www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES of FOUNDRY ENGINEERING

DE GRUYTER OPEN

ISSN (2299-2944)
Volume 14
Issue 4/2014

DOI: 10.2478/afe-2014-0079

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

21 – 26

Idea of the Integrated Recycling System of Used Moulding Sands with Organic Resins

R. Dańko
AGH - University of Science and Technology, Faculty of Foundry Engineering,
Reymonta 23 Str., 30-059 Kraków, Poland
Corresponding author. E-mail address: rd@agh.edu.pl

Received 23.06.2014; accepted in revised form 15.07.2014

Abstract

The paper presents the idea of the integrated recycling system of used moulding sands with organic resins. A combination of the method of forecasting averaged ignition loss values of moulding sands after casting and defining the range of necessary matrix reclamation treatments in order to obtain its full recycling constitutes the basics of this process.
The results of own investigations, allowing to combine ignition loss values of spent moulding sands after casting knocking out with amounts of dusts generated during the mechanical reclamation treatment of such sands, were utilized in the system.

Keywords: Moulding sand, Self-setting sand, Recycling, Reclamation, System

1. Introduction

From the point of view of the economy of materials for preparation moulds and cores the problem of reusing of matrix materials appears essential in processes of making castings in sand moulds with using materials, such as moulding sands with organic binders. In case of this type of moulding sands, it is not possible to consider any sands circulation process since after each casting cycle they are not directly suitable for a further use. At the current stage of the moulding sands technology only the matrix can be utilized again, but only in case of its proper preparation (e.g. reclamation). The simplified scheme of the circulation of the matrix of spent moulding sands is presented in Figure 1. The most important - for the proper economy of moulding materials and proper preparation of technological processes - stages of the matrix circulation are marked by symbols I-III in the Figure 1. The proposed monitoring system would be implemented at those three stages of the process:

I. Preparation of a moulding sand

Assuming as an initial parameter, that the moulding sand is prepared from fresh components (high-silica sand, resin, activator - hardener), the material, which will meet the requirements of the casting mould technology - from the point of view of technological properties - and will lead to producing sound casting, should be prepared in this process.

II. Knocking out and a preliminary crushing of spent sands

This process is essential for the circulation of sands with organic binders, since the properties of the matrix material obtained at this stage determine the successive steps. The degree of a thermal destruction due to an influence of liquid metal on moulding sands decides on properties of a spent sand and its matrix obtained after the casting production.

III. Reclamation of a spent matrix

This is the process deciding on properties of the matrix (reclaimer), which is used as the main component of moulding sands in multi-cycle systems of the matrix circulation.

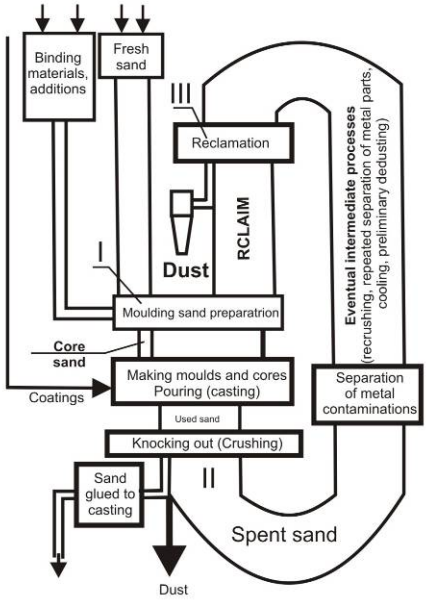

Fig. 1. Scheme of the multicycle circulation of the matrix of spent moulding sands

2. Monitoring and control system of the circulation of the matrix with organic binder

On the basis of previous research, carried out in AGH – UST within previously carried out works and projects, it is possible to propose the detailed description of the Integrated Recycling System of Used Moulding Sands with Organic Resins (Figure 2). This description presents the most important operations, their interconnections and propositions of control methods allowing either a partial or fully automated circulation process.

