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**ANALYSIS OF FACTORS EFFECTING POWER CONSUMPTION & ARC EFFICIENCY IN ELECTRIC ARC FURNACES (EAF)**

**Singh Kapil Dev1 and Makarov Anatoliy Nikolaevich2,**

*1PhD. Scholar, Tver State Technical University, Tver, Russia.*

*2Prof. and Doctor of technical sciences, Tver State Technical University, Tver, Russia. E-mail:* *tgtu\_kafedra\_ese@mail.ru*

# *Abstract*

*The analysis of factors like arc length and slag height in the entire range of electrical arc steel-making furnaces (EAF) from 0.5 to 120 ton was carried out to determine their influence on power consumption and arc efficiency in EAF. It was found that as the slag height increases, the arc efficiency increases to up to 70% to 80 % and power consumption decreases, whereas on the other hand when arc length at constant slag height increases to 1.42 times, the arc efficiency decreases to 30%, power consumption increases up to 25% to 30%, and thermal radiation fluxes increases to 1.3 -1.6 times.*

# Introduction

Russia is the 5th largest steel producing nation in the world, with 48 million tons of steel produced only in the year of 2019, with around 50 electrical arc steel-making furnaces (EAF) nationwide. With increasing global demand and competition a great emphasize is on increasing the efficiency of EAF and on cost effective steel production1. The slag layer and arc length in an EAF and their influence on the arc efficiency and electric power consumption in the entire range of steel making furnaces from 0.5t to 120t was studied.

# Slag Height

The high power heavy duty electric arc steel making furnaces use coal powder injectors and oxygen for foaming, as a result slag height reaches 400-500 mm but in small capacity furnaces EAF-6, foaming devices are not used and slag height remains 40mm. We will further study how it influenced the efficiency of arcs and specific power consumption in furnaces.

# Effects of slag height on arc efficiency and specific power consumption in EAF.

In figure1, graph 1, describes the change in arc efficiency depending on the ratio of the arc length 𝐻𝐷/𝐻𝐿 in the EAF -100 furnace, whereas graph 2 shows the change in arc efficiency η=f(𝐻𝐷/𝐻𝐿) in the EAF-6 furnace, where devices are not used for foaming slag. As can be seen from figure1, graph 1, the arc efficiency increase unevenly with the height of the slag layer and the height of the arc depth into the slag in the EAF-100 furnace.

At an arc voltage of 280V and arc length of 325mm arc efficiency increased just by 8% from 0,45 to 0,49, as an increase in slag height from 0 to 195 mm was inefficient as 𝐻𝐷/𝐻𝐿 = 0.6, but with further increase in the height of the slag layer in the EAF - 100 furnace from 195 to 325 mm and 𝐻𝐷/𝐻𝐿=1.0, increased arc efficiency by 35% from 49 to 75 as specific power consumption decreased in EAF-100 to 385 kWh/t. The experimental studies were carried out on the EAF-120 of OJSC Ural steel10, which proved the outcomes of arc efficiency calculation. Studies proved that with increase in height of the slag layer from 238 to 356mm, specific power consumption decreased from 260-205 kWh/t as a result of decrease in heat losses of arcs, and increase in the efficiency of arcs due to increased shielding of arc radiation by slag10. As we know the parameters of arc for EAF-100 and EAF-120 are same, graph 1 in fig 1 was used to determine the efficiency of arcs of the EAF=120 furnace of OJSC Ural steel and it was found that with an increase in the height of the slag layer from 278 to 356mm, the arc efficiency increased from 0,55 to 0,77 i.e. by 29% and the specific power consumption decreased from 260 to 205 kWh/t by 22%.



**Figure 1.** The dependence of the arc efficiency of the EAF-100 (I) and EAF-6 (II) furnaces on the penetration of the arcs into the metal bath and slag.

Analyzing graph 2, it was found that, as the distance from arcs to the wall is 0.69m or 3 times less compared to EAF-100, it effects arc efficiency which is η=0.35 for EAF-6 which is 24% less compared to EAF-100, as slag foaming devices are absent in EAF-6 and as a result of which it has slag height of 35mm to 40mm, long operating time and low arc efficiency results in specific power consumption increment in EAF-6 to 475kWh/t for melting the charge and upto 750 kWh/t for overall melting. Use of slag foaming devices in EAF-6 furnace can increase the arc efficiency in by 15% to η=0.67 and decrease the specific power consumption to 11% to 15% but while considering use of such devices we need to keep in mind the factors like investment in gas cleaning, the furnace downtime, effect of oxygen and carbon containing material injection on the increase in the waste of expensive alloying elements (chromium, molybedrium, vanadium etc) on the quality of the finished metal.

# Arc length

Another important factor affecting energy consumption and efficiency in an EAF is arc length. At present, EAF-100 furnaces operate on both long and short arcs, and there is ongoing discussion about the advantages and disadvantages of working with long and short arcs. To determine better arc length, it is necessary to calculate and analyze the distribution of arcs over the surface of the walls of a 100 ton furnace. When changing the length of the arcs, it is necessary to find out the effect of the length of the arcs on the efficiency of arcs and the specific power consumption in arc EAF.

# Effects of arc length on arc efficiency and specific power consumption

A very important factor while determining effect of arc length on arc efficiency and specific power consumption is to calculate the densities of the thermal radiation fluxes of the arcs along the height and perimeter of the walls of a 100 ton EAF at various length of arc at constant power. Figure 2 shows the necessary construction for calculation in AutoCAD & Excel program.

