



Utilisation of Products of the Thermal Reclamation of Post Reclamation Dusts in the Production Technology of Ceramic Building Materials

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Abstract

The problem related to the management of post reclamation dusts generated in the reclamation process of waste moulding sands with organic binders is presented in the hereby paper. Waste materials generated in this process are products hazardous for the environment and should be utilised. The prototype stand for the utilisation of this dangerous material in its co-burning with coal was developed and patented in AGH in Krakow. The stand was installed in one of the domestic casting houses. As the utilisation result the transformed waste product is obtained and its management in the production of ceramic materials constitutes the subject of the presented publication

Keywords: Moulding sand, Mechanical reclamation, Post reclamation dust, Environmental protection

1. Introduction

Dusts generated during the mechanical reclamation belong, in majority, to hazardous wastes (containing dangerous substances), since they contain binders removed in the reclamation process of spent moulding sands [1,2]. Contrary to dusts generated in metallurgical processes [3], presently none of the companies, producers of reclamation systems, offers technologies or devices for the utilisation of these dusts, which would be efficient, would require neither additional employees nor increased investment and maintenance costs (since they are already quite high) of the existing reclamation installations. Considering the perspective of this problem it can be stated that growing requirements concerning a reclaim quality, including the minimal dust content,

would cause that along with a further development of moulding sands with organic - chemically hardened - binders, amounts of post reclamation dusts would be constantly increasing. The problem of the management of dusts, originated from the reclamation of moulding sands with resins, is very essential for foundry plants applying this technology, mainly due to high costs of the thermal utilization of dusts. Also storing of these dusts in the specially designated parts of dumping grounds causes high costs, to be borne by foundry plants. Some foundry plants, having at their disposal large bases, store dusts in containers of the big-bag type. However, some owners of dumping grounds additionally require that these containers will undergo decomposition after a certain stability time (the so-called: ecological big-bags).

The project entitled: 'Development of the innovatory technology of the thermal utilisation of post reclamation dusts from foundry processes with the possibility of the waste heat utilization' was realised in the Faculty of Foundry Engineering of AGH - University of Science and Technology within the Program "INNOTECH" in the IN-TECH path. The innovatory device for the thermal utilization of post reclamation dusts in the co-burning process with coal [4,5] was designed, constructed and subjected to industrial tests, within the frame of this project.

2. Experimental stand for the utilization of post reclamation dusts

The developed installation (Fig. 1) allows co-burning of post reclamation dusts with hard coal or brown coal in a continuous motion. The installation is equipped with automatic feeders of fuel and dusts. Both components are supplied to the mixing chamber, and then fed on the grill by means of the screw conveyor.



Fig. 1. Prototype of the experimental coal-fired installation built within the scope of the project

An important element of the combustion chamber constitutes the rotary grill system (retort), onto which the element called dephlegmator is periodically lowered in the furnace heating channel (Fig. 2). Its aim is a periodical forcing through the grill and removal of remains from the combustion process (slag). The installation is equipped with the cyclone and fabric filter for cleaning waste gases (some tests with the electro-filter of a new structure were also performed). This prototype installation for the thermal utilization of post reclamation dusts is connected to the heating system of the Department with the possibility of fast switching for the MPEC supply system, when the installation is not operating. The preliminary tests indicated the utility efficiency of the whole installation of burning and a heat circulation at the level of 45%.



Fig. 2. Furnace interior with the dephlegmator

3. Investigations pathway

Investigations were performed using the described above prototype stand for the utilization of post reclamation dusts. The thermal utilization process of dusts, originated from the reclamation process of spent moulding sand with furfuryl resin, was carried out in this prototype device. The mixture of post reclamation dusts and pea coal in proportion 50%-50% was subjected to the thermal utilization process. Pea coal and the prepared mixture are seen in Figure 3. As the utilization result the coarse-grained product of sintering post reclamation dusts was obtained.