The very essential parameter of the description is the knowledge of the basic initial data, such as:

- Ignition loss of the moulding sand from which the mould is made of,
- Mould thermal load,
- Time of the casting cooling down in the mould,
- Mould geometry.

On the basis of these parameters, with the application of simulation programs expanded by the computational module for the moulding sand state prognosis, it will be possible to determine the ignition loss of the matrix of the spent moulding sand with organic binder, at the stage of the casting knocking out. In addition, the simulation investigations in cooperation with the knowledge gained from research works, can allow to calculate the moulding sand gas evolution rate, including amount of toxic gases generated in the pouring process, etc.

Casting knocking out is one of the operations of the preliminary matrix reclamation process of spent sands and is usually carried on insulated, dedusted, shake out grids. Energy aspects of the casting knocking out process have not been lately the subject of scientific publications. Industrial practice is mainly based on own experiences of the engineering staff of the foundry plant. It seems, that the knowledge of the moulding sand impact toughness as well as of the high temperature influence on this impact toughness can constitute the essential parameter of the optimization process of shake out grids operations. An integration of data concerning impact toughness of moulding sands with the computer simulation results of the temperature distribution in the mould, can become the essential parameter influencing this optimization.

In the knocking out process, preliminary matrix crushing and reclamation a certain amount of dusts is generated. These dusts are exhausted in the system of shake out grids and can be quantitatively estimated by the measuring method making use of the triboelectric effect. The amount of measured dusts at this stage influences the ignition loss value of the spent sand matrix after the secondary reclamation process.

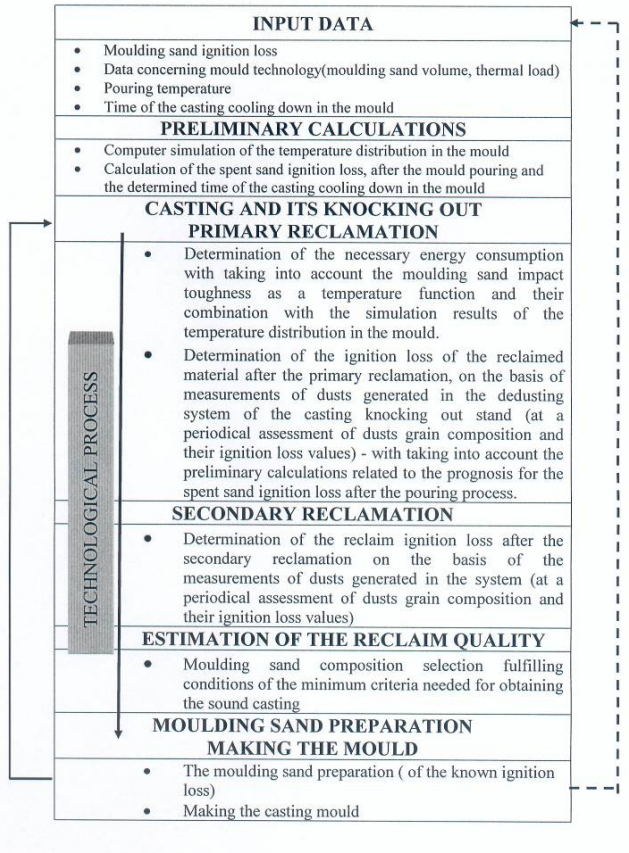

Fig. 2. Idea of the integrated recycling system of used moulding sands with organic resins

The most essential for the idea of the Integrated Recycling System of Used Moulding Sands with Organic Resins are:

– method of determining ignition losses of spent moulding sand with organic binder after the casting production,
– new developed assessment method of purification degree of spent moulding sand grains from binder remains basing on the measured amount of dust generated during reclamation treatment.

