ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

Improvement of Waste Gas Recycling Technology in Arc Steel Furnace (ASF)

U.M. Halikulov

Senior teacher, Departments "Technology mountainmetallurgical processes", Almalyk branch of NUST «MISiS»

ABSTRACT: This article analyses the risk features of pre-heating raw materials with waste gases during melting processes of steel-smelting furnace. Peculiarities are shred out of a number of characteristics and criteria of raw materials of furnace structure and technologies implemented in particle board and arc-furnace plants.

KEYWORDS: electric steel smelting plant, hot briquetted iron, charge composition, high temperature, risks on industrial facilities, dangerous factors safety, mechanisms and methods of safety,JSC "Uzmetkombinat,".

I. INTRODUCTION

The metallurgical complex, being the basic industry, makes a significant contribution both to the economy of the Republic of Uzbekistan and to environmental pollution.

The trend of increasing demand for steel production products obliges to increase the capacity of the domestic steel production industry, where the main role is played by JSC "Uzmetkombinat" located in the city of Bekabad of Tashkent region.

Smelters using electrical energy as a means of generating process heat have significant thermal, technological, structural and environmental advantages. Direct-heating arc steel furnaces are most common, in which the electric arc burns between the electrode and heated (melting) metal.

Due to structural changes and a significant change in the approach to the production cycle, JSC "Uzmetkombinat" managed to increase its production more than one and a half times and according to forecasts in 2019 the volume of production of grade-rolled products will be more than 1 million tons.

It should be noted that the main furnace of the electric steel melting shop (ESMS) of JSC "Uzmetkombinat" is an arc steel furnace (ASF) with capacity of 100 tons.

At the same time, the production itself with increased production capacity is carried out without significant replacements of the main units used for smelting. For example, with increased capacities, smelting of steel is carried out in a single furnace.

Structural and technological features of arc electric furnace make it an extremely mobile melting unit, allowing using various schedules of operation: continuous, 5 days per week, 1-2 shifts a day, etc.

In terms of the nature of the raw materials used, JSC "Uzmetkombinat" has not been uniform recently, as previously prior to structural transformation mainly metal scrap and carbon steel waste were used, and now with increased capacities it is used together with metal scrap and hot briquetted iron (HBI) waste. Accordingly, the standards and requirements for the gas-cleaning system of the ESP change due to the chemical composition of the released gases in the process of melting.

Under these conditions, the requirements for metal scrap are unchanged. For example, the charge should not be much oxidized since the presence of a large amount of rust contributes significant hydrogen content to the steel. Depending on the chemical composition, the scrap should be sorted into appropriate groups. It is necessary to interrupt the melting

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

process and load the charge. This increases the melting time, leads to higher power consumption, lower efficiency of arc steel furnaces. This increases the risks associated with stopping and/or restarting the process.

II. THE MAIN FINDINGS AND RESULTS

Alloyed wastes are formed in electric steel smelting shop in the form of under filled ingots, gates; in cleaning compartment in the form of chips, in rolling shops in the form of trim and scrap, etc.; also alloyed scrap in larger quantity comes from machine-building plants. Use of alloyed metal wastes allows saving valuable alloying substances, increases economic efficiency of electric furnaces. 0.01 - 0.15% C and <0.020% P are kept in the iron. Pure aluminum is used as deoxidant in addition to ferromanganese and ferrosilicon. For carburization the limit cast iron, electrode snout, is used; for slag guidance, freshly burned lime, hydrofluoric spar, chamottemahach, dolomite and MgO are used. Carbonaceous and alloyed chips shall be degreased and shredded. The following process requirements are met to ensure process safety.

- Non-ferrous metals (copper, bronze, tin, lead, brass, etc.) are not allowed in the scrap; therefore the non-ferrous scrap is separated from the scrap and sorted;
- Permissible content of phosphorus in the scrap for the main arc furnaces should not exceed 0.050% (the exception is wastes of group B22);
- Scrap should not be strongly oxidized due to the possibility of loss of control over the smelting process.

