T. LIS, K. NOWACKI

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OPTIONS OF UTILISING STEELMAKING DUST IN A NON-METALLURGICAL INDUSTRY

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Recycling of by-products of the steelmaking process in electric arc (EAF) furnaces is an important activity from the perspective of environmental protection as well as the steelmaking industry itself. This article is a discussion concerning the selected research results in terms of utilisation of steelmaking dusts containing 4 - 12 % of zinc in manufacture of cement bricks, ceramic construction materials as well as coloured glass products. The research conducted has implied that using steelmaking dusts in non-metallurgical industries is both possible and reasonable.

Key words: EAF, steelmaking dust, non-metallurgical industry, zinc

Opcije rabljenja čeličanske prašine u nemetalurškoj industriji. Recikliranje nus proizvoda čeličanskih procesa u elektro lučnim pećima (ELP) je važna aktivnost sa gledišta zaštite okoliša kao i osobno za čeličansku industriju. Ovaj članak se tiče rasprave selektivnih rezultata istraživanja sa gledišta rabljene čeličanske prašine sa sadržajem 4-12 % cinka pri proizvodnji cementnih blokova, keramičkih materijala kao i obojenih staklenih proizvoda. Provedena istraživanja su ukazala da rabljenje čeličanske prašine u nemetalurškoj industriji je moguće i razborito.

Ključne riječi: ELP, čeličanska prašina, nemetalurška industrija, cink

INTRODUCTION

The metallurgical industry is one of the largest sources of wastes such as sludge and dust from waste gas purification processes conducted in sintering plants, blast furnaces and steel plats, equipped with both converters and electric furnaces [1,2]. Utilisation of steelmaking dusts generated in the steel manufacturing processes taking place in electric arc furnaces is one of the most urgent issues. Electric arc furnace dusts are among the most troublesome products of metallurgical processes being particularly difficult to store and transport as well as posing a serious environmental threat [3,4]. They contain various water-soluble compounds of heavy metals (Zn, Pb, Cd, Cr) and are highly dusting. 900 thousand tons of such dusts are produced in Europe every year. The most commonly recommended manner of utilising the steelmaking dusts is their recycling by repeated processing in the steelmaking process, in the sinter production or in the zinc recovery processes [5]. For some steelmaking dusts, however, mainly those of low zinc content that due to various reasons are not subjected to recycling [6], the reusing may take place in non-metallurgical production processes [7]. The efforts undertaken in the scope of the steelmaking dust recovery in non-metallurgical processes constitute one of the environmentally friendly activities aimed at adjustment of electric arc furnaces to the technological and environmental standards imposed by the European Union.

T. Lis, K. Nowacki Silesian Technical University, Department of Metallurgy, Katowice, Poland

CHARACTERISTICS OF STEELMAKING DUSTS

Steelmaking dusts are waste materials originating from the steel manufacturing process in electric arc furnaces (EAF). The general principles of managing those wastes are regulated by Council Directive 75/442/EEC concerning wastes as amended by Council Directive 91/156/EEC. The latter has established a legal framework for managing wastes and obliged the member states to ensure that the wastes are recycled or disposed in a manner nor endangering the human life and not causing any harm to the natural environment. A separate set of regulations applies to the requirements concerning hazardous wastes. This subject is provided for in Council Directive 94/31/EC concerning handling of hazardous waste. A list of those wastes, officially referred to as the Hazardous Waste List, has been published as Council Decision 94/904/EEC.

In accordance with the said EU regulations, the solutions recommended for EAF mainly include environmentally friendly activities aimed at reduction of the quantities of dusts generated and ensuring their recovery through various forms of recycling and utilisation.