3. Method of determining ignition losses of spent moulding sand with organic binder after the casting production

This method was described in details in publications [1, 2]. High temperatures cause self-acting burning of a part of the moulding sand being near the casting surface, which enables to determine local and averaged ignition losses after the casting production. The effect of 'self-reclamation' in the immediate vicinity of walls, of a part of a moulding sand occurs in the zone (Fig. 3) in which a moulding sand is heated, by the casting, to a temperature causing a thermal degradation of a binder, which loses its binding and strength properties. The binder being in the sand becomes totally or partially burned out, which improves the matrix knocking out and reclamation (in mechanical systems) ability.

Fig. 3. Effect of the thermal 'self-reclamation' in the immediate vicinity of walls of a moulding sand with an organic binder

The way of determining the relative degree of the thermal degradation of a moulding sand $D_{m(T)}$ heated to the given temperature and thus the change of its ignition loss, at quasi stable other parameters of the technological process, can be determined from the equation:

$$D_{m(T)} = (1 - \frac{SP_{(T)}}{SP_{(ini)}}) \cdot 100\% \quad (1)$$

where:
$D_{m(T)}$ – relative degree of the thermal degradation of a moulding sand at a temperature T, %
$SP_{(T)}$ – ignition loss of a moulding sand heated at the determined temperature; %,
$SP_{(ini)}$ – ignition loss of a moulding sand prior to pouring metal into mould (initial state); %.

It can be assumed that thermal resistance of a moulding sand $O_{m(T)}$ can be expressed by the equation:

$$O_{m(T)} = (\frac{SP_{(T)}}{SP_{(ini)}}) \cdot 100\% \quad (2)$$

where:
$O_{m(T)}$ – thermal resistance of a moulding sand at a temperature T, %

Information concerning the actual thermal degradation degree $D_{m(T)}$ of the investigated moulding sands subjected to heating at the determined temperatures, can be used for the ignition loss forecasting of a moulding sand after making the casting, under the given conditions of the realised process. The empirically determined moulding sand destruction degree (at the determined temperature ranges) and the moulding sand volume, which was overheated to a temperature causing either complete or partial thermal degradation of a binding material is required for the $D_{m(T)}$ determination.
The degradation degree of the whole moulding sand forming the casting mould, after making in it the casting, can be determined from the following dependence:

$$D_{mf} = \sum_{T=T_{ot}}^{T_{cd}} \frac{V_{(T)}}{V_{(C)}} \cdot D_{m(T)} = \sum_{T=T_{ot}}^{T_{cd}} \frac{V_{(T)}}{V_{(C)}} \cdot (1 - \frac{SP_{(T)}}{SP_{(ini)}}) \cdot 100\% \quad (3)$$

where:
D_{mf} – thermal degradation of a moulding sand in a casting mould, %
T_{cd} – temperature of a complete binder destruction, ^{0}C,
$V_{(T)}$ – volume of a mass heated to a temperature T, cm^3, m^3,
$V_{(C)}$ – total volume of a moulding sand, cm^3, m^3,
$D_{m(T)}$ – as in Eq. (1).

Temperatures T, characteristic for a binder, usually analysed every 100^{0}C, are taken into account in the equation. Values of $D_{m(T)}$ for these temperatures and moulding sand volumes overheated to their values are determined and then related to the total mould volume. Values of $D_{m(T)}$ were determined within the temperature range 23^{0}C-800^{0}C, applying the temperature interval of 100^{0}C.
Knowing the total thermal degradation degree of a moulding sand D_{mf}, it is possible to calculate the ignition loss of spent moulding sand:

$$SP_{(mz)} = SP_{(ini)} \, (1 - 0{,}01 \cdot D_{mf}); \ \% \quad (4)$$

$SP_{(mz)}$ – spent moulding sand ignition loss, %

In paper [2] the full presentation of the described method is presented with its practical verification and usage of MAGMA simulation programme.
Information concerning the ignition loss of spent moulding sands after the casting knocking out is very important for the proper performance of the recycling process. It allows the proper determination of the binder amount left on the spent matrix grains, which should be removed in the mechanical reclamation process as long as the existing technique state allows.

