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ScientEvents
ProScience 1 (2014) 300-305
ProScience

Conference Proceedings
1st International Conference on Atmospheric Dust - DUST2014

Physicochemical characteristics of dust generated during mechanical reclamation of used sand moulds

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Abstract

The paper presents results of investigations concerning evaluation of physicochemical properties of after reclamation dust, generated in foundry industry. Mechanical reclamation processes of used moulding sands generate large amounts of after reclamation dusts containing mainly rubbed spent binding agents and quartz dusts. An amount of after reclamation dusts - in dependence of the reclamation system efficiency and the reclaim dedusting system - can reach 5-10% in relation to the total reclaimed spent moulding sand. The proper utilization of such a material is a big problem facing foundries these days.
Different dusts generated in mechanical reclamation process of used organic sands, delivered from foundries, were tested in respect of determination of its chemical composition, granular characterization and physicochemical properties. As a result of investigations the possible ways to utilise that dusts are also presented.

Keywords: Dust; recycling; environmental protection; reclamation; moulding and core sands.

1. Introduction

Mechanical reclamation processes of spent moulding sands, which is the most often used method of utilization of sand matrix from molds used to casting production generate large amounts of after reclamation dusts containing mainly rubbed, spent binding agents and quartz dusts. After reclamation dusts originated from spent moulding sands with different kinds of resins mostly belong to dangerous wastes, since they contain chemo-setting binders with dangerous substances removed in the reclamation process (Dańko et al., 2007).

*Corresponding Author: rd@agh.edu.pl
ISSN: 2283-5954
Selection and peer-review under responsibility of DUST2014 Scientific Committee
DOI:10.14644/dust.2014.049

Contrary to the dusts generated in metallurgical processes, none of the companies producing mechanical reclamation systems offers presently the complex technology and equipment for utilisation of after reclamation dusts, which would meet technical and economic expectations of foundry plants (Dańko et al., 2014), (Jezierski et al., 2011).

The waste management problem of these dusts is essential for each foundry plant applying this technology, mainly due to high costs of their thermal utilisation. Storage of these dusts in the outlined part of the waste stockpile is associated with high costs. Some foundry plants, having spacious back up facilities, store dusts in big-bags.

2. Physicochemical properties of after reclamation dusts

Aimed at the development of the utilisation method of after reclamation dusts generated in the dry reclamation process of moulding sands with furfuryl resins the following basic physical and chemical properties of after reclamation dusts were tested.

- chemical composition and properties,
- grain size analysis, physical and bulk density of dusts from the reclamation of moulding sands with furfuryl resins
- loss on ignition,
- energetic properties.

According to the data generated by practical foundry knowledge, no bake moulding sands with organic resins applied in a foundry practice have presently the highest share in the castings production out of technologies using no-bake sands, in which quartz matrix is bound by chemisetting binding agents (Holtzer, 2011).

Basing on this these four different dusts originated from the reclamation process of no bake furan resins and two various dust originated from the reclamation process of basic resin technology (ALPHASET, alkyd) were chosen for tests. The experiments were realised in the Faculty of Foundry Engineering, AGH University of Science and Technology within the Project (Project INNOTECH, 2012), which is aimed at the development of the utilisation method of after reclamation dusts generated in the dry reclamation process of moulding sands. Dusts chosen for investigations originated from various Polish foundry plants. These dusts are marked as follows:

I. Dusts with acid resin residues applied in investigations:

P1: Dust originated from foundry producing steel castings of a mass up to 20 Mg. The composition of the furfuryl moulding sand on quartz matrix: sand 100 parts by mass, furfuryl resin 1.3 – 1.6 parts by mass, hardener 0.7 – 0.9 parts by mass. In this moulding sand Kaltharz XA20 resin was used as a binder, while 100T3 as an activator (Bulletins and manufacturers information). The used sand was subjected to mechanical reclamation process in GUT reclaimer and to magnetic separation. The amount of after reclamation dusts in a year was 600 - 840 Mg.

P2: Dust originated from foundry producing grey iron castings of a mass up to 80 Mg were produced in the moulding sand with furfuryl resin: Furanol FR75A and hardener PU5S (Bulletins and manufacturers information). The initial composition of moulding sand: sand 100 parts by mass, furfuryl resin 1.0 part by mass, hardener 0.5 part by mass. The powdery fraction originated from the reclamation of the spent moulding sand in IMF Company reclaimer is submitted for the utilisation by the special unit. The amount of after reclamation dusts in a year was ca. 1500 Mg.