The steelmaking dusts being the subject of the research discussed originated from the process of dry dedusting of waste gases in steel plants equipped with electric arc furnaces as well as two-stage purification installations for the gases removed from the arc furnace chamber and the steel plant's hall. The overall content of metals in the steelmaking dust depends on the process handling manner and the chemical composition of the charge materials. In the steel plats manufacturing high-quality steel grades, the content of zinc in the dust varies from 3,7 to 15,6 %, whereas in the steel plants manufacturing regular quality steel, the content of zinc in the dust discharged from the installation amounts to 20 - 30 %. The steelmaking dusts examined are dusty solids of dark brown colour and low content of water (0,33 % - 1,4 %). The grain size analysis has implied that the fraction of less than 5 μm constitutes the largest share in the dusts (76,5 % - 93,8 %). The chemical analysis of the water extract prepared based on the steelmaking dust has shown its basic nature (9,3 pH - 12,1 pH). The chemical compounds forming the dusts are mainly oxides, and the percentage share of the individual elements in the said oxides is as follows: 31,853 - 33,018 % Fe; 2,872 - 12,012 % Zn; 0,596 - 2,878 % Pb; 0,004 - 0,013 % Cd; 1,993 - 2,883 % Mn; 0,190 - 0,209 % Cu; 0,006 - 0,146 % Ni; 0,213 - 0,813 % Cr; 0,009 - 0,011 % As; 0,324 - 0,807 % K; 0,336 - 0,886 % Na; 2,674 - 4,190 % Ca; 0,018 - 0,270 % Cl; 0,160 - 2,400 % F; 0,349 - 0,767 % S; 0,064 - 0,158 % P.

UTILISATION OF LOW-ZINC STEELMAKING DUSTS IN NON-METALLURGICAL PROCESSES

Production of cement brick

Production of cement brick is one of the ways of utilising various kinds of industrial wastes including dusts and sludges from the waste gas purification processes conducted in the steelmaking industry. These wastes constitute a valuable raw material due to the high content of iron compounds required to obtain the appropriate quality of cement. In most cases, the basic raw materials for production of cement brick contain too few fluxing agents occurring mainly in the form of iron compounds, therefore, the standard batch of raw materials is supplemented by various iron-bearing corrective materials. The quantity of the said additives is adjusted individually to the raw material sort and depending on the method of the cement brick manufacture. The main criterion for determination of the iron-bearing raw material usability is the iron content which, after being converted into Fe_2O_3, should be higher than 25 % as well as the zinc content of less than 12 %.

Depending on the brick manufacturing method applied (wet or dry), the iron-bearing raw material must meet additional requirements regarding the content of moisture (< 30 %), alkalis (< 1,5 %) and chlorine which is to be lower than 0,02 % and 0,1 % for the dry and wet method respectively.

The technology of using steelmaking dusts containing heavy metals in the cement brick production is based on the process well known to the cement chemistry, namely the incorporation of these metals in the crystallographic lattice of the brick minerals as a result of which the compounds formed are characterised by low metal leachability. Such possibilities can be attributed to the specific conditions present in a rotary brick kiln. In order to verify these possibilities under industrial conditions, the degree of inactivation of the heavy metals introduced in to the charge material together with the steelmaking dust was examined by establishing their emission to the atmosphere and the quantities remaining in the internal circulation of metals. The tests in question comprised a chemical analysis of the following elements: basic raw materials, cement brick, dusts discharged from the kiln and those discharged through the smokestack to the atmosphere, as well as determination of leachability of the pollutants from the dusts discharged through the smokestack for both methods of the brick production (Table 1) [8] and from the cement brick manufactured based of the steelmaking dusts. The values obtained have been compared with the maximum permissible concentrations applicable to the wastes introduced to water and land in Poland.

Table 1 **Results of the leachability tests for the steelmaking dust pollutants discharged from the smokestack and from cement brick [8].**

Metal	Heavy metal concentration / mgl-1			Maximum permissible concentra-tion for wastes
	dry method	wet method	cement brick	
Zn	< 0,05	0,165	< 0,05	2,0
Pb	< 0,05	0,440	< 0,05	0,5
Cd	< 0,01	0,154	< 0,01	0,1
Cu	0,10	0,033	< 0,05	0,5
Fe	0,01	0,132	0,72	10,0
Cr	0,21	0,132	0,72	0,5
Ni	< 0,01	0,165	< 0,01	2,0

The physical-chemical tests conducted have confirmed the usability of steelmaking dusts in the production of cement brick, particularly due to its high content of Fe_2O_3 (47 ÷ 53 %) [8] and the conformity with all the other requirements regarding the content of alkalis, chlorine and heavy metals. By way of industrial testing of the cement brick production process, the recommended percentage share of the steelmaking dust as the iron-bearing additive has been determined on the level of 9,5 kg/Mg of brick for the wet method and 8 kg/Mg of brick for the dry method.

