New Engineering Solutions in Creation of Mini-BOF for Metallic Waste Recycling

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Abstract. New engineering solutions used in design of the mini melting unit capable of recycling industrial and domestic metallic waste with high content of harmful impurities are provided. High efficiency of the process technology implemented with its use is achieved due to the possibility of the heat and mass transfer intensification in the molten metal bath, controlled charge into it of large amounts of reagents in lumps and in fines, and cut-off of remaining process slag during metal tapping into the teeming ladle.

The European Slag Association and the Institute of Processed Raw Materials Industrial Circulation were founded some time ago to solve the problems related to increase of the portion of the dormant scrap with high content of foreign matters and accumulation of environmentally harmful waste including ferrous and non-ferrous metals. According to these organizations, the total volume of slag utilization in developed countries have already exceeded 93%, and recycling of metal containing wastes allows the experts to produce annually useful goods worth more than $ 70 billion [1, 2].

Implementation of advanced technologies of industrial by-products utilization requires special melting facilities functioning within mini- and micro-plants, which best respond to market requirements of leading economies [3]. The positive experience of application of oxygen mini-cupolas and mini-blast furnaces for production of steel-making and commercial iron from coal and metallurgical sludge at such plants speaks for practicability of search for options to use small melting facilities capable to convert hot metal and metal-containing wastes with high content of harmful impurities into steel of acceptable quality without steel refiners in the processing chain.

As is well known, such units shall meet a set of requirements such as provision of thorough mixing of the molten bath, capability to control the feed of powdery reagents of varying composition into it, and prevention of releases of large quantities of the remaining slag into the receiving container during tapping [4].

According to the program of scientific and technological co-operation between the Mechanical Equipment of Iron and Steel Works department of the Donetsk National Technical University and the Process Equipment Engineering department of the National University of Science and Technology MISiS, the experts of these departments have been carrying out the work on creation of the basic oxygen mini-furnace complying with all requirements mentioned above over the past five years.

As a result of the performed comparative analysis of advantages and disadvantages of the known melting systems, a basic oxygen furnace with two rotation axes designed for the Kaldo process for producing steel from high-phosphorous iron at high consumption (40-50%) of metal scrap was used as
a prototype when selecting the structural scheme of the unit being developed [5]. Due to necessity to eliminate several significant deficiencies identified in the BOF of this type, which have become the main reason for ceasing its industrial application in Europe, Japan, and the US, new technical solutions protected by Ukrainian and Russian patents were applied in design of the upgraded melting unit. The modified kinematic configuration of mechanisms of the converter body rotation about its longitudinal axis must first be noted. The upgraded mechanism (Figure 1) includes the bevel pinion shaft connected with the drive gearbox through the coupling and installed in bearing assemblies inside the cylindrical channel made in the trunnion body 2. The hollow trunnion is integral with the cover connected with the collar, where the shaft 1 with the bevel gear 4 set onto it and engaged with the gear shaft 3 is placed on frictionless bearings. The straight tooth gear mating with the toothed rim of the converter body is installed on the bottom end of the shaft [6].

Such design of the mechanism of the converter body rotation permitted allocation of its drive beside the corresponding trunnion of the mounting ring of the steel melting unit. It is much easier to mount, maintain and repair the rotating mechanism drive when it is permanently fixed on the work site [7].

The converter was equipped with the system of molten metal stirring with an inert gas in order to improve the conditions of fast scrap melting, to increase the dephosphorization level along with reduction of burnt lime consumption, to reduce aluminium and ferromanganese consumption for killing steel, and to improve the refractory lining wear-resistance due to formation of less aggressive slag. This system allows, without using expensive automation tools, conducting the bottom stirring during unit body rotation in the pre-breakdown mode of the utility outflow considering the varying depth of lance submergence into the liquid bath. The offered stirring system (Figure 2, (a)) includes the main gas-feed pipe 1, the gas distribution unit 2 and several (3 – 4) multi-channel lances 3 mounted in the lining of the converter lower vessel cone 4. The gas-feed pipe, put through the channel in the driving trunnion of the converter, is laid up to the gas distribution unit 2 combined with the lower trunnion of the melting unit. The gas distribution unit (Figure 2, (b)) contains the hollow flanged trunnion 8 rigidly fixed by bolts 2 with nuts 3 to the bottom 1 of the converter body, and installed in roller bearings 7 and 10 located in the fixed support 11 connected by beams to the supporting trunnion ring of the melting unit. The shell 9 is mounted in the cavity of the trunnion 8 on slid fit. At some distance from its exposed face, the shell has a profiled slot 4 made at the lower semi-circle. The calculated width of the slot is maximal in the middle part, and it gradually narrows to the edges. The after end of the shell 9 is rigidly connected by the flange 12 to the body of the fixed support 11 and the cover 13 with the choke 14 connected with the pipe line 15. Through threaded holes are made at equal distance from each other in the body of the hollow trunnion. The longitudinal axes of the holes are in the trunnion’s cross-section matching the axial semi-circle of the profiled slot 4 and the shell 9. The chokes 5 are screwed into the specified holes and connected with stirring lances by pipe lines 6.