The density of the thermal radiation flux of the arc q falling on the design site located on the walls of the EAF was determined by the expression [1]:

 q = $\frac{α\_{cl}P\_{arc}cosαcosβl\_{opn}}{π^{2}r^{2}l\_{arc}}$ (1)

where $α\_{cl}$ is the proportion of arc power released in the arc column, determined by the method described in [1]; $P\_{arc}$ is the arc power, kW; k is the absorption coefficient of the furnace gas atmosphere, varies in the EAF from 0.1 to 1.3 [1], we take the average absorption coefficient K=0.7 [1].



**Figure. 2**. Diagram for calculating the fluxes of thermal radiation of arcs on the walls of EAF.

The symbols used in figure 2 are as follows:

0...5 – the calculated points on the walls of furnaces; $l\_{arc}$ – arc length, m;

$l\_{opn}$– is the length of the open part of the arc radiating heat flux on the calculated area, m;

r – ray, the distance from the arc to the calculated points on the walls, m;

α – angle between the ray r from the middle of the open part of the arc and the perpendicular N1 to the axis of the arc, held at the beginning of the ray r on the arc, grad.;

β – the angle between the normal N2 to the surface of the walls to the calculated point and ray r, grad..

The results of calculating thermal radiation fluxes showed that when furnace operates at short length = 300mm and long = 425mm respectively, and when the arc length is increased from

300 to 425 mm in radiant furnace atmosphere the maximum flux densities of thermal radiation from the arcs increase from 600 to 650 kW in the lower part of the walls at 70mm. Densities of heat fluxes of radiation on sections of walls located opposite and between the arcs was found that long arc's 425mm is 15% -30% more in comparison with density of heat fluxes of radiation on the walls of short arc’s 300mm. The higher density of thermal radiation from long arcs 𝑙𝑎𝑟𝑐= 450 mm on the walls of the EAF-100 furnace is associated with the higher open, not buried in the slag, height of the arcs, and the lower efficiency of the arcs. For long arcs $l\_{arc}$= 450 at $h\_{p}$/$l\_{arc}$ = 300/450 = 0.67, efficiency of arcs η = 0.52. For short arcs $l\_{arc}$= 300 at $h\_{p}$/$l\_{arc}$= 300/300 = 1.0, efficiency of arcs η = 0.74.

Thus, with an increase in the arc length from 300 to 450 mm, the density of heat radiation fluxes of three arcs along the height and perimeter of the walls of the EAF-100 furnace increases by 15 - 30%, the heat losses by radiation of arcs increases by 30% into the surrounding space, on the walls, vault, absorbed by the dust and gas atmosphere of the furnace as a result the efficiency of the arcs decreases by 30%. When comparing the energy consumption for the production of 1 ton of high-quality high-alloy steel in electric arc steel- making furnaces with short arcs and new EAF with long arcs when melting ordinary and reinforcing steel, it was found that the energy consumption in new EAF with long arcs is 100 kWh / t higher compared to with short arcs [19].

# Conclusion

With an increase in the height of the slag layer, the efficiency of the arcs increases and the power consumption and the density of heat fluxes on the walls decreases. With an increase in the length of the arc, the efficiency of the arc decreases and the consumption of electricity and the flux of thermal radiation of the arcs and on the walls increases. Thus, it is possible to increase the efficiency of the arc and reduce the specific power consumption with an increase in the height of the slag layer, and regulation of the arc length and flows of thermal radiation of the arc to the walls.

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**АНАЛИЗ ФАКТОРОВ, ВЛИЯЮЩИХ НА ПОТРЕБЛЕНИЕ ЭЛЕКТРОПИТАНИЯ И ДУГОВЫЙ ЭФФЕКТИВНОСТЬ В ДУГОВЫХ ПЕЧИ (ДСП)**

**Сингх Капил Дев1 и Макаров Анатолий Николаевич2,**

***1****Аспирант, Тверской государственный технический университет, Тверь, Россия.*

*2Проф. и доктор технических наук, Тверской государственный технический университет, г. Тверь, Россия. Электронная почта: tgtu\_kafedra\_ese@mail.ru*

*Анализ таких факторов, как длина дуги и высота шлака во всем диапазоне электродуговых сталеплавильных печей (ДСП) от 0,5 до 120 тонн, был проведен для определения их влияния на потребляемую мощность и КПД дуги в ДСП. Было обнаружено, что с увеличением высоты шлака КПД дуги увеличивается до 70-80%, а потребление энергии снижается, тогда как, с другой стороны, когда длина дуги при постоянной высоте шлака увеличивается до 1,42 раза, КПД дуги снижается до 30 %, энергопотребление увеличивается до 25% - 30%, а потоки теплового излучения увеличиваются в 1,3 - 1,6 раза.*

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**Сингх Капил Дев**, аспирант ФГБОУ ВО «ТвГТУ», г. Тверь, Россия. E-mail: kapil92singhdev@gmail.com

**Макаров Анатолий Николаевич,** д-р техн. наук., профессор, заведующий кафедрой «Электроснабжения и электротехники» ФГБОУ ВО «ТвГТУ», г. Тверь, Россия. E-mail: tgtu\_kafedra\_ese@mail.ru