All ferroalloys shall be up to quality with applicable standards and specifications.

Calculation of charge by elements is carried out taking into account production of the whole charge in metal by melting: during the blow down period at least 0.30% of carbon must be oxidized; Ni, Mo - for medium cooking content; Other elements - to the lower limit; Scrap angle is 7% of the total weight of the brew.

Composition of charge at remelting by method of complete oxidation:

- carbonaceous scrap (alloy-free scrap);
- ferroalloys;
- crushed electrodes.

When remelting the alloyed waste without carrying out the oxidation period (fusion method), the charge is made up of 100% of the own waste. In order to reduce phosphorus content in metal, partial replacement of own wastes with low phosphorus iron is allowed to 30% of the total weight of the winding.

Big power and high temperature of an electric arch ($T_d \approx 800\ U_i$ where U_i is the average potential of ionization of a digit interval) allow to heat and melt quickly furnace charge, at the same time temperature of heating of the melted metal can be significantly higher, than in other melting units. The arc furnace has relatively small dimensions, the arc in the furnace burns in the immediate vicinity of the charge, so the transfer of heat to the charge is considerably facilitated and accelerated.

The practical turn to electrometallurgical technologies of steel production, and their development are connected with the emergence of additional problems of energy and environmental nature. Large-volume arc steel furnaces, which have become increasingly common in recent years, have a capacity of more than 100 tonnes and a capacity of up to 100 tonnes per hour or more. Preference for such furnaces is given to the production of steel duplex by a process where the intermediate is melted from scrap metal in the ASF and the subsequent alloying is carried out in an Integrated Steel Treatment Unit. As a result of the continuous improvement of steel smelting technology in arc furnaces, there have been significant changes in their performance. In recent years, the mass of smelts produced by large-scale ASF has increased from 86 to 110 tons, the melting time has decreased from 105 to 60-70 minutes, the power of transformers has increased from 60 to 80 MV-A, the electrode consumption has decreased from 2.9 to 1.9 kg/t, and the specific electricity consumption has decreased from 450 to 300-320 kWh/t.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

In order to ensure safety requirements, modern large-volume ДСП are equipped with gas removal and purification systems characterized by huge volumes of cleaned gases. The capacity of such systems reaches 15 thousand m3 of cleaned gases per ton of molten steel, which is tens of times higher than the gas release of these furnaces and is associated with significant capital and energy costs for cleaning. Energy consumption, only for transportation of cleaned gases, can reach 40-60 kWh/t, which is 15-20% and more of the total energy consumption for steel smelting in the furnace. Therefore, the search for ways to improve the efficiency of gas purification systems is relevant both from the point of view of safety and from the point of view of energy saving.

Since the minimum cost of electric power for cleaning 1 m3 of gas only from dust in such systems reaches 3 Wh, which exceeds the cost of cleaning in bag filters by up to 5 times.

It should be noted that the problem of ensuring the safety of clean steelmaking can be solved by preventing unorganized emissions and increasing the efficiency of gas removal and purification systems. Correct accounting of quantitative indices of process and removed gases, correct organization of gas removal and preparation system allows to significantly reduce capital and operating costs, which at modernization of gas cleaning equipment can reach 50% of expenditures of main production.

The relationship between energy output and environmental performance is clear. This points to the need to identify significant energy-environmental indicators and, based on them, to improve methods of gas removal and purification, as well as to the need to identify and take into account them in the design of gas purification systems. In connection with these factors, the issue of improving the exhaust, afterburning and cleaning systems of large-volume arc steel furnaces is naturally formed, aimed at increasing their energy-ecological efficiency, reducing the volume of gases to be cleaned and reducing the emissions of pollutants into the atmospheric air.