3. Purification degree of spent moulding sand grains from binder remains

Purification process of spent moulding sand grains from the binder remains is realised in reclamation processes, mainly mechanical reclamations [3-6].
As the result of performed investigations the influence of the amount of dusts generated in the mechanical reclamation process

of spent moulding sands with an organic binder (removed later on in the classification process) on the reclaim ignition loss was calculated. This constituted the grounds of the idea allowing for the indirect assessment of the spent moulding sand ignition loss on the basis of measuring dust amounts generated in the reclamation process. The performed investigations concerned three spent moulding sands with synthetic resins:

- Spent moulding sand with the furfuryl resin: Kaltharz U404, and hardener: 100T3 (F),
- Spent moulding sand with the phenolic resin: Rezolit AM, and hardener: PRESTAL-R1 (P),
- Spent moulding sand with the alkyd resin: LT 72, and hardener: Desmodur 44V20 (A).

The reclamation treatment was carried out on the stand of the rotor tester of grinding-crushing operations AT-2 (Fig. 4). The variability range of the rotor rotational speeds and reclamation treatment times are presented in Figure 5.

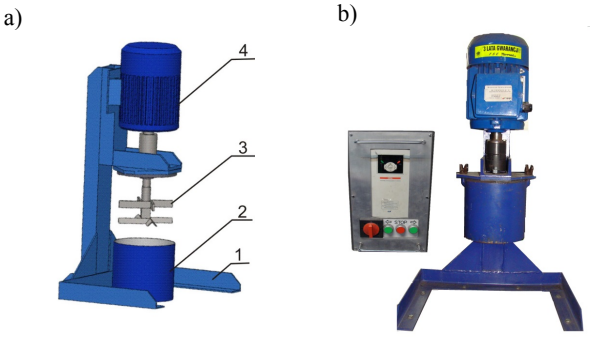

Fig. 4. (a) – General scheme of the rotor tester AT-2 of the grinding-crushing operation: 1 – base, 2 –container for the spent reclaim, 3 – rotor of the impact-abrasive system, 4 – motor, (b) – View of the apparatus

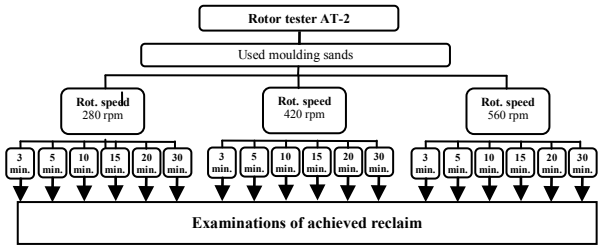

Fig. 5. Variability range of parameters of the spent moulding sands reclamation treatment

The hereby publication is focused on the presentation of dependencies essential from the point of view of the matrix reclamation integrated process, while the wider elaboration of the performed investigations-was featured in the work [1].

The accumulated diagram (Fig. 6) of the results obtained for three kinds of spent moulding sands with organic binders indicates the linear dependence of the reclaimed matrix ignition loss on the amount of after reclamation dusts in the reclaim - for the whole range of the reclamation treatment, regardless of the treatment intensity and its realization time.

The content of dusts generated during the process is the element merging influences of individual investigated values to provide the total liberation effect of matrix grains from the spent binder coatings. It represents the general potential of the matrix purification degree from spent binding materials.

The assessment of the degree of reclamation of the spent moulding sand, of known ignition loss before the reclamation, can be indirectly determined on the basis of the forecasted ignition loss of the ready reclaim. Forecasting is done on the basis of measurements of the amount of dusts generated during the process and the knowledge of organic material (resin) content in dusts drawn off from the reclaimer (which – as it was shown in paper [ ] - is practically constant during the reclamation process and depends on a binder kind).

