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INVESTIGATIONS OF PHYSICOCHEMICAL PROPERTIES AND THERMAL UTILISATION OF DUSTS GENERATED IN THE MECHANICAL RECLAMATION PROCESS OF SPENT MOULDING SANDS

BADANIA WŁAŚCIWOŚCI FIZYKO-CHEMICZNYCH ORAZ UTYLIZACJA TERMICZNA PYŁÓW GENEROWANYCH W PROCESIE REGENERACJI MECHANICZNEJ ZUŻYTYCH MAS FORMIERSKICH

The after reclamation dusts originated from various foundry plants, applying moulding sands with organic binding agents, mostly resins, are characterised by different properties in dependence of the used binders, reclamation systems, spent sands overheating degree and the efficiency of the system dedusting the reclaimed material operating in individual foundry plants.

In the article the results of investigations of physicochemical properties and thermal utilisation possibility referring to six kinds of after reclamation dusts generated in the mechanical reclamation process of spent moulding sands with furfuryl resins and six other kinds of after reclamation dusts obtained from reclamation process of spent moulding sands with alkaline resins have been presented. All tested dusts originated from various Polish foundry plants of cast iron and cast steel applying the mechanical reclamation process of moulding sands with resins, obtained from different producers.

Keywords: foundry used sands, mechanical reclamation, after reclamation dusts, thermal utilisation

W artykule przedstawiono charakterystykę pyłów powstających w procesie regeneracji mechanicznej mas zużytych ze spoiwami organicznymi, głównie żywicami. W badaniach uwzględniono rodzaj użytego spoiwa, system regeneracji, stopień przepalenia masy formierskiej oraz skuteczność systemu odpylania systemu regeneracji zainstalowanego w instalacjach przemysłowych.

Badaniu poddano właściwości fizykochemiczne oraz możliwości utylizacji termicznej sześciu rodzajów pyłów poregeneracyjnych powstających w procesie regeneracji mechanicznej mas zużytych z żywicą furfurylową oraz sześciu rodzajów pyłów powstających w procesie regeneracji mechanicznej mas zużytych z żywicą alkaliczną. Wszystkie pyły poddane badaniom pochodziły z krajowych odlewni żeliwa i staliwa stosujących technologię mas samoutwardzalnych z żywicami pochodzącymi od różnych producentów, w których stosowana jest mechaniczna regeneracja mas zużytych.

1. Introduction

After reclamation dusts originated from spent moulding sands with organic binding agents belong to dangerous wastes, since they contain chemisetting binders with dangerous substances removed in the reclamation process [1-8].

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.

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. However, some owners of storage grounds additionally require special big-bags, which would decompose after a certain real time, the so-called ecological big-bags.

In a foundry practice, moulding sands with furfuryl resins applied 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 [9].

A quality of castings produced in such moulding sands is high, the technology is universal – to a considerable degree – both in respect of the applied casting alloy (cast steel, cast iron) and in respect of a size and complexity of castings.

A free alcohol content in resins used currently in foundries is within a range of 50-95%. Furfuryl resins of the latest generation do not contain free phenol and aldehyde, and the free furfuryl alcohol content is decreased to significantly below 50%.

Spent foundry sands with furfuryl resins can be well reclaimed by the mechanical method, allowing efficient recycling process of the quartz matrix, in which a significant amount of fresh high-silica sands can be substituted by the reclaimed material at a simultaneous decreasing the resin addition to the newly prepared moulding sand.

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Regulations by law of the European Union drastically limit the free furfuryl alcohol content, classified as a toxic product, to a level below 30% as well as elimination of dangerous **B**(enzene)**T**(toluene)**E**(thylbenzene)**X**(ylene) and **P**(olycyclic)**A**(romatic)**H**(ydrocarbons) gases emitted during foundry processes.

As a result of restrictions – being in force – the producers of binding agents for moulding sands are obliged to search for new binders, more environment and employees friendly.