Table 1 - Main characteristics of steel production methods

indicator	Type of steel-smelting furnace aggregation		
	open-hearth furnace	converter	electric arc furnace
Loss of iron, kg/t liquid steel (LS) with dust	10	14	32-36
with into slag	24	15	5
with oxide into slag	4	13	4
Overall	38	42	35–75
Per unit loss of heat, liquid steel	0,94	0,064	0,45
Portion of carbon, have been oxidized till CO,%	0	90	70
Volume of air inflow into furnace, kg/t of steel	21,42	2,08	6,4
Specific gas furnace, m3/t steel	353	92	297
Specific slag volume, kg/t steel	114,1	95,5	82
Charge of lining, kg/t of steel	24	3,2	5

Domestic metallurgy faces the following challenges:

- identification of the level of impact of dangerous factors on human activity;
- improving methods for calculating and estimating gas emissions from particle boards;
- study of process gas afterburning conditions of particle boards and optimization of modes of their afterburning and cooling units operation;
- finding ways to increase efficiency of discharge and purification of particle boards gases with reduction of energy consumption for purification;

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

- development of scientifically based recommendations to ensure the safety of particle boards.

It should be noted that the component composition of the pollutants which are thrown out by large-capacity chipboards has to be significantly expanded at the expense of such ingredients as cyanides, carbon (soot), vapors of oils and also highly toxic pollutants - benzpyrene, dioxine and furan. It has been shown that despite the small mass share of supertoxic pollutants (benzpyrene, dioxins and furans) in ДСП, their contribution to environmental pollution is significant, which requires measures to reduce them.

Theoretical and experimental studies in laboratory conditions as close as possible to the conditions of the electric steel smelting shop of JSC "Uzmetkombinat" have made it possible to improve the method of gas release calculation, taking into account the specifics of gas release in the ДСП both in the working space of the furnace and in their afterburning at the outlet of the furnace. The studies made it possible to assess the impact of the process characteristics of the ДСП operation on the gas release process and to improve the reliability of the gas purification system design.

Practice shows that the installation behind CPD of cleaning systems using bag filters reliably and effectively solves the problem of cleaning gases from dust and partly from condensate (including benzpyrene, cyanides and some fluorides, dioxins and furans). The formation at high temperatures of other gaseous harmful substances (nitrogen oxides, persistent organic pollutants (POPs), including dioxins and furans) and their emissions depend heavily on the temperature regime and oxidation potential of gases in the furnace atmosphere and along the gas removal path. The carbon monoxide content of the exhaust gases, which is not very difficult to detect, is a reasonably reliable indirect indicator of the presence of various organic compounds therein.

The proposed method of improving the afterburning and cooling conditions of process gases can reduce the total volume of gases to be cleaned, and therefore the energy costs of their transportation and capital costs for the construction of treatment plants, as well as contribute to a significant reduction of emissions of persistent organic pollutants, the most toxic of which are dioxins and furans. Despite the huge amounts of gases supplied for purification, the issues of efficient afterburning and cooling of process gases of modern ASF have not been solved. At the same time, the basis for solving the environmental problem of ASF is complete destruction of dioxins in the zone of high-temperature afterburning of gases. At the same time, the conditions of efficient operation of the systems of evaporative cooling of gases have been estimated, which allow to reduce the volume of gases to be cleaned by several times, and therefore the energy costs for their transportation and capital costs for the construction of treatment facilities. The solution to the problem of efficient afterburning and cooling of process gases is their high-temperature afterburning followed by evaporative cooling.

It has been found that an important tool contributing to the reduction of energy consumption in electric steel smelting production can be the reduction of energy consumption of gas purification systems. At the same time, one of the most effective ways of saving is to reduce energy costs by reducing the cost of transporting gases by reducing the unnecessarily large amount of aspiration gases supplied for cleaning. Analysis of the operation of modern aspiration systems pointed to the need to eliminate their non-specific function - the need to cool process gases. Cooling of process gases can and should not be carried out by dilution with low-temperature aspiration gases, but by more efficient and energy-efficient methods: sprayer evaporation cooling by water injection, or cooling using recovery boilers or heating of metal scrap.