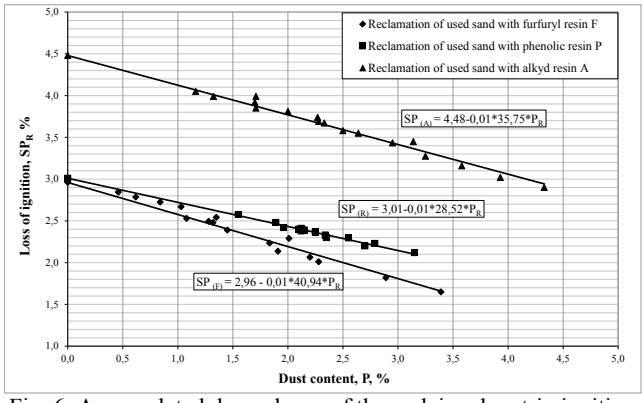

Fig. 6. Accumulated dependence of the reclaimed matrix ignition losses, after the pneumatic classification, on the dusts content generated during the reclaim treatment of three kinds of spent moulding sands in the rotor tester AT-2

Taking into account these data, it can be assumed that the ignition loss of the ready reclaim $SP_{(R)}$ is expressed by the equation:

$$SP_{(R)} = SP_{(mz)} - 0{,}01 \cdot SP_{(P)} \cdot P_R \tag{5}$$

$SP_{(R)}$ – ignition loss of the reclaim, %
$SP_{(P)}$ – average ignition loss of dusts, %
P_R – amount of dusts drawn off from the reclaimer (% in relation to the total mass amount in the reclaimer),
$SP_{(mz)}$ – ignition loss of a spent moulding sand before the reclamation, %,

This - theoretically defined and experimentally verified - regularity can be used as the base of the matrix recycling modern system equipped with automatic measuring and monitoring of dusts. This system is also equipped with the on-line current control of the purification degree of matrix grains from the organic binder remains, which is done by combining ignition losses in the spent sand after casting knocking out with the amount of dusts generated during the matrix mechanical reclamation.

4. On-line control of the purification degree of the spent moulding sand from binder remains

The linear dependence, experimentally confirmed, of the amount of dusts generated during the reclamation of spent, uniform moulding sands with organic binders, and ignition loss value of the obtained reclaim, was applied - in the developed system – for the current control of the matrix recycling process. The ignition loss values of the reclaim is – in this system - considered the main index of the degree of liberating polydispersive sand grains from remains of binding materials, while the other, traditionally determined physical and chemical properties of the matrix, play the role of auxiliary factors, suitable at the stage of its integrated assessment.

The experimental stand, designed and built for investigations of the matrix recycling process, was equipped with the current on-line control system of the degree of liberating matrix grains from remains of organic binders with a simultaneous combining ignition loss values in the spent sand after casting knocking out with the amount of dusts generated during the mechanical reclamation treatment of this moulding sand.

The stand layout maintains the solution idea developed by D. Boenisch [6], however at a significant diversification of the reclaiming element structure.

The experimental rotor reclaimer, marked RD-6, equipped with the system for automatic on-line measurements of amounts of dusts generated in the grinding-crushing treatment is presented in Figure 7.

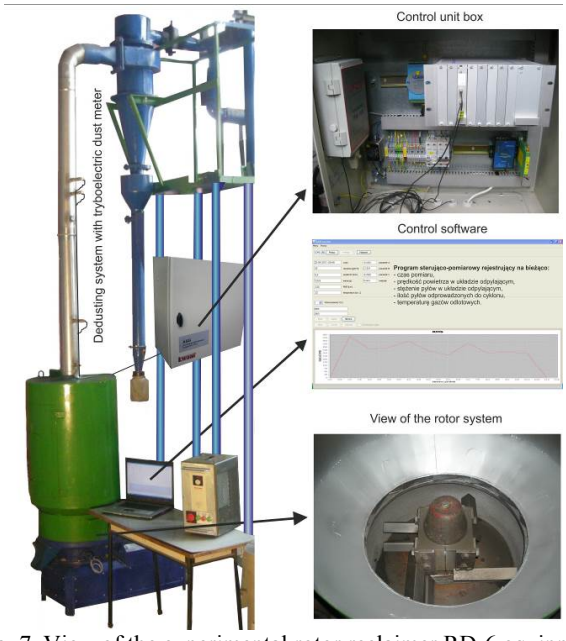

Fig. 7. View of the experimental rotor reclaimer RD-6 equipped with the system of triboelectric dust meter for automatic on-line measurements of amounts of dusts generated in the grinding-crushing treatment of the matrix

