	5
5	Total	95

This above continuity corresponds to the value of time of one smelting cycle/80-95minutes/; shown in the work on the basis of working index of high productive modern EAF/650-800kV.A/ton/, by authors of the furnaces of 3rd generation.

Continuity of smelting cycle reduced even in subsequent years; in 1985, better results for furnaces capacities (100-120) ton closed to 70minutes. Continuity reduced as a result of intensification of technological periods of smelting and organization of methods, directed to the reduction of delay caused by internal and inter-smelting breaks.

For cutting down the melting time of budding materials under current [2] nowadays, widely use addition of oxygen gas to the working plane of furnace, oxygen chamber , positioned in the wall of the furnace between electrodes and on the windows . Generally, use of oxygen rise to $30m^3$/ton, to be mentioned during the melting period up to (20-25) m^3. Continuity of refinery is one of the basic variants of continuity of oxidizing period/ one slag process/, and was accepted to be equal to 20min. Value of temperature can be something else depending on the condition of the process.

Circumstances that have effects on the continuity of oxidizing period are as follows:

-Carbon content during melting,Content of phosphorus in the budding materials,Degree of alloying metal,Organization of holding the process.

Value of T defines the relative continuity of refinery

$$\text{tpa}_\varphi = \frac{T-t}{G.60.K.P.T}.\text{Hours/ton} \qquad (1)$$

Where T- total continuity of process of refinery (minutes)

t_{nkt} -continuity of stopping the current for refining period (minutes)

G- Furnace capacity (ton)

$K_{t\,cu}$- coefficient of throwing the current for oxidation period=1.09

By varying the T from 20-40 (minutes), we calculated /on the computer /electric and working characteristics according to methods used in [8-10]. Result of the calculation and optimization parameters of the refinery is as shown in the Table 2. and Figure 1.

3. Results

The results obtained are presented in Tables 2 to 5. Table 2 shows the effect of continuity on usage and productivity of electric arc furnace.

Table 2 Effect of continuity of refinery on usage of electric-energy and efficiency (productivity) of furnace for refinery period.

T, minutes	T_{tex}, Hour/ton	I_1,A	q_{ref},ton/Hour	T, Hour/ton	W_{ref}mW-Hour/ton
20	0.00397	34934	253.0	0.00395	0.0542
25	0.00527	33457	190.0	0.00526	0.0662
35	0.00703	32293	142.5	0.00702	0.0823
40	0.01009	31199	99.2	0.01008	0.1103

If the line is straight, then of course we can say that relation between x and y is linear;

Y=AX+B, where A and B are constants. (2)

For non-linear dependent types of formula, we can define through compare of the drawn with the curves.

Analytic criteria exist for checkup of linear dependence between X and Y; by experimental data defined.

$\Delta Xi = Xi+1 - Xi$: $\Delta Yi = Yi+i - Yi$; $Ki = \Delta Yi / \Delta Xi$ (i=1, 2...., n-1). If K1=K2=....=Kn-1. (3)

Then at point (Xi, Yi) position for example on a straight line: If Xi is constant, i.e. value of Xi are equally distributed, and then convinced enough that ΔYi is also constant (or almost constant).

During analysis and writing chemical laws and physio-chemical processes and phenomenon of empirical formula is common choose within the following functions (4-42):

Y=Ax+B (Linear); (4)

$Y=AB^x$ (Exponential); (5)

Y=1/Ax=B (Rotational); (6)

Y=Alnx+B (Logarithmic); (7)

$Y= AX^B$ (Exponential, which if B is =0, graph is parabolic and if B=0, graph is Hyperbolic);(8)

$Y=A+\frac{B}{X}$ (Hyperbolic); (9)

$Y=\frac{X}{Ax+B}$ (Rational); (10)

In order to define which of the function is better or suitable for the experimental data, it is necessary to perform the following operations:

$Xap= \frac{x1+xn}{2}$ (average arithmetical x and y); (11)

X_1 =0.01407; X_4 =0.02019 (12)

$Xap = \frac{0.01407+0.02019}{2}$ =0.01713 (13)

Xreom= $\sqrt{x1 + xn}$ (average geometrical); $\qquad$ (14)

Xreom= $\sqrt{0.01407 + 0.02019}$ =0.0168 $\qquad$ (15)

Xrapm= $\frac{2x1.xn}{x1+xn2}$ (average harmonic); $\qquad$ (16)

Xrapm= $\frac{2x0.0407x0.02019}{0.0407+0.02019}$ =0.01658 $\qquad$ (17)

Yap $\quad = \frac{yi+yn}{2}$ $\qquad$ (18)

Yap $\quad = \frac{y1+y4}{2} = \frac{126.499+71.26}{2}$ =98.879 $\qquad$ (19)