To this group belong, among others, binders used in the ALPHASET technology (the technology of self-hardening mixtures phenol resin – ester is based on the two-component binding system, where the alkali phenol resin is the binding component). These binders are of a basic character.

Spent foundry sands with alkaline resins can be reclaimed by the mechanical methods, allowing efficient recycling process of the quartz matrix, in which a significant amount of fresh high-silica sands can be substituted by the reclaimed material with a simultaneous decreasing the resin addition to the newly prepared moulding sand [10-11].

One of the main criteria of assessing the obtained reclaim quality in systems of multiple circulations of a matrix – which decides on its qualifying as the fresh sand substitute at preparing moulding sands – is the reclaim ignition loss, which should be below 3%. In case of insufficient removal of spent binders from surfaces of matrix grains the moulding sand has a high gas evolution rate [8] and increased N and S content in the matrix (which should not exceed 0.15%). The nitrogen content in a matrix can be the reason of defects in cast iron and cast steel castings, while the sulphur content above 0.15% can cause a flake graphite occurrence on surfaces of iron castings with nodular graphite [12-16].

The presented below investigations were realised in the Faculty of Foundry Engineering, AGH University of Science and Technology within the Project [17-19], which is aimed among others at the development of the thermal utilisation method of after reclamation dusts generated in the dry reclamation process of moulding sands with acid resin residues (furfuryl resins) and with basic resin residues (phenolic, alkyd, alphaset type resins) applied in investigations.

2. Investigations of physicochemical properties of after reclamation dusts – in an aspect of their management possibility

The investigated dusts originated from various foundry plants, applying moulding sands both with acid and basic resins, are characterised by different physicochemical properties and thermal utilisation possibility of dusts in dependence of the used resins, mechanical reclamation systems, spent sands overheating degree (kind of casting material -cast iron or cast steel, casting sizes) and the efficiency of the system dedusting the reclaimed material operating in individual foundry plants. The following basic physical and chemical properties of after reclamation dusts were tested and measured in the preliminary stage of investigations:

– chemical composition and properties,
– grain size analysis of dusts from the reclamation of used moulding sands

– gas evolution rates,
– loss on ignition,
– energetic properties.

2.1. Technological outline of after reclamation dusts applied in investigations

Six kinds of after reclamation dusts generated in the mechanical reclamation process of spent moulding sands with furfuryl resins and seven other kinds of after reclamation dusts obtained from reclamation process of spent moulding sands with alkaline resins were prepared for investigations. They originated from various Polish foundry plants of cast iron and cast steel applying the mechanical reclamation process of moulding sands with resins (obtained from different producers). These dusts are marked as follows:

I. Dusts with acid resin residues applied in investigations (furfuryl resins type HA)

P1: Steel castings of a mass up to 20 Mg were produced using moulding sand containing – as its matrix – high-silica sand and chromite sand (in proportion 30:1). The composition of the 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. The resin addition to the chromite matrix was 1.2 parts by mass, while hardener 0.6 parts by mass. In this moulding sand Kaltharz XA20 resin was used as a binder, while 100T10 as an activator (produced by Hüttenes Albertus Company). 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: Grey iron castings of a mass up to 80 Mg were produced in this moulding sand with furfuryl resin: Furanol FR75A and hardener: PU5S and PU5W (produced by PRECODLEW). 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: Castings of grey and ductile cast irons, of a mass up to 15 Mg, are made in 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 (produced by Hüttenes Albertus Company). 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.

P5 Steel castings of a mass up to 500 kg are produced in the moulding sand of the initial composition: high-silica sand 100 parts by mass, Permaset 839 furfuryl resin 0.7-0.8 parts by mass, Permacat hardener 0.35-0.40 parts by mass. The mechanical reclamation system of the EUROTEK (TROJAN) Company is applied. The after reclamation dusts amounts in a year app. 30 Mg are handed over to an external company.