P4: Dust originated from foundry producing grey and ductile iron castings of a mass up to 15 Mg. Moulds are made in furfuryl moulding sand of the following initial composition: matrix: 90 mass% reclaim of high-silica sand + 10 mass% fresh high-silica sand - together 100 parts by mass, Kaltharz 8117 furane resin 0.90 parts by mass and 100T3 activator 0.35 parts by mass (Bulletins and manufacturers). The spent moulding sand reclamation process is performed in the vibratory crusher and column reclaimer (of the IMF Company) of a yield 15 – 20 Mg/h. The after reclamation powdery fraction in amounts of 900 – 1200 Mg in a year, are submitted for the utilisation by the special unit.
P6: Dust originated from foundry producing ductile iron castings of a mass up to 55 Mg. Moulds are produced in the furfuryl moulding sand containing Furanol 75A resin and PU6 hardener (Bulletins and manufacturers information). The initial composition: high-silica sand 100 parts by mass, Furanol 75A resin 0.8 parts by mass, PU6 hardener 0.40 parts by mass. The reclamation process is performed by the mechanical method in devices of the GUT Company. The after reclamation dusts amounts in a year: approximately 180 Mg are handed over to an external company.

II. Dusts with basic resin residues applied in investigations (phenolic, alkyd, ALPHASET type resins)
P3: Dust originated from foundry producing steel castings of a mass up to 12 Mg. Castings are produced in moulds prepared with ALPHASET moulding sand of the initial composition: matrix (40% of fresh high-silica sand and 60% of a reclaim). As a binder in sand composition the phenolic binder Permabind 44 with ester hardener Permabind 132 is applied (Bulletins and manufacturers information). The spent moulding sand reclamation process is performed in the vibratory crusher and column reclaimer (of the IMF Company) of a yield 15 – 20 Mg per hour.
P7: Dust originated from foundry producing steel castings of a mass up to 75 Mg. Castings were produced in alkyd moulding sand containing - as its matrix - high-silica sand and chromite sand (in proportion 5.7:1 respectively). As a binder in sand the alkyd binder resin SL2002 and hardener KL is applied (Bulletins and manufacturers information). The reclamation process is performed by the mechanical method in the GUT reclaimer. After reclamation dusts amounts in a year of approximately 1500-1800 Mg, are handed over to an external company.

3. Results of investigations

To assess the possibility of storage or management of after reclamation dusts it is necessary to determine their the basic physicochemical properties.
The basic physicochemical properties of the investigated after reclamation dusts are collected in Table 1 for moulding sands with furfuryl resins and with alkaline resins.
The chemical composition of the investigated after reclamation dusts from the moulding sands with furfuryl resins and with alkaline resins (data in round brackets) is given in Table 2.

Table 1. Basic physicochemical properties of the investigated after reclamation dusts from moulding sands with furfuryl resins and with alkaline resins.

Determined properties of dust	**Marking of after reclamation dust**					
	Dust from furfuryl sands				**Dust from alkaline sands**	
	P1	**P2**	**P4**	**P6**	**P3**	**P7**
Mass density, g/cm^3 (average value)	2.28	2.40	1.92	2.15	2.50	1.9
Bulk density, g/cm^3 after calcinations during 1 hour in temperature 850^{o}C	1.12	1.28	0.82	0.99	-	-
pH value	5.02	4.14	5.52	4.30	10.2	9.01
Moisture, % by mass	1.60	0.80	3.10	2.50	1.30	1.15
Acid Demand Value, ADV	-	-	-	-	40.50	24.50
Electrolytic conductivity, mS	4.12	2.11	8.82	4.51	7.35	0.84
Loss on ignition at temp. 950^{o}C, % by mass	18.96	10.24	44.36	28.09	5.50	22.17
Emissivity of gases at temperature 1000^{o}C in CO_2, cm^3/g of dust	106	102	154	151	36	125

Table 2. Chemical composition of the investigated after reclamation dusts from the moulding sand with furfuryl resins and with alkaline resins.

Chemical component	**Marking of after reclamation dust, content in % by mass**					
	P1	**P2**	**P4**	**P6**	**P3**	**P7**
Al_2O_3	9.74	1.18	3.05-3.31	7.65	13.12	10.03
C	14.3-18.96	6.2-10.24	34.8-3.16	21.3-28.1	-	-
CaO	0.82	0.15	0.76-0.81	0.35	0.62	0.51
Cl	0.008	0.007	0.020	0.003	0.014	0.012
Fe_2O_3	6.90	1.12	2.85-3.06	3.64	1.99	3.51
K_2O	0.52	0.19	0.59	0.23	1.92	0.14
MgO	0.77	0.08	3.08-3.19	0.16	1.70	0.92
Na_2O	0.21	0.11	0.44	0.065	0.44	0.54
SiO_2	53.53	82.70	av. 40.00	50.05	71.70	50.80
SO_3	2.75	1.13	4.9-5.0	4.63	0.15	1.12
ZrO_2	1.08	0.078	0.045-.22	2.02	0.23	2.06
Total	87.9-92.6	93.0-97.05	90.53-9.8	90.1-96.90	97.38	91.82

The selected data of the size analysis of dusts from the moulding sands with furfuryl resins and with alkaline resins (data in round brackets) performed by the laser diffraction method by means of the Analysette 22 Nano Tec apparatus is presented in Table 3. Since one of the directions of the management of after reclamation dusts originated from moulding sands with organic binders is their thermal utilisation, e.g. in the co-burning with carbon carriers process or in individual burning, it is necessary to determine energy properties of these dusts. The results of technical analysis and energy properties data of after reclamation dusts are presented in Table 4.