Manufacturing of cement brick using steelmaking dust is an environmentally safe process which does not cause further air pollution. Moreover, it neither leads to any disturbances in the furnace operation nor decreases the qualitative parameters of the cement brick manufactured.

Production of ceramic ware

The concept of utilising steelmaking dust in the process of manufacturing ceramic ware is based on the following premises [9]:

- commonly known capabilities of aluminosilicates to incorporate with the crystallographic lattice of heavy metals causing their permanent bonding,

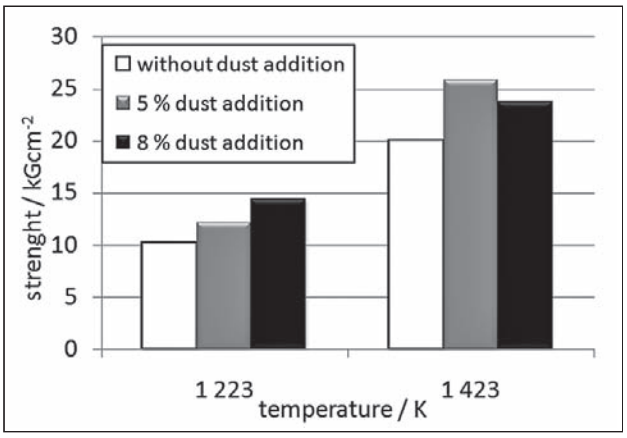

Figure 1 Influence of adding the steelmaking dust to the brick mass on its compression strength at the firing temperature of 1 223 K and 1 423 K.

- necessity of increasing the content of iron in clay in order to improve the product colour,
- possibility of enhancing the product's mechanical properties.

Using the dust as a technological additive required applying individual solutions for the individual conditions of the technological process, i.e. the raw material properties, the machinery used for the sake of the clay processing as well as the brick kilns. Based on the laboratory tests conducted, it was determined that adding the steelmaking dust to the brick mass causes:

- slight increase of open porosity,
- minimum increase of absorbability on low firing temperatures,
- increase of apparent density,
- increase of compression strength on the firing temperature of 1 223 K and 1 423 K (Figure 1).

The results of the leachability test conducted for the pollutants present in the ceramic mass with the steelmaking dust additives as well as for the finished ceramic products imply that the applicable requirements provided for discharge of wastes to water and land are met. The steelmaking dust addition to the ceramic mass, as determined based on the tests conducted, is 5 %.

Concluding the analysis, one can be claimed that the results of the laboratory and industrial tests conducted confirm the positive assessment of the of the brick production technology proposed, involving the addition of steelmaking dusts. This technology may be implemented in brickyards after certain minor modifications of the technological line have been introduced, for instance by using a dust batcher at the stage of preliminary clay processing.

Production of domestic glassware

The steelmaking dusts can also be used in production of domestic coloured glassware. These products are manufactured based on molten glass mass of specific optical properties, chemical and thermal resistance as well as harness. If the glass is to be manufactured using steelmaking dust, one must bear in mind the conditions related to the glass production technology and the required quality of the finished products. It was assumed that adding steelmaking dust containing heavy metals such as: iron, zinc, lead and cadmium may improve or change the colour of the goods manufactured. Based on many years of experience of glass production engineers, glass melting tests were conducted with the addition of 1 %, 5 % and 10 % of the dust [10]. The industrial glass production test using steelmaking dust was conducted by application of three different technologies:

- manufacturing of glass products based on uniform, coloured glass using the steelmaking dusts as dyes in the molten glass mass preparation process,
- ornamenting by laying dry dyes (paints) on the surface of a semi-finished product (powdering method) using the dry steelmaking dust as the decorating dye,
- ornamenting by laying wet dyes (paints) on the surface of a semi-finished product (sulphite method) using the dry steelmaking dust water emulsion as the decorating dye (Figure 2).

