Recycling of heat from the metallurgical industry wastes

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In XXI century special attention is paid to environmental issues, first of all, due to the unprecedented economic growth of various types of industrial production, inevitably accompanied by a simultaneous catastrophic growth of solid, liquid and gaseous wastes. The concept of sustainable development aimed at solving urgent environmental issues, including introduction of «Ecologically sustainable industrial development» model, was approved and is being efficiently implemented in the leading countries worldwide. The main goal of this concept is to meet the human needs of present and future generations without disrupting the main natural processes.

In recent years, the metallurgical industry in Kazakhstan has become one of the leading industries, after the oil industry, which receives special attention from the government. Kazakhstan is among the world leaders in metallurgy. Kazakhstan enterprises provide with metallurgical products not only own market, but also export non-ferrous metals to other countries.

For the metallurgical industry, searching for the ways to reduce energy and material resources consumption, as well as improving the environmental friendliness of production, are primary and challenging issues.

It is known that reducing resource consumption can be achieved in one of the two ways:

- the first - the cessation of economic growth (closure of existing enterprises);

- the second is improvement of production technologies, use of resource-saving solutions, improvement of product quality and processing of generated and accumulated industrial wastes. The criteria for the effectiveness of the proposed technical solutions aimed at improving and modernizing existing enterprises can be the amount of energy consumption, recycling options and the amount of emissions to the environment.

In our understanding, the term “recycling” means returning own wastes back to the current production. It should be noted that metallurgy is a universal branch of the economy, capable of utilizing a significant part of its own production and consumption wastes.

An example of an effective reduction of the resulting amount of waste from ferrous metallurgy is the option of secondary smelting of accumulated scrap and other wastes in electric steel-smelting furnaces. The use of scrap can significantly reduce the energy intensity of steel production. When using a mixture containing 30% of pig iron and 70% of scrap, the energy intensity of steel production in electric furnaces is about 1.5 times lower than for blast furnace – converter method, and is about 16 GJ/t [1]. Small-scale plants, created based on the electric steel-making process using only scrap, substantially exceed all full-cycle plants in almost all technical and economic indicators. The power consumption for rolled steel production is almost 2.5 times lower, and labor productivity is three to five times higher than at a traditional full-cycle plant. An important feature of small-scale plants is the use of electricity as the only and most technologically advanced and environmentally friendly source of energy.

Another focus is the use of pyrometallurgy. Currently, many alternative technologies are being developed with solid-phase and liquid-phase reduction, which use different types of energy, as well as a variety of ore materials and reducing agents. The most typical and implemented in the industry processes of solid phase reduction are Midrex and several modifications of the HyL process. The Romelt and Corex process is a liquid phase process - a combined process: it consists of solid phase (reduction) and liquid phase (production of pig iron) stages. In the process of "Midrex" there is no coke-chemical production. The energy intensity of the metal according to this technology is about 1.5 times less than that obtained by the blast furnace - converter process, and carbon dioxide emissions are less than about twice. At the same time, technology requires the use of a scarce and expensive energy source and a reducing agent – natural gas. The main advantage of the Corex process is the use of thermal coal in the production of pig iron. However, the energy intensity of this process is almost 2 times higher than the energy intensity of the blast furnace process, and the volume of emission of greenhouse gases is higher [2].

Reducing the anthropogenic effect of non-ferrous metallurgy enterprises on the environment is of fundamental importance for Kazzinc Ltd. (Kazakhstan). The company consists of zinc, lead and copper production, with a full cycle of production of high grade (HG) commodity metals. The company is located inside the city of Ust-Kamenogorsk. Therefore, the task of developing and introducing environmentally friendly technologies that reduce emissions to the atmosphere, discharges to water and utilization of solid waste generated in the production cycle is always relevant.

One of such possible solutions to the problem of reducing the greenhouse gas emissions of an enterprise into atmospheric air is an attempt to recover heat from waste gases and solid products from the lead plant's blast furnace. At the first stage of the study, a model analysis of pyrometallurgical processing of lead and zinc production of Kazzinc Ltd. was performed. It has been revealed that the studied stages of reduction smelting of lead rich ISASMELT slag in blast furnace, fuming of zinc-bearing blast furnace slag and processing oxidized zinc-bearing materials in Waelz-kiln have certain potential savings in the cost of carbon-containing energy and the associated reduction of greenhouse gas emissions [3]. These reserves consist of the possibility for heat recovery from waste gases and produced molten materials (recycling of heat), which can be directed to heating of the air blast to the existing pyrometallurgical production [4].

Currently, Kazzinc Ltd. consumes about 165,000 tons of carbon-containing solid fuel worth about 23 million euros. Based on the calculations, it was found that heating of the air blast sent to lead plant's blast furnace up to 600-700 ºC through the heat recovery from waste slags saves the carbon-containing reducing agent (coke) consumption to 30-40%. This will save about 7 million euros. This improvement along with the economic benefits can significantly reduce the amount of CO_2 emitted, in proportion to the amount of saved carbon-containing reducing agent.

Waste slags constitute a significant share in the material and heat balances of the main processes of non-ferrous metallurgy. Heat loss from the slag in the heat balance amounts to 30-40%, while the temperature of the liquid slag is 1300-1350°C. To recover heat from waste gases, which can be used to preheat the feed, air blast, fuel, to generate electricity and steam, it is required to equip the existing metallurgical furnace with appropriate devices for introducing innovation. At the next stage of the study, mathematical calculations of the granulator necessary for dry granulation of slag melts were performed for the subsequent modernization of the existing equipment scheme of the plant. Based on mathematical modeling of the process, a device for dry granulation of slag melts was developed. The design features of the laboratory granulator were determined. The geometry of the tray - disperser was calculated, allowing to ensure the performance of the granulator within 262-488 granules/s. The form of the cooling surface, which consists of two or more pipes cooled from the inside with running water, has been developed. A sample of a laboratory granulator was prepared, which allows to work out the optimal parameters for dry granulation of slag melts. The test results will allow to give the initial data for the technical regulations in order to create a granulation plant for industrial slag volumes. In the process of developing a model for the process of dry granulation of slag melts, an algorithm was developed for dispersing a jet of a melt by the self-decomposition method, which is a scheme for determining the parameters of jet flow and dispersion, on the basis of which the granulation process can be organized. In addition, diameter of the granules formed during dispersion of the melt jet depending on dispersion mode was calculated. It has been determined that when the diameter of the melt jet (d_{JET}) varies from 5 to 20 mm, the diameter of the formed granules changes under the drip mode from 9.5 to 37.8 mm; for the spray mode from 8.0 to 30.0 mm. Based on numerical studies carried out according to the developed algorithm for coordinating drainage and cooling regulations on the rotating surface of the cooling pipe, it was determined that the actual melt drain and the cooling surface area can be coordinated through disperser-tray and the cooling pipe rotation speed, at this cooling pipes rotating speed depends on the rate of slag melt discharge.

Thus, the use of a dry granulation unit for slag melts will allow to recycle waste slag heat and to improve state of the environment by reducing emissions of carbon-containing reducing agent into the air. The results of the researches on the development of a sample laboratory granulator can be recommended for use in various enterprises of ferrous and ferrous metallurgy.

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