P6: Castings of ductile cast iron of a mass up to 55 Mg are produced in the furan moulding sand containing Furanol 75A resin and PU6 hardener (produced by PRECODLEW) [14]. 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.

P9: Steel castings of a mass up to 5 Mg are produced in furane moulding sand of the initial composition: matrix (15% of fresh high-silica sands and 85% of a reclaim) 100 parts by mass, XA20 furfuryl resin 1.1 part by mass, activator 100T3 0.35 parts by mass (produced by Hüttenes Albertus Company). The mechanical reclamation of the IMF Company of a yield of 12 Mg/h is applied.

II. Dusts with basic resin residues applied in investigations (phenolic, alkyd, alphaset type resins)

P3: Steel castings of a mass up to 12 Mg are produced in moulds prepared with moulding sand of the initial composition: matrix (40% of fresh high-silica sands and 60% of a reclaim). As a binder in sand composition the phenolic binder (Permabind 44 – producer Eurotek England) with ester hardener (Permabind 132) is applied. 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. After reclamation dusts were submitted for the utilisation by the special unit.

P7: Steel castings of a mass up to 75 Mg were produced in 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 – producer PRECODLEW Poland). The reclamation process is performed by the mechanical method in the GUT reclaimer. The reclaimed sand was subjected to magnetic separation. After reclamation dusts amounts in a year of approxi-

mately 1500-1800 metric tons, are handed over to an external company.

P10: Cast iron and steel castings of a mass up to 500 kg are produced in moulding sand containing as its matrix 40% of fresh high-silica sands and 60% of a reclaim. As a binder in sand composition the resin from ALPHASET technology is applied (resin Avenol 700 NB, hardener Katalysator 4040 – producer ASK Chemicals). The spent moulding sand reclamation process is performed in mechanical system of the EUROTEK (TROJAN) Company. Dusts amounts in a year of approximately 50 metric tons, are stored in foundry and them handed over to the outlined part of the waste stockpile.

In research, on account of a low reclaiming ability of spent moulding sands from the ALPHASET technology, the additional tests aimed at the reclamation improvement were performed. In this case, in order to obtain dusts P13-P15 the spent moulding sand (the same which was described in the case of dust P10) was reclaimed in the new type of the vibratory reclaimer, integrated with the cascade air classifier, called REGMAS [16].

P13, P14, P15: three additional after reclamation dusts, obtained from the same spent moulding sand as dust P10, by means of the reclamation, at the following conditions of the reclamation treatment in the vibratory device REGMAS:

P13 – dust generated during the I-st reclamation cycle;
P14 – dust generated during the II-nd reclamation cycle;
P15 – dust generated during the III-rd reclamation cycle.

2.2. Physicochemical properties of after reclamation dusts

To assess the possibility of storage or management of after reclamation dusts it is necessary to determine the basic physicochemical properties of the investigated dusts.

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.

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											
	Furfuryl dust						ALPHASET dust					
	P1	P2	P4	P5	P6	P9	P3	P7	P10	P13	P14	P15
Mass density, g/cm^3 (average value)	2.28	2.40	1.92	2.38	2.15	2.31	2.50	1.9	2.57	2.26	2.42	2.59
Bulk density, g/cm^3 after calcinations during 1 hour in temperature 850°C	1.12	1.28	0.82	1.24	0.99	1.16	–	–	–	–	–	–
pH value	5.02	4.14	5.52	4.67	4.30	4.81	10.2	9.01	10.42	7.85	7.64	7.99
Moisture, % by mass	1.60	0.80	3.10	1.00	2.50	1.70	1.30	1.15	2.26	1.90	2.00	0.90
Acid Demand Value, ADV	–	–	–	–	–	–	40.50	24.50	11.73	10.50	8.00	11.50
Electrolytic conductivity, mS	4.12	2.11	8.82	4.79	4.51	5.80	7.35	0.84	6.24	12.86	7.59	4.71
Loss on ignition at temp. 950°C, % by mass	18.96	10.24	44.36	12.0	28.09	16.56	5.50	22.17	3.59	9.79	8.94	4.42
Emissivity of gases at temperature 1000°C in CO$_2$, cm^3/g of dust	106	102	154	103	151	112	36	125	21	66	53	30