In the dynamics of experiments, it has been found that the effective operation of aspiration systems of steel smelters is largely determined by the sealing of furnaces, the continuity of their operation and the stability of the gas mode, the choice of the design and system of installation of umbrella, the use of aspiration gases as an oxidizer of combustible components and the possibility of reducing their specific volume to 2-3 thousand m3/t.

One of the main and most effective tools for intensification of electric steel smelting production and increase of its energy-ecological efficiency recently is application of furnace-ladle technology (complex steel treatment unit) as a method of liquid steel treatment. Currently, most large-volume arc steel furnaces only refine cast iron, scrap steel or direct reduction iron to produce liquid unrefined steel, which significantly reduces the melting time. In addition, the emergence of new, more complex grades of steel, with the highest degree of purity, requires special accuracy in finishing. This is only possible when using modern furnace-ladle technologies. Modern ASF with a capacity of more

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

than 100 tons operating capacity is up to 100 t/h and is mainly intended for smelting of the intermediate product. In Germany, for example, ladle-furnace technologies are used in all metallurgical plants where there are currently 32 evacuation units and 29 ladle-furnace plants in operation, which allow the processing of melts with a mass of up to 400 tons.

The complex steel treatment unit allows not only to reduce the melting time in the furnace, but also to significantly improve the energy-environmental indicators. According to literary data, these furnaces are characterized by a high share of chemical energy of fuel - up to 65-70%, a significant charge angle - up to 8.5-12% and a high value of heat released in the working space due to exothermic reactions 550-650 kw/t. The minimum power consumption in these furnaces is 250-300 kw/t. On the other hand, the use of furnace-ladle methods contributes to improving the environmental efficiency of its operation, primarily by reducing the time of melting in the pit. In the ladle refining process, there is no need for the furnace refining and therefore the need to maintain a reducing atmosphere in the furnace working space, which in turn allows efficient suction of gases from the furnace during all melting periods and minimization of non-organisms. Analysis of the operation of modern aspiration systems pointed to the need to eliminate their non-specific function - the need to cool process gases. Cooling of process gases can and should not be carried out by dilution with low-temperature aspiration gases, but by more efficient and energy-efficient methods: sprayer evaporation cooling by water injection, or cooling using recovery boilers or heating of metal scrap.

The same advantages are also distinguished by the technology of smelting the intermediate product in ASF and further argon-oxygen refining (AOR) in a bottom-blown converter. The total duration of the steel treatment process (converter refining and semi-product smelting in ДСП) in such a process is 4 less than the steel smelting in ASF according to conventional technology. Metal coal is reduced to 4-5 kg per ton of steel against 4.5-6 kg/t during steel smelting in ASF according to traditional technology. This method of steel production allows to significantly reduce unorganized emissions both in the production of intermediate product in ASF and in the converter itself, and dust removal will not exceed 2-4 kg per ton of steel.

Intensification of ASF operation by injecting oxygen into the furnace working space was initially used to replace iron ore in decarburization and dephosphorization processes. Currently, oxygen is used not only to carry out the oxidation period of melting, but also to intensify the melting process (oxidation melting) as well as to "trim" scrap at the beginning of melting. The use of oxygen gas significantly intensifies the decarburization process and the carbon burn-up rate increases by about 3-5 times. During the oxidation period of melting, dust and gas emissions are greatest (thick brown smoke comes from the furnace). In order to reduce dust formation during this period, it is attempted to reduce the temperature of the metal in the purge reaction zone by dispersing the blast, adding various coolants to the reaction zone, increasing the circulation of liquid metal near the reaction zone, etc. The greatest effect is achieved with so-called deep blowdown.