Yreom = $\sqrt{y1 \times yn}$ = $\sqrt{y1 \times y4}$ = $\sqrt{126.499 \times 71.26}$ = 94.9437 $\qquad$ (20)

Yrapm = $\frac{2 \times y1 \times yn}{y1 \times yn}$ = $\frac{2 \times y1 \times y4}{y1 \times y4}$ = $\frac{2 \times 126.499 \times 71.26}{126.499 \times 71.26}$ = 91.1647 $\qquad$ (21)

Y*ap= $Yi + \frac{yi+1-yi}{xi+1-xi}$ (Xap-Xi) $\qquad$ (22)

Where Xi, Xi+1 -Given value among which falls within the range Xap (Xi<Xap); Yi < Y* <

Yi+1 (I=1, 2, … n)

0.01713 <Xap< 0.02919, then 71.26 < Yap 91.16;

Y*ap = 71.26 = $\frac{91.16-71.26}{0.02019-0.01710}$ (0.01713-0.01713) =71.26 $\qquad$ (23)

0.01537 <Xreom< 108.68;

Y*roem = 91.16 + $\frac{71.26-91.16}{0.01713-0.01537}$ (0.01685-0.01537) =74.42 $\qquad$ (24)

0.01407 <Xrapm< 0.01537; 108.68 <Yrapm< 126.499;

Y*ap =108.68+ $\frac{126.499-108.68}{0.01537-0.01407}$ (0.01658-0.01407) =143.08 $\qquad$ (25)

3.1. Finding quantities using following equations

ϵ_1 = $\left| Y*ap - Yap \right|$; $\qquad$ ϵ_1 = $\left| 71.26\text{-}98.879 \right|$ =27.61 $\qquad$ (26)

ϵ_2 = $\left| Y*ap - Yreom \right|$; $\qquad$ ϵ_2 = $\left| 71.26\text{-}94.94 \right|$ =23.68 $\qquad$ (27)

ϵ_3 = $\left| Y*ap - Yrapm \right|$; $\qquad$ ϵ_3 = $\left| 71.26\text{-}91.164 \right|$ =19.90 $\qquad$ (28)

ϵ_4 = $\left| Y*reom - Yap \right|$; $\qquad$ ϵ_4 = $\left| 143.08\text{-}98.879 \right|$ =44.20 $\qquad$ (29)

ϵ_5 = $\left| Y*reom - Yreom \right|$; ϵ_5 = $\left| 74.42\text{-}94.94 \right|$ =20.52 $\qquad$ (30)

ϵ_6 = $\left| Y*rapm - Yap \right|$; $\qquad$ ϵ_6 = $\left| 143.08\text{-}98.879 \right|$ =44.20 $\qquad$ (31)

ϵ_7 = $\left| Y*rapm - Yrapm \right.$] ϵ_7 = $\left| 143.08\text{-}91.16 \right|$ =51.92 $\qquad$ (32)

And define minimum value of ϵ = min {$\epsilon_1, \epsilon_2 - \epsilon_7$}

3.2. Select empirical formula among the function 1-7. Known empirical formula will have the following form:

$Y=Ax+B$, if $\epsilon = \epsilon_1$;   (33)

2. $Y=AB^x$, if $\epsilon = \epsilon_2$;   (34)

$Y=1/Ax=B$,if $\epsilon = \epsilon_3$;   (35)

$Y=Alnx+B$,if $\epsilon = \epsilon_4$;   (36)

$Y= AX^B$,if $\epsilon = \epsilon_5$;   (37)

$Y=A+\dfrac{B}{X}$,if $\epsilon = \epsilon_6$;   (38)

$Y=\dfrac{X}{Ax+B}$,if $\epsilon = \epsilon_7$;   (39)

It follows that we must consider that functions 1-7 are monotonous, and therefore to answer them through experimental data (Xi, Yi) when ΔXi= Xi+1-Xi > 0 (I = 1, 2,... n-1). We must have permanent sign. Alternatively, dependence 1-7 will be opposite. This method of choosing the type of empirical formula is a crude form, so far it does consider all the value of (Xi, Yi). Apart from that, it can happen that variables X and Y obey another law, and the type of empirical formula will be different from function 1-7, so we choose function 3, as it is min $\{\epsilon = \epsilon_3 = 19.9\}$ and has form:

$$Y=\frac{1}{Ax+B}\ ; \quad q=\frac{1}{0.9985tTEX-0.000006}\ ; \qquad\qquad (40)$$

The remaining equations were chosen in the same way. By the derived equations, tables and graphs were plotted. From them it is clear that the calculation by equations corresponded to the initial data of graph. While varying the continuity of refinery, dependence of working index of the furnace were as presented in Table 3.