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

Chemical component	Marking of after reclamation dust, content in % by mass											
	P1	P2	P4	P5	P6	P9	P3	P7	P10	P13	P14	P15
Al_2O_3	9.74	1.18	305-3.31	3.53-6.31	7.65	8.58-8.81	13.12	10.03	5.35	2.20	1.98	1.11
C	14.3-18.96	6.2-10.24	34.8-3.16	7.4-12.00	21.3-28.1	15.6-16.56	–	–	–	–	–	–
CaO	0.82	0.15	0.76-0.81	0.22-0.33	0.35	1.10-1.15	0.62	0.51	0.89	0.28	0.31	0.36
Cl	0.008	0.007	0.020	av.0.0055	0.003	0.013	0.014	0.012	0.027	0.012	0.012	0.010
Fe_2O_3	6.90	1.12	2.85-3.06	1.59-2.06	3.64	1.58-2.23	1.99	3.51	2.16	0.87	0.96	0.90
K_2O	0.52	0.19	0.59	0.48-0.59	0.23	0.55	1.92	0.14	0.32	0.47	0.45	0.36
MgO	0.77	0.08	3.08-3.19	0.57-0.64	0.16	0.24-0.26	1.70	0.92	0.45	0.16	0.17	0.16
Na_2O	0.21	0.11	0.44	0.19-0.33	0.065	0.24	0.44	0.54	4.31	1.09	0.92	0.47
SiO_2	53.53	82.70	av.40.00	av.75.3	50.05	55.40	71.70	50.80	81.00	81.80	84.80	87.95
SO_3	2.75	1.13	4.9-5.0	0.75-0.40	4.63	2.30-2.8	0.15	1.12	0.01	0.05	0.03	0.01
ZrO_2	1.08	0.078	0.045-.22	0.005-1.09	2.02	5.02-5.55	0.23	2.06	0.46	0.42	0.38	0.35
Total	87.9-92.6	93.0-97.05	90.53-9.8	94.04-99.0	90.1-96.90	90.6-91.10	97.38	91.82	98.57	97.14	98.95	96.09

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	P5	P6	P9	P3	P7	P10	P13	P14	P15
Arithmetic mean of dust particle diameter, μm	49.12	54.23	44.11	58.22	31.26	48.12	92.56	46.79	31.08	74.65	77.7	78.87
Specific surface of dust particles, cm^2/g	6927	9638	10403	9191	10143	9748	6037	18998	9143	6272	5662	6776
Homogeneity of dust	0.71	0.95	0.89	0.82	0.89	0.81	0.81	0.79	1.71	0.80	0.71	0.70
Mass fraction of dust particles size of 1,0-56,0 μm, % by mass	73.98	65.652	76.59	55.15	90.030	82.20	40.24	35.39	84.94	47.94	44.58	42.95

The chemical composition of the investigated after reclamation dusts from the moulding sands with furfuryl resins and with alkaline resins is given in Table 2. 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.

2.3. Energy characteristic of after reclamation dusts

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.