Reclamation tests of the spent moulding sand with the Kalharz U404 resin hardened by paratoluenesulphonic acid 100T3, were performed in the reclaimer RD-6. The following operation parameters were applied:

METHOD I –rotational speed of the rotor n = 270 rpm, time of treatment τ_{reg} =15 min, air rate in the dedusting system v_{odp} = 8.5 m/s.

METHOD II – n = 540 rpm, τ_{reg} =15 min, v_{odp} = 8.5 m/s.

METHOD III – n = 810 rpm, τ_{reg} =15 min, v_{odp} = 8.5 m/s.

METHOD IV – rotor speed n being changed during the reclamation treatment:

– cycle 1: τ_{1reg} = 0 - 1 min, n_1 = 270 rpm,
– cycle 2: τ_{2reg} = 1 – 10 min, n_2 = 540 rpm,
– cycle 3: τ_{3reg} = 10 -15 min, n_3 = 810 rpm.

Total treatment time τ_{reg} =15 min, air rate in the dedusting system v_{odp} = 8.5 m/s.

METHOD V – rotor speed being changed during the reclamation treatment:

– cycle 1: τ_{1reg} = 0 -1 min, n_1 = 270 rpm,
– cycle 2: τ_{2reg} = 1 – 5 min, n_2 = 540 rpm,
– cycle 3: τ_{3reg} = 5 -15 min, n_3 = 810 rpm.

Total treatment time τ_{reg} =15 min, air rate in the dedusting system v_{odp} = 8.5 m/s.

Monitoring on-line the amount of dusts removed in the air stream from the reclaimer to the cyclone as a time function, allowed determining changes in their amounts during the spent moulding sand reclamation treatment carried out by the given way. Amounts of dusts measured by means of the triboelectric dust meter PM 103D, for the described I-V methods of recycling, are presented as time functions in Figure 8. Ignition loss values $SP_{(R)}$, are graphically presented in Figure 9.

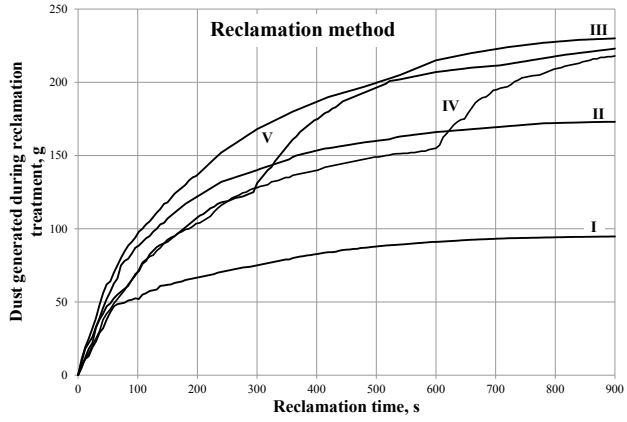

Fig. 8. Accumulated diagram of the dusts content, measured by means of the triboelectric dust meter PM 103, in the air drawn off from the experimental reclaimer prepared on the basis of the on-line monitoring of the matrix recycling performed by I–V methods