Fig. 3. Pea coal applied in tests and the mixture pea coal-dust prepared for the utilization

The conception of investigations concerning using this co-burning product to obtain ceramic building materials is based on the assumption, according to which these materials will be leaning agents. Rational reasons for utilising these raw materials in the mentioned direction are their chemical and mineral compositions and the form of occurrence. However, the final verification of these preliminary assumptions can be only done on the bases of the results of the comparative analysis of properties of two kinds of ceramic materials, it means the reference and experimental materials. It should be explained that the reference materials represent ceramic moulding sands of the appropriate raw materials composition, in which raw clay material is the clay from the Kolbuszowa-Kupno deposit, while the leaning agent constitutes natural high-silica sand. Respectively, the experimental materials will be obtained from ceramic moulding sands of identical quantitative compositions but of different qualitative compositions, since the mentioned products of co-burning post reclamation dusts will serve as leaning agents. These materials will be introduced into individual plastic moulding sands substituting the natural high-silica sand in equivalent amounts.

4. Investigation results

The following initial raw materials were used to obtain samples of the ceramic material of the discussed kind:

- coarse-grained product of sintering post reclamation dusts originated from the installation in Rybnik (symbol R2),
- slips bulk (symbol ML)

In case of slips bulk, ML, only tests of basic physical parameters related to its density and viscosity were performed. The obtained results are presented in Table 1. In addition, in order to select the proper burning temperature of the ceramic material, the characteristic temperatures were determined for the slips bulk.

These determinations were carried out by means of the high-temperature microscope of the Hesse Instruments Company with an automatic recording of sample changes as the temperature function. The obtained results are shown in Table 1.

Table 1.
Results of slips bulk tests, ML

Parameter	Tested slips bulk, ML
Viscosity	1180 mPas
Density	1,87 g/cm ³
Sintering start	940 °C
Sintering maximum	> 1305 °C
Softening	no
Melting (temp. of hemisphere)	no
Flow	no

4.1. Preparation of moulding sand and samples formation

The way of the ceramic moulding sand preparation, based on the coarse-grained product of sintering post reclamation dusts, consisted in mixing it with the proper amount of the slips bulk. This amount was experimentally selected by gradual increasing the slips bulk amount at a continuous mixing, up to the moment of obtaining the coverage of the whole surface of the aggregate grains by the thin layer. Such prepared ceramic moulding sand of a densely-plastic consistency was used, by means of vibration method of steel moulds, for making shaped elements in a cube form of a nominal edge dimension being 100mm. Samples were left in moulds for 24 h, then dried under natural conditions and finally dried to a constant weight under artificial conditions at a temperature of 100°C with the usage of the laboratory drier. Samples obtained in this way are shown in Figure 4.



Fig. 4. Samples of ceramic material obtained on the bases of the lightweight aggregate R2, in a dried state

After the drying process samples were subjected to the thermal treatment related to their burning. The burning process of samples was carried out in the laboratory furnace at a temperature of 1100°C, applying the standard temperature changing rate in the furnace chamber. Samples after the burning process are presented in Figure 5.

4.2. Characteristics of the obtained ceramic material

In order to recognize the basic functional properties of the ceramic material, obtained on the bases of the lightweight aggregate being products of sintering waste post reclamation dusts, certain investigations were performed. They consisted of the determination of the water absorption, open porosity, density and compression strength. On account of the limited number of samples at first tests of their net density, water absorption and porosity were performed by the hydrostatic method and then the same samples were used for testing strength features. The obtained results are shown in Table 2.

Table 2.
Basic functional properties of ceramic materials

Sample symbol	Tested feature			
	Density, net g/cm ³	Water absorption %	Open porosity %	Compression strength MPa
R2-1	1.2104	27.82	33.68	-
R2-2	1.1758	28.41	33.40	0.34
R2-3	1.1506	30.51	35.13	0.31
Average value	1.1789	28.9	34.1	0.33

4.3. Investigations of thermal properties

In order to recognize thermal properties of the obtained ceramic materials the thermal conductivity coefficients were determined. Sample R2-1 cut into three parts by means of the diamond saw, was intended for investigations. To achieve the proper flatness, required by the applied testing technique, the cutting planes were grinded on an abrasive paper.