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

Determined property, symbol, metric unit	Marking of after reclamation dust											
	P1	P2	P4	P5	P6	P9	P3	P7	P10	P13	P14	P15
Ash content ^{a}, % by mass	80.3	87.9	55.2	87.7	71.3	82.7	93.9	77.4	96.7	93.2	93.9	96.3
Volatile matter content ^{a}, % by mass	6.92	3.96	12.50	4.29	9.94	5.98	3.70	7.82	2.08	4.85	4.47	2.64
Heat of combustion ^a_s, J/g	5004	2806	13746	3101	7108	4570	1382	6770	209	1520	1363	1110
Calorific value ^a_i, J/g	4838	2717	13439	3016	6884	4448	1304	6590	161	1440	1230	1050
Total sulphur contetnt ^a_t, % by mass	0.81	0.50	1.94	0.63	1.13	0.85	0.04	0.02	0.01	0.02	0.02	0.01
Ash sulphur content ^a_A, % by mass	0.16	0.02	0.35	0.06	0.06	0.23	0.04	0.02	0.01	0.02	0.02	0.01
Combustible sulphur content ^a_C, % by mass	0.65	0.48	1.59	0.57	1.07	0.62	–	–	–	–	–	–
Content of carbon ^a_t, % by mass	14.7	8.4	35.3	8.7	20.1	13.0	4.0	18.4	1.1	4.2	3.8	2.9
Content of hydrogen ^a_t, % by mass	0.65	0.34	1.16	0.32	0.86	0.48	0.29	0.77	0.14	0.34	0.31	0.17
Content of Nitrogen ^{a}, % by mass	0.09	0.43	0.46	0.17	0.80	0.11	0.08	0.77	0.02	0.07	0.07	0.04

3. Discussion of the results of dusts investigations

After reclamation dusts originated from the mechanical reclamation processes of moulding sands with various furfuryl 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. Out of six investigated reclamation systems three were produced by the IMF Company (Italy), two by the GUT Company (Germany) and one by EUROTEK Company.

pH values of after reclamation dusts are slightly higher than the ones of the reclaimed materials and equal from 4 to 5.5. Electrolytic conductivity of the investigated dusts is also diversified, from 2 to nearly 9 mS. When the emissivity of gases is concerned, dusts P4 and P6 emit, in a temperature of 1000°C, approximately 50% more gases than the remaining dusts. These dusts contain also visibly larger amounts of volatile matter in relation to the remaining dusts, which is confirmed by high values of ignition losses.

The main component of after reclamation dusts constitutes silica. Its content equals from 40 to more than 80 mass%. Moreover, the less SiO_2 in dusts the more substances containing carbon (it means binding agents removed from sand grains surfaces). Thus, it can be assumed that: the more carbon compounds are in such dusts the more efficient is the reclamation process and the dedusting system is properly set (it does not carry off excessive amounts of a matrix). Dusts P4 and P6 of the highest carbon content, are characterised by a significantly lower ash content, being respectively 55.2 and 71.3% (which means a lower content of inorganic components, mainly SiO_2, than in the remaining dusts).

Other major components of after reclamation dusts are: Al_2O_3 – up to 10%, Fe_2O_3 – up to 7%. The content of sulphur compounds originates, of course, from the hardeners applied for moulding sands with furfuryl resin (sulphonic acids + sulphuric acid) is characteristic. The total sulphur content in dusts approaches 2% (dust P4). Generally in all investigated dusts occurs combustible sulphur. The highest sulphur content was found in dusts (P4, P6) obtained from the reclamation of moulding sands in which hardeners containing large amounts of paratoluenosulphonic acid (PTS), such as e.g. 100T3 hardener (PTS content approximately 65%), were used. On the other hand, dusts (e.g. P5) obtained from the reclamation of moulding sands with furan resins, for which hardeners contained large amounts of sulphuric acid (VI) (10-30%) and did not contain sulphonic acids, had significantly less sulphur. The sulphur presence in after reclamation dusts influences the emission of sulphur compounds into the environment, during thermal treatments of these dusts, and constitutes a hazardous phenomenon [15].

The main fraction of all dusts constituted grains of sizes: 1-56 μm (see Table 3). The mass fraction of dust particles size of 1.0-56.0 μm, vary from 55.147 to 90.030% by mass to all tested dusts. The amount of grains below 1 μm equalled maximum 3.135% (dust P4). The highest homogeneity in respect of grain composition had dusts P2, P4 and P6. These dusts had also the largest specific surface.