Figure 1. Design of the Converter Body Rotation Mechanism.
The principle of the gas distribution unit operation is the following. When the body 1 of the melting unit is rotating about its longitudinal axis, the trunnion 8 is turning in bearings 7 and 10 about the support 11 and the shell 9 rigidly connected to it. Gas delivered under pressure from the pipe line 5 through the choke 14 arrives to the cavity of the shell 9 and then through its profiled slot 4 to the channel of the pipe line, the choke of which currently coincides with it. Thus, gas is supplied by turns to each stirring lance in the automatic mode when they are below the molten metal level in the converter. Thanks to the changing slot widths, gas consumption is increased proportionally with the lance deepening into the molten metal achieving the maximum level in the lowest point of its immersion, and then it is gradually going down and its supply is interlocked when the lance is leaving the molten bath. Such operation of stirring lances provides efficient use of the inert gas and high efficiency of molten metal stirring thanks to elimination of so called breakdown mode of its outflow considering deepening of each lance [8].

In order to raise the efficiency of sulphur and phosphorus removal from the molten metal, the converter was equipped with the advanced system of top blowing by reagent powder in oxygen stream. The structural scheme of this system is provided on Figure 3. The system includes the mechanism of lance movement and the unit for metered feeding of the fine material. The mechanism of lance movement includes the trolley 5 equipped with two pairs of travelling rollers 4 installed on the inclined rails 3 (the angle of inclination is 30°). The lance trolley is moved by the screw drive mechanism consisting of the drive screw 18 rotated in the bearing assembly by the geared motor 17. The lead nut is located in a special housing attached to the bottom part of the trolley with the capability of self-alignment against the screw. The top part of the lance 1 is fixed on the supporting disc in the coupling 8, and together with the disk it can perform oscillating movement related to the trolley by means of the crank mechanism 6 within the elongated hole of the hood 2 and provided with the socket for connection of the gas exhaust duct. In turn, the collar 8 together with the lance 1 held by it has the capability to turn about the supporting disc in vertical plane by a certain angle by means of the cam 7 installed on the output shaft of the geared motor 9 attached to the disc itself. Thus, thanks to the availability of the crank-lever mechanism and the cam mechanism, the lance provided with the nozzle in the lower part is enabled to perform oscillating movements relative to the trolley in two planes simultaneously when both mechanisms are on, or separately when the drive unit of one of them is off. Depending on the combination of amplitudes and oscillation frequency of the lance in two mutually perpendicular planes, the resulting trajectory of its nozzle movement is of different forms. During the steel-making process, it allows the operators to set such oscillation profile relative to the molten metal bath surface, at which the efficiency and factors of thermal performance of the process unit are improved the most. The lime powder metering device includes the sealed bin 13 fixed on four columns above the inclined rails and provided with a feeder located inside. This feeder consists of the geared motor 16 connected to the vertical hollow shaft 15 installed in the bearing assembly in the cavity of the protective pipe 14 and carrying the screw feed 12.
on the shank. The lower part of the screw feed provided with the nozzle 11 is located in the mixing chamber connected with the choke of the oxygen lance 1 by a flexible pipe 10. When the gaseous oxygen is supplied to the cavity of the vertical shaft rotated by the geared motor at the permanent set angular velocity, the screw feed connected to it supplies the calculated amount of the lime powder into the mixing chamber, where its particles are captured by oxygen stream coming out of the nozzle and are taken to the lance duct by the pipe line mixing with the major amount of the oxidizing agent blown in to the converter bath [9].

In order to prevent the aggressive remaining slag from entering the teeming ladle, which might cause the excessive loss of deoxidizing agents and alloying additives, the upgraded mini-converter is equipped with the system of gas dynamic cut-off of the molten slag, schematically shown in Figure 4. It includes the hollow cylindrical rod 5, carrying on the front end the arc-shaped distribution box 8. In the wall of this distribution box, the slotted nozzles are present along the external perimeter. The rod is connected in a mobile manner with two pairs of rotary racks 3 and 7 pinned to supports 2 and 6 installed at different levels. A flexible gas-feed sleeve 4 is connected to the back of the rod, and a power pneumatic cylinder is used for rotation of the back pair of racks 3. The dimensions of racks 3 and 7 and the distance between their supports 2 and 6 are accepted based on the condition that they form the parallelogram mechanism together with the rod 5. Thanks to that, the rod is capable of parallel-plane movement in the vertical plane and it keeps the constant angle of inclination to the horizontal plane. Eventually, it provides the permanence of the set impinging angle of the flat gas jets, coming out of slotted nozzles of the distribution box 8, relative to the bath level of metal poured through the edge of the converter’s nose into the ladle. The optimal impinging angle of gas jets provides effective holding of the molten slag in the converter due to pushing the slag aside from the converter nose under the influence of the dynamic head of gas flow [10].
The thorough inspection of correctness of engineering solutions made during development of the upgraded design of the 10-tonnes basic oxygen furnace, performed on the current model of the unit, led to the conclusion that thanks to suggested innovations it has been possible to eliminate main deficiencies of the known equivalent [11]. Practical application of new developments will make possible the implementation of the efficient technology of steel production from low-quality charge materials without using additional facilities designed for refining of metal to be produced.

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