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Granulation of Manganese-Containing Dust Generated during Ferroalloy Production and Its Utilization as a Secondary Raw Material

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Abstract
The article addresses the utilization of manganese-containing technogenic wastes generated during ferroalloy production. Particular attention is given to the granulation technology for finely dispersed dust accumulated in the gas-cleaning systems of the Zestafoni Ferroalloy Plant and to the possibility of returning this material to the production cycle as a secondary raw material. The physicochemical composition of the dust, the technological granulation process, and the main technical characteristics of the equipment used are described.
Within the framework of the study, the properties of granules produced using both water and a specially formulated liquid binder were evaluated. It was established that the use of the specially developed binder significantly increases the thermal stability of the granules, ensuring their structural integrity at elevated temperatures and enabling their effective utilization in electric-thermal furnaces.
The article demonstrates that implementation of the proposed technology reduces manganese losses, improves the technical and economic performance of ferroalloy production, decreases the accumulation of technogenic wastes, and significantly reduces the environmental impact of the plant. The results confirm that granulation of manganese-containing dust is an effective and practically significant approach to the rational utilization of secondary resources and to enhancing the environmental sustainability of ferroalloy production.
Keywords:
Ferroalloys; technogenic wastes; manganese-containing dust; granulation; secondary raw materials; thermal stability; environmental safety; waste utilization; resource recovery.

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I. Introduction

One of the major challenges facing modern metallurgical industry is the rational utilization of technogenic wastes generated during production processes. This approach simultaneously addresses environmental protection objectives and the improvement of production efficiency. During ferroalloy production, significant quantities of finely dispersed manganese-containing dust are generated. Its accumulation under open-air conditions can result in contamination of the atmosphere, soil, and water resources, while the loss of this material reduces the efficiency of manganese utilization.

The reintegration of secondary mineral resources into the production cycle represents one of the key directions of sustainable development. From this perspective, the technological potential for granulating manganese-containing dust collected by gas-cleaning systems and subsequently returning it to the production process is of particular interest. This approach makes it possible to reduce raw-material losses, improve the technological conditions of furnace operation, and significantly decrease the environmental impact of the plant.

The objective of the present study is to evaluate a technological scheme for the utilization of manganese-containing dust generated during ferroalloy production, analyze the characteristics of the granulation process, and investigate the thermal stability of granules produced using a specially formulated liquid binder. The results demonstrate that the proposed technological solution ensures high thermal stability of the granules, enhances the efficient utilization of secondary resources, and creates favorable conditions for improving both the technical and economic performance of production and its environmental efficiency.

The ferroalloy production process is accompanied by unavoidable technological losses of manganese in oxide form—including discard slag, dust captured by gas-cleaning equipment, and other residues—and in metallic form, including fines generated during size classification, metal droplets produced during casting, crust-like residues, and other metallic wastes.

Clearly, successful ferroalloy production also implies the effective utilization of these industrial wastes. However, before discussing the economic aspects of the issue, it is appropriate to briefly consider the environmental problems associated with technogenic waste.

The emissions from the electric-thermal furnaces of the Zestafoni Ferroalloy Plant (ZFP), in the form of fumes enriched with manganese and silicon oxides, caused severe environmental damage not only in the immediate vicinity of the plant but also beyond the boundaries of the Zestafoni district. In the atmospheric air around the plant, the concentration of manganese dioxide was five times higher than the maximum permissible concentration (MPC).

Environmental pollution was also caused by manganese ore beneficiation sludges, manganese-containing internal residues accompanying liquid metal, and other pollutant sources. The open-air storage of these wastes (Fig. 1) posed a significant environmental hazard to surface water and groundwater resources and contributed to the contamination of the Kvirila River through wastewater discharge. The manganese concentration in the river was 15 times higher than the maximum permissible concentration (MPC).

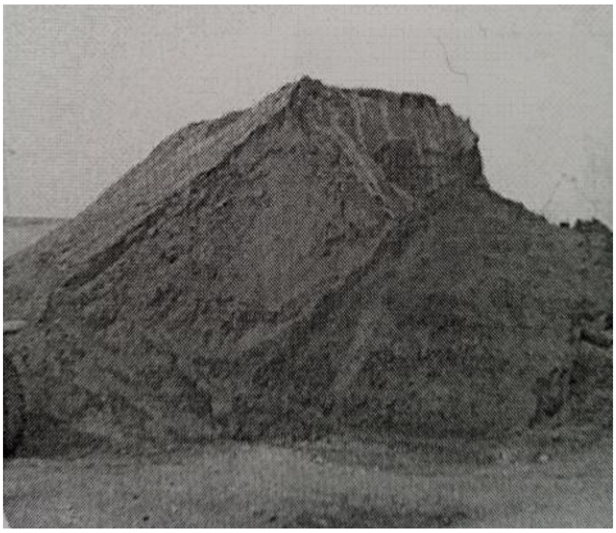

Fig. 1. Stockpile of manganese-containing dust sludged by atmospheric precipitation