The industrial test conducted has implied the following:

- full usability of steelmaking dusts in production of dyed glass through modification of the batch of raw materials used as dying compounds, without the necessity of changing the glass melting technology,
- possibility of obtaining green colour of the glass when using the steelmaking dust in the amount of ca. 5 %, and black colour when the dust is added in the amount of ca. 10 %,
- possibility of decreasing the share of the primary batch of raw materials from 70 % to 5 % and, at the same time, increasing the share of cullet from 30 % to 90 % (for the green glass production) and from 30 % to 80 % (for the black glass production),
- full inactivation of the heavy metals introduced into the batch,
- shorter charge melting time and decrease of the glass melting temperature as a result of which the gas consumption drops and the furnace brickwork service life extends.

CONCLUSIONS

The results of examinations conducted imply that steelmaking dusts are fully usable in non-metallurgical industry. Utilisation of the dusts causes no negative environmental impact both in the course of the manufacture and while using the finished goods, and the products obtained are characterised by at least equivalent properties.

Using low-zinc steelmaking dusts in the non-metallurgical processes as secondary raw materials is significant from the environmental and economic perspective. It reduces the environmental nuisance of such wastes

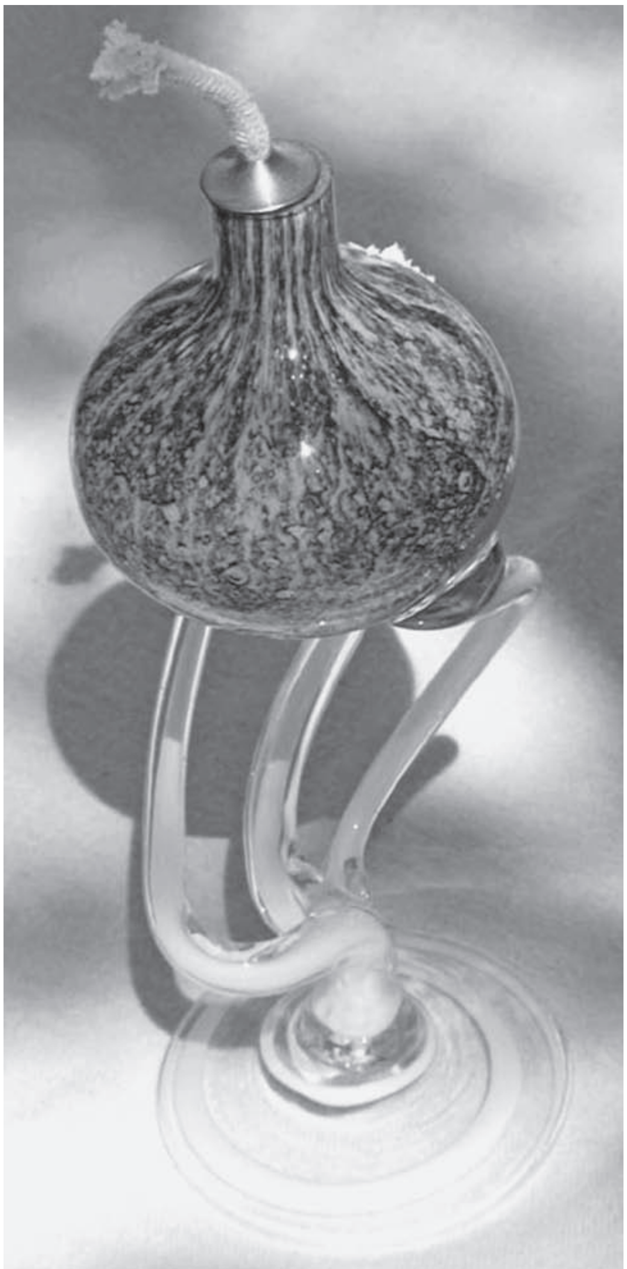

Figure 2 Glass ornamented by laying wet steelmaking dust on a semi-finished product [10].

and decreases the general environmental protection costs incurred by those generating the wastes. Furthermore, substituting the primary raw materials enables saving the natural resources and may bring considerable economic benefits to the entities utilising them mainly by reducing the production costs.

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