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 P2 and it was less than 3 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 of ignition losses and calorific values of dusts on the total content of carbon, hydrogen and combustible sulphur – for the whole range of the investigated furan dusts.

Parameterisation of measurements allows for a direct utilisation of temporary determined ignition loss values for an approximate assessment of calorific values of after reclamation dusts. These simplifies procedures of a rational and practical qualifying or eliminating – without complex measurements, already at the foundry plant stage – given dusts for the thermal utilisation joined with the heat recovery. The statistical elaboration of the given data for dusts obtained from reclamation used furan sands allows to calculate the calorific value in the following way:
– in dependence of the total content of carbon, hydrogen and combustible sulphur:

$$Q_i^a \text{[J/g]} = 334 \cdot [\Sigma(C_t^a + H_t^a + S_C^a)]; R^2 = 0.984 \qquad (1)$$

– in dependence of the carbon content:

$$Q_i^a \text{[J/g]} = 362 \cdot C_t^a; R^2 = 0.987 \qquad (2)$$

– in dependence of dusts ignition loss values:

$$Q_i^a \text{[J/g]} = 279.97 \cdot SP; R^2 = 0.969 \qquad (3)$$

As can be seen, linear dependencies of calorific values of after reclamation dusts on the analysed values as well as their statistical elaborations are characterised by high values of the correlation coefficient $R^2 = 0.9698$-0.9870.

The statistical elaboration of the given data allows to calculate the calorific value data for dusts obtained from reclamation of used alkaline sands in the following way:
– in dependence of the carbon content:

$$Q_i^a \text{[J/g]} = 354.35 \cdot C_t^a; R^2 = 0.997 \qquad (4)$$

– in dependence of dusts ignition loss values:

$$Q_i^a \text{[J/g]} = 251.5 \cdot SP; R^2 = 0.969 \qquad (5)$$

In this case the values of the correlation coefficient equals $R^2 = 0.9997$-0.969.

4. Conclusions

1. Analysis of obtained data indicate 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 as well the linear dependence of ignition losses and calorific values of dusts on the total content of carbon, hydrogen and combustible sulphur – for the whole range of the investigated furan after reclamation dusts. The statistical elaboration of the given data simplifies procedures of a rational and practical qualifying or eliminating given dusts for the thermal utilisation joined with the heat recovery.

2. Taking into account relatively high calorific values of some investigated dusts (P3 and P6) it can be assumed, that the efficient method of their utilisation will be either a combustion in the gas stream (for the initiation and later on when needed to sustain burning) or co-burning with solid carbon carriers (e.g. hard coal or brown coal). Within the research Project these both directions of the utilisation of after reclamation dusts originated from the mechanical reclamation of moulding sands with organic binders are realised.

3. A large carbon and sulphur content in after reclamation dusts and simultaneously a high calorific value of such dust indicates that it contains significant amounts of organic compounds separated from the quartz matrix during the reclamation process. The more efficient is the reclamation process, aimed at removal binder coatings from grain surfaces, the larger is the dust amount. Too large content of a binder in a moulding sand, which covers grains with a thicker (than it is necessary) layer, which is easier removable in elementary reclamation processes (rubbing, abrasion, crushing) is also a factor generating increased amounts of after reclamation dusts. Another factor influencing amounts of after reclamation dusts can be the efficiency of the dedusting system. 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. However, it is a cause of matrix losses.

4. The obtained results for six different dusts originated from the mechanical reclamation processes of moulding sands with furfuryl resin hardened by acids containing sulphur indicate that these dusts can be significantly different, even in cases when the same resin or the same reclamation system is applied. Also, within the same installation successive batches of dusts can differ between themselves in their chemical compositions (mainly in carbon and silica content), and thus in calorific values. 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.

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