Among these technogenic losses at the Zestafoni Ferroalloy Plant, manganese losses in oxide form were generated during the production of ferromanganese and ferrosilicon predominate. Therefore, our primary focus is on the utilization of these losses. They are collected in the gas-cleaning units of Workshops No. 1 and No. 4 in the form of finely dispersed manganese oxide dust with a particle-size fraction of 0–1 mm. Depending on the number of furnaces in operation, the daily quantity of collected dust ranges from 50 to 80 tones. The manganese content of this dust reaches 25%. In addition to manganese oxides, the dust contains 38–40% SiO_2, 2–5% Al_2O_3, 3–8% CaO, 1–3% Fe, 0.5–1% MgO, 0.07–0.2% P, and up to 2% H_2O.

It is evident that manganese residues in the form of such finely dispersed dust cannot be directly returned to the production process. The primary reason is that electric metallurgical processes impose certain particle-size (granulometric) requirements on the furnace charge. Under the disturbances associated with the electric arc, a finely dispersed charge tends to become entrained and ejected from the furnace. To prevent this phenomenon, the charge is converted into a lump form using preliminary briquetting, pelletizing, or other agglomeration methods.

At the Zestafoni plant, a Ukrainian-manufactured T-300-disc pelletizer (agglomerate) is used. The unit operates by the wet granulation method, generally using process water, to produce spherical granules with diameters ranging from 3 to 20 mm (Fig. 2).

Fig. 2. Granules

The principal component of the pelletizer is an inclined, rotating, flat-bottomed disc. The disc is driven by an electric motor through a special reduction gearbox that regulates its rotational speed. The disc is enclosed by a cover equipped with a spray nozzle for applying the binder, a device for cleaning the bottom and walls of the disc, process access openings, and other components. The inclination angle of the disc can be adjusted by means of a special mechanism.

The formation of spherical granules occurs as follows. As a result of the adhesion of wetted powder particles, initial spherical granule nuclei are formed. Similar to the formation of snowballs, these nuclei grow and become densified as they roll over the rotating disc. By varying the inclination angle and rotational speed of the disc, the size of the resulting granules can be controlled.

It is well known that, during agitation of a heterogeneous dispersed system, the fine-fraction component tends to migrate downward, whereas the coarse-fraction component tends to move upward. In accordance with this principle, granules are classified by size as they roll over the rotating inclined surface: the lower layers become enriched in finer granules, while the coarser fraction migrates upward and, upon reaching a certain size, is discharged over the rim of the pelletizer.

The T-300 pelletizing unit installed at the Zestafoni Ferroalloy Plant is characterized by the following parameters:

Disc diameter: 3000 mm
Capacity: 4–12 tonnes/h
Rotational speed: 13 rpm
Drive power: 18 kW
Granule size: 3–20 mm
Disc inclination angle: 45–60°

The granules produced by granulation of manganese-containing dust must possess high porosity and ensure good gas permeability of the furnace charge. Their mechanical properties are also of critical importance. The granules must withstand transportation and repeated loading and unloading operations and, most importantly, must possess high thermal stability. This means that the granules must not disintegrate or crumble while passing through the hot zone of the furnace under the influence of elevated temperatures.

Granules produced using water alone do not meet the above-mentioned technical requirements. In particular, experimental studies demonstrated that at approximately 340°C, the granules begin to develop audible cracking, while at 360°C they disintegrate (Fig. 3).

The Production and Technical Department of the plant developed a liquid binder formulation for the pelletization of manganese-containing dust collected by the dry gas-cleaning system of the Zestafoni Ferroalloy Plant. The use of this binder significantly increased the thermal stability of the granules (Fig. 4). Specifically, whereas granules produced using water alone disintegrated at 360°C, those produced using the specially developed binder retained their structural integrity up to 900°C.

It may be assumed that this effect—namely, the increased thermal stability of granules produced with the developed binder—is associated with the addition to the water of a surface-active reagent that improves the wettability of manganese dioxide by water and, consequently, enhances particle adhesion.

Fig. 3. Granules produced using water after heating

Fig. 4. Granules produced using the specially formulated binder after heating

Thus, manganese-containing granules, serving as a lump raw material, are returned to the production process together with the furnace charge as a manganese-containing raw material and secondary resource.

On the one hand, this measure eliminates the need to store and accumulate the dust within the plant premises, thereby improving the plant's environmental conditions. On the other hand, returning the granulated material to the production process reduces the loss of manganese as the principal alloying element. This has a positive effect both on the manganese balance, particularly manganese recovery into the alloy, and on the technical and economic performance indicators of the production process.

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