A significant portion of the energy (up to 20%) introduced into the furnace is lost with off-gases, corresponding to power losses of up to 200 kw/t. These energy losses are made up of the physical heat of the gases (50-65 kw/t) and the chemical heat that can be released by their afterburning (oxidation of carbon monoxide and hydrogen). Afterburning of process gases in working space of furnace is aimed at improvement of energy balance of melting and increase of furnace productivity. This method of melting intensification was essentially a continuation of the development of another technological element - slag foaming, in which a large amount of CO is released. The efficiency of afterburning systems is characterized mainly by two parameters: the degree of afterburning of CO and the efficiency of heat transfer (ratio of afterburning energy, transferred bath and charge, to theoretical afterburning energy). Typically, the degree of afterburning is 60-100% and the heat transfer efficiency is 60%. The resulting efficiency is 35-65%. The maximum energy savings achieved during the afterburning of process gases amounted to 60 kWh/t during operation of the ASF with a capacity of 100 tons of the mini-plant "Huta Czestochowa" (Poland).

However, it should be noted that it is not necessary to adjust the degree of CO afterburning in the furnace working space to 100%, since in this case the content of nitrogen oxides (NOx) in the exhaust gases is increased, the wear of the lining and the lateral consumption of the electrodes are increased, the probability of the wall panels being run-off is increased, and the yield of useful iron oxides with process gases is decreased as a result of large carry-over. Developed in NITU "MISiS" vortex radiation injector with metal water-cooled diffuser for production of fan flame, afterburning

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

CO near the roof surface allowed reducing electric power consumption for melting by 20-34 kw/t (4-6%) without marked increase of NOx concentration.

The fuel and oxygen consumed in the burners partially replace the electricity required. The number of burners varies from 1 to 9. Specific power - up to 200 kw/t. The total capacity for electric furnaces with a capacity of up to 50 tons is up to 10 MW, from 50 to 120 tons - 10-20 MW and from 120 to 150 tons - 20-25 MW. The operation time of TCG is about 15-20 minutes. With properly organized oxygen-gas blowing it is possible to reduce dust formation, reduce the angle of alloying elements and increase the yield. Therefore, oxygen-gas blowing, along with reducing atmospheric pollution, allows for a significant economic effect. Approximately, the introduction of modern oxygen-gas technology in the conditions of ASF (capacity 100 tons), according to experts, allowed to reduce the specific consumption of electricity by 40 kw/t.

Increasing the carbon content of the charge, as well as using TCG, is an effective way to accelerate the electric smelting. The use of iron ore concentrate powders in the oxygen stream leads to a reduction of dust content in the exhaust gases by 4-8 times compared to its content during oxygen blowing. The yield increases by 2.5%. The same effect is followed to the end by slag foaming, which is carried out by injecting the melting of powdered carbon to more efficiently transfer energy and protect the water-cooled panels from radiation. For example, with the purpose of energy saving in mine furnaces of JSC “Severstal”, slag is foamed with ground coke blown in the furnace in an amount of up to 11.6 kg/t by means of injectors. Operation of furnaces on expanded slag, heating of scrap in furnace shaft, optimization of electric mode of melting and optimization of TCG operation made it possible to significantly reduce power consumption of furnace and bring them to 269.6 kw/t.

An important requirement to ensure safety, out-of-furnace treatment is to cut off furnace slag during discharge. The first step in simplifying and improving the reliability of the slag cut-off was to use a so-called siphon outlet, i.e. to place the furnace outlet below the molten bath level. The next step was the method of bottom central and then out-of-center (oriel) output. Bath mixing in arc furnaces is used to accelerate slag and scrap melting, average bath temperature and composition, activate the slag-metal reaction in the low-temperature melt zone, and deazotation reaction of steel. Mixing is carried out by bottom injection of argon or nitrogen. At the same time the productivity of furnaces is increased by 3-6%, the consumption of electric power on refractory is reduced by 10%. The next stage of melting intensification will be injection into the bath through special tuyeres installed in the bottom, a mixture of oxygen, coke, coal, lime. Intensification of bath mixing process leads to reduction of reaction zone temperature and reduction of dust formation intensity. Therefore, feeding argon into the bath to intensify mixing brings to the reduction of dust formation and shrinkage of the waste of the alloying agents.