Investigations of thermal properties of the analysed ceramic materials were performed by the non stationary method, the so-called 'hot disc' method, by means of the device ISOMET 2104 (Applied Precision Inc.) for the determination of the thermal conductivity coefficient. This device is equipped with measuring heads destined for materials of thermal conductivity coefficients being within the range 0.015-0.3 W/(m·K) and 0.3-2.0 W/(m·K).

The measurement of the thermal conductivity coefficient is done indirectly. One side of the sample is heated by a probe - in a form of a plate - placed on the tested sample. The heating rate of the sample is measured.

The measurement of the thermal conductivity coefficient by this device is possible in the range 0.015 ÷ 6.00 W/mK in dependence of the measuring head used. The device operates within the temperature range: from -20°C to +70°C. Each measurement takes app. 10 minutes. The obtained results are shown in Table 3.

Table 3.
Thermal conductivity coefficient values

Sample	λ [W/(m·K)]	Average value
R2-1/1	0.263	0.292
	0.314	
	0.299	
R2-1/2	0.364	0.363
	0.363	
	0.351	
R2-1/3	0.291	0.324
	0.351	
	0.339	

The presented results of testing ceramic material, obtained on the bases of the coarse-grained product of sintering post reclamation dusts, should be treated as the preliminary results. Nevertheless the analysis of these results provides the bases to formulate some general conclusions. The presented characteristics of the discussed ceramic material indicates that, in accordance with the adopted preliminary assumption, we succeeded in obtaining a porous material of a low density and thus of a relatively low thermal conductivity coefficient, λ . This means that the basic research aim was achieved and its conceptual approach justified. However, the applied method should be modified. Taking into account the obtained compression strength values it should be stated that they are relatively low in relation to this material density. Admittedly there are some possibilities of improving this parameter, but they are significantly limited. An improvement of strength values of this kind of material can be obtained relatively easy by increasing the slips bulk fraction in relation to the used aggregate amount. However this way is not efficient, since the basic factor determining strength features of such material is the mechanical strength of the aggregate itself. Admittedly, the crushing resistance of this aggregate was not determined during the performed tests, but an estimating assessment indicates that it is quite small. Nonetheless, the estimated compression strength level of the discussed ceramic material does not disqualify it to be used as a material for insulation layers in chimney systems. However, the final verification of this assumption requires further and wider laboratory tests.

4. Conclusions

On the bases of the obtained preliminary results concerning possibilities of utilising wastes from foundry plants in a form of products of sintering post reclamation dusts for obtaining ceramic building and thermo-insulating materials, the given below conclusions can be formulated.

1. From the technological point of view, the mentioned waste materials can be components of plastic ceramic materials intended for the production of ceramic building materials, in which these industrial wastes are typical leaning agents.
2. The analysed waste materials together with raw clay materials, originated from the Kolbuszowa-Kupno deposit, allow to obtain:

- Plastic moulding sands of good rheological properties and the products obtained from them have none external defects after drying as well as after burning,
 - Ceramic materials of full values characterised by functional features meeting standard criteria of ceramic products of a porous or sintered shard.
3. The discussed waste materials, due to combustible organic substances occurring in their composition, are characterised by relatively high calorific values. These substances constitute the so-called 'secondary fuel', which - combusting during the products burning process - are emitting additional amounts of heat, thus decreasing the fuel consumption needed for burning products.
 4. The production process of ceramic building materials obtained with fractions of products of sintering post reclamation dusts, is not influencing more negatively the natural environment than in case when traditional raw materials are used.

On the bases of this coarse-grained product of sintering post reclamation dusts it is possible to obtain the ceramic material characterised by a high porosity and low density, thus having favourable thermal properties, which can find applications in structural solutions requiring materials of low thermal conductivity values.

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