Table 3. Selected data of the dust size analysis of dusts from the reclamation of moulding sands with furfuryl resins and with alkaline resins.

Determined size parameter of dust	Marking of after reclamation dust					
	P1	P2	P4	P6	P3	P7
Arithmetic mean of dust particle diameter, µm	49.12	54.23	44.11	31.26	92.56	46.79
Specific surface of dust particles, cm^2/g	6927	9638	10403	10143	6037	18998
Homogeneity of dust	0.71	0.95	0.89	0.89	0.81	0.79
Mass fraction of dust particles size of 1,0 - 56,0 µm, % by mass	73.98	65.652	76.59	90.030	40.24	35.39

Table 4. Energy properties data and technical analysis of dusts from the mechanical reclamation process of moulding sands with furfuryl resins and with alkaline resins.

Determined property, symbol, metric unit	Marking of after reclamation dust					
	P1	P2	P4	P6	P3	P7
Ash content A^a , % by mass	80.3	87.9	55.2	71.3	93.9	77.4
Volatile matter content V^a , %by mass	6,92	3.96	12.50	9.94	3.70	7.82
Heat of combustion Q_s^a , J/g	5004	2806	13746	7108	1382	677o
Calorific value Q_i^a , J/g	4838	2717	13439	6884	1304	6590
Total sulphur content S_t^a , % by mass	0.81	0.50	1.94	1.13	0.04	0.02
Ash sulphur content S_A^a , % by mass	0.16	0,02	0.35	0.06	0.04	0.02
Combustible sulphur content S_C^a , % by mass	0.65	0.48	1.59	1.07	-	-
Content of carbon C_t^a , % by mass	14,7	8.4	35.3	20.1	4.0	18.4
Content of hydrogen H_t^a , % by mass	0.65	0.34	1.16	0.86	0.29	0.77
Content of Nitrogen N^a , % by mass	0.09	0.43	0.46	0.80	0.08	0.77

4. Discussion

After reclamation dusts originated from the mechanical reclamation processes of moulding sands with various resins significantly differ in their physicochemical properties, chemical compositions and energy properties. It is mainly caused by the applied reclamation system and its efficiency, reclaimed material dedusting system efficiency as well as by the efficiency of the mixture separation of high-silica and chromite sands applied as moulding sands matrices. From the point of view of the possibility of utilising energy stored in after reclamation dusts in the process of their individual combustion (e.g. in gaseous furnaces) or co-burning with carbon carriers (e.g. hard coal, brown coal etc.) the highest possible content of combustible substances (it means mainly carbon compounds) is essential. As it was already mentioned, the carbon content in the tested dusts was very different (even 4-times). The dust calorific value is strictly related to the carbon content. The highest calorific value had dust P4. It was more than 13 MJ/kg of dust (at the dust carbon content app. 35%). The lowest calorific value had dust P3 and it was 1.304 MJ/kg of dust. Analysis of data shown in Table 4 allows to state that an amount of the heat, generated in the combustion process of organic components of after reclamation dusts, represented by the calorific value can be related to values which are used for the procedures of the dusts quality estimation and even for the estimation the reclamation process quality such as ignition loss values, carbon content or organic substances total content. The obtained data indicate the linear dependence loss of ignition and calorific values of dusts on the total content of carbon, hydrogen and combustible sulphur - for the whole range of the investigated furan dusts.

5. Conclusions

Six different dusts originated from the mechanical reclamation processes of moulding sands with furfuryl, ALPHASET and alkyd resins were investigated. The obtained results indicate following conclusions:

- Taking into account relatively high calorific values of some investigated dusts (mainly P4 and P6) it can be assumed, that the efficient method of their utilisation will be either a combustion in the gas stream or co-burning with solid carbon carriers.
- A large carbon content in after reclamation dusts and simultaneously a high calorific value of such dust indicates that it contains significant amounts of organic compounds.
- Too intensive dedusting can cause an excessive carrying off silica dusts, which will generate larger amounts of dusts but neither will increase calorific values of these dusts not will cause a better purification of matrix grains from binder coatings.
- Therefore it is necessary to develop such system of the thermal utilisation of these dusts, which would allow self-regulation of energetic fuel additions in dependence of the current calorific value.
- The more efficient is the reclamation process, aimed at removal binder coatings from grain surfaces, the larger is the dust amount. Another factor influencing amounts of after reclamation dusts can be the efficiency of the dedusting system.

6. Acknowledgements

The research is financed by NCBiR within the Project INNOTECH-K1/IN1/57/156360/NCBR/12 realised in years: 2011-2015 at AGH University of Science and Technology - Foundry Engineering Faculty, Krakow, Poland.

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Bulletins and manufacturers information concerning foundry chemicals: HÜTTENES – ALBERTUS, EUROTEK, PRECODLEW and other.