Not only the quality of the metal charge, but also the way it is loaded into the furnace significantly affected the environmental characteristics of the ASF. The use of continuous charge loading is not only one of the effective ways to increase the intensification of metallurgical processes in the ASF, but also an effective method of improving environmental indicators. With occasional loading of, for example, steel furnace charge materials, the volume of unorganized gas flow increases dramatically and uncontrolled, which is practically impossible to remove or clean and use in a controlled manner.

III. CONCLUSION

Improving the quality of scrap and heating it appears to be one of the effective ways to improve the energy-environmental indicators of ASF. In order to save energy resources, the technological use of heat of furnace exhaust gases, which form a significant part of the thermal balance of the electric furnace (more than 19-25%), seems very tempting. The technology of electric steel smelting with preliminary heating of scrap allows creating super-heavy ASF in their most expected variant in the future - without fuel use.

REFERENCES

[1]. Suleymanov A.A., Gafforia M.A. Probability theory in risk assessment in emergency situations in the oil and gas industry. The collection of theses of the student's scientific conference "Oil and Gas 2018", RGU Branch of oil and gas (NIU) of I.M. Gubkin in Tashkent, Tashkent Page 75.

[2]. Suleymanov A.A. Review of the monograph "Technology of purification and recycling of oil wastes using local sorbents." Monograph Shomansurov S.S. - Saarbrücken, S. 3-7.

[3]. Halikulov U. M., Saidova K.A. Study of filtration processes with steam space collation. Materials of the Republican Scientific and Technical Conference "Mining and Metallurgical Complex: Achievements, Problems and Prospects of Innovative Development" - Navoi, 2016. - P.115-116.
[4]. Fett, F.; Pfeifer, H.; Siegert, H.: EnergetischeUntersuchungeines. Hochleistungslichtbogenofens. Stahl und Eisen 102 (1982), S. 461-465.
[5]. Brod, H.; Kempkens, F.; Strohschein, H,:Energieruckgewinnungauseinem UHP- Elektrolichtbogenofen. Stahl und Eisen 109 (1989) 5, S. 229-238.
[6]. Kiselev A.D., TuluevskyYu.N., Zinurov I.Y.: Increasing efficiency of gas removal of arc steel furnaces. M.: Metallurgy of 1992. Page 11-12.
[7]. Gudim YU, Zinurov I.Y., Kiselyov A.D., Schumakov A.M.: Rational ways to intensify smelting in modern arc steel furnaces. Journal of South Ural State University, № 9 (109) 2008. Page 11-13.
[8]. Y.Smolyarenko V.D.: New generation electric arc furnaces. Institute "AO VNIIETUO". Moscow - June 2006 - 7 p.
[9]. Timm, K.:Kreisdiagramm: Grundlagen von Drehstromofen. IFB - InstitutfQrBildung. 25. Seminar Elektrotechnik des Lichtbogenofens. Kehl, Oktober 2001. S. 4-12.
[10]. Hoinkis, J.; Lindner, E.: Chemie fur Ingenieure - ChemischeReaktionen. WILEY-VCH. ZwolfteAuflage, 2001. S. 93, 96-97.
[11]. Povolotsky D. Y.: Basics of steel production technology. Chelyabinsk, Publishing House of YuurSU, 2004, p. 67-69.
[12]. Nikolsky L.E., Zinurov I.Y.: Equipment and design of electric steel smelting shops. M.: Metallurgy, 1993. Page 70-71.
[13]. Pfeifer, H.:Energiebilanzen des Drehstrom-Lichtbogenofens. IFB - InstitutftirBildung. 25. Seminar Elektrotechnik des Lichtbogenofens. Kehl, Oktober 2001. S. 11.
[14]. Heinen K.-H.: Elektrostahl-Erzeugung - Energiebilanz. 4., volligneubearbeitete und erweiterteAuflage. StahlundEisen, Diisseldorf, 1997. S. 116.