Table 3 Effect of increasing continuity of refinery on productivity of furnace and relative usage of electric through smelting.

T	$T_{tex\epsilon}$	I_{1ref}	W_{ref}	W_ϵ	Q_{ref}	Q_ϵ
Min	Hour/ton	A	mW-Hour/ton	mW-Hour/ton	ton/Hour	ton/Hour
20	0.01405	6.1497	0.0542	0.5463	253.0	71.15
25	0.01536	33457	0.0662	0.5583	190.1	65.09
35	0.01712	32293	0.0823	0.5744	142.5	58.42
40	0.02018	31199	0.1103	0.6024	99.2	49.55

$$q'\epsilon tTex = \frac{1}{0.99922tTEX-0.0000157}\ , \text{ton/Hour.} \qquad\qquad (41)$$

Calculate values received from those equations were presented in the Table 2.

Table 4 Effect of continuity of refinery on productivity of furnace and relative usage of electric throughout the smelting.

T, Min	20	25	35	40
T_{Tex}, Hour/ton	0.01405	0.01536	0.01712	0.02018
W_ϵ Mw-Hour/ton	0.5406	0.5550	0.5744	0.6079
q_ϵ,ton/Hour	71.15	65.09	58.40	49.59

Usage by limit can be defined as follows:

$$Ct_{TEX} = n/0.99922t_{TEX} + 0.0000157 = m/11t_{TEX} + 0.386 + A' \qquad (42)$$

$Ct_{TEX\ min}$ =1329.27/0.099922×0.01405 + 0.0000157/ + 13.58/ 11× 0.01405 + 0.386/+14.938

=40.96Rouble/ton.

$Ct_{TEX\ max}$ = 1329.27/0.099922×0.02018 + 0.0000157/ + 13.58/ 11× 0.02018 + 0.386/+14.938

=50.02Rouble/ton.

ΔCt_{TEX}= $Ct_{TEX\ min}$ - $Ct_{TEX\ max}$ = 50.02 – 40.96 = 9.06 Rouble/ton.

Calculated values of dependence of expenditure by limit were presented in Table 2 and on Figure 1.

Table 5 Effect of continuity of refinery on expenditure by limit.

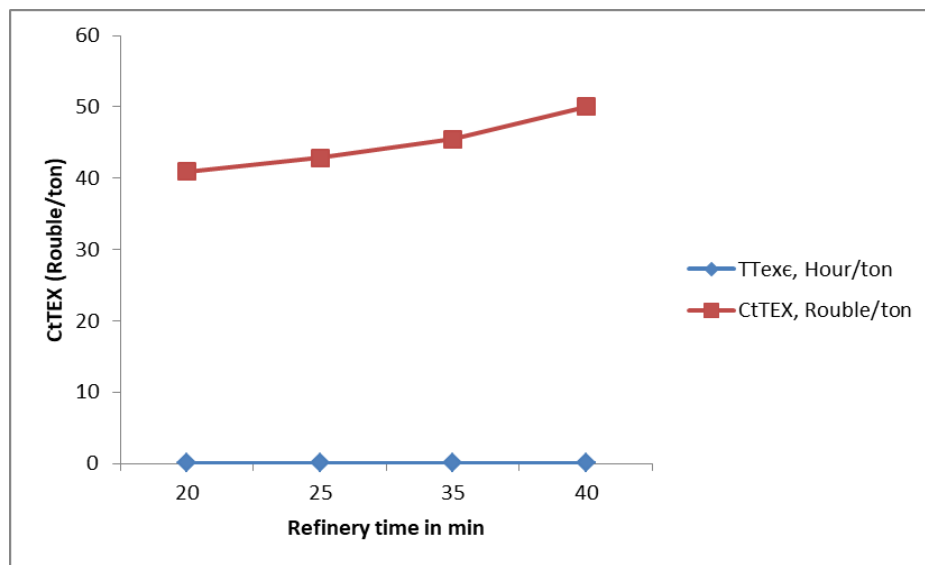| T, min	20	25	35	40
$T_{Texe,}$ Hour/ton	0.01405	0.01536	0.01712	0.02018
$Ct_{TEX,}$ Rouble/ton	40.96	42.89	45.49	50.02

Figure 1 Plot of EAF expenditure versus refinery time in min.

4. Discussion

Similar results were obtained in past research where increase in refinery time increased cost of production and reduced productivity [11].

5. Conclusion

We can conclude that with increase in continuity of refinery, cost of expenditure by limit also increased. Within the checking limit Time rises from 20 to 40mins; increasing the continuity of the process of smelting within every 10minutes, the cost limit increases by 4.53 Rouble/ton or by 11% thus productivity reduces. It can be concluded that increasing refinery continuity reduces working productivity of the electric arc furnace.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest

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