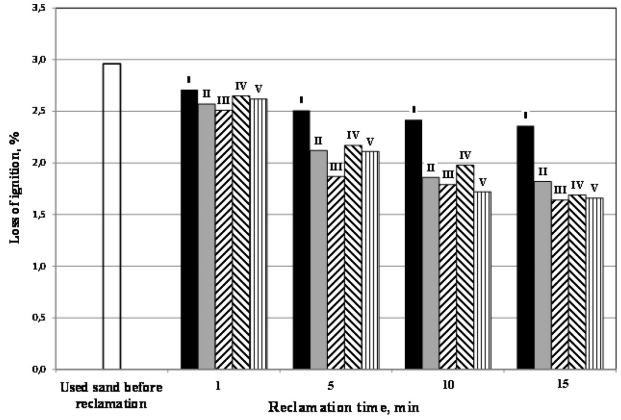

Fig. 9. Ignition loss values of the matrices reclaimed in the recycling process performed according to I-V methods

The morphology of reclaimed matrix after reclamation treatment carried out by methods I, II, IV and V and 10 minutes duration of the process are presented in Figure 10. On this basic it can be stated that taking into account the grains shape method II is the most destructive, when methods I, IV and are not destructive for the sand grains.

It can be conclude that the achieved loss on ignition of the reclaim is not the only parameter which should be taken into account considering reclaim quality. The grain shape is also very important and it can influence the mould and casting quality. As it is showed in Figure 10 it depends mostly from the method of reclamation treatment, its progress and intensity.

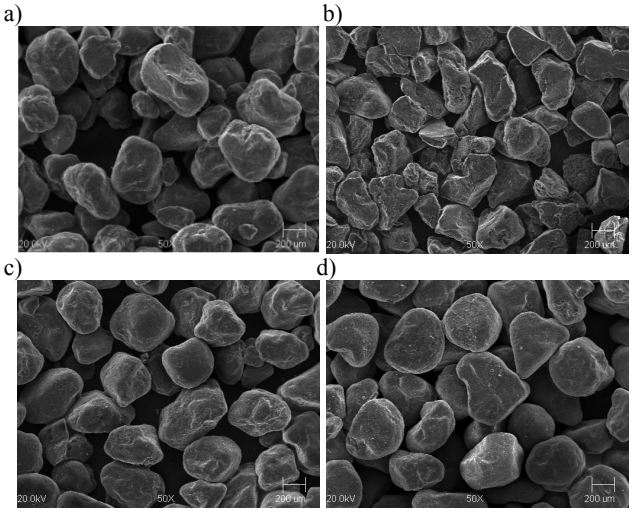

Fig. 10. Surface morfology of the reclaims after 10 minutes of reclamation treatment: a) I reclamation method, b) III reclamation method, c) IV reclamation method, d) V reclamation method

5. Conclusions

The synthesis of the integrated recycling process of the matrix of uniform self-setting moulding sands with the organic binder, which ensures obtaining moulding sands of the expected technological strength – was presented in the paper. The thesis of the possibility of forecasting the average value of ignition losses of spent moulding sands after the casting knocking out, also with the application of simulation calculations of temperature fields realised in the MAGMA program with the simultaneous correlation of these investigations results by monitoring the amounts of dusts generated during the matrix reclamation in the recycling process, was also presented.

The experimental reclaimer RD-6, for the verification investigations concerning this field, was designed and constructed. The reclaimer is equipped with the on-line monitoring system of the dust amount generated in the recycling process, which allows the on-line control of the purification degree of matrix grains from the left-over of a spent organic binder and forecasting the ignition losses of the reclaimed material being sent to the sand preparation plant.

The integrated recycling system, based on a deepened control of the matrix ignition losses and on the investigation results of moulding sands containing the reclaimed material, performed with regard to their technological properties and environmental impact, provides new possibilities of active influencing the process pathway in the real time. This brings the possibility, of obtaining moulding sands of the expected technological properties in automated systems of its preparation, nearer the solution.

Acknowledgements

This work was elaborated under research and development study no 11.11.170.318, task 2

References

[1] Dańko, R. (2012). *Strength model of self-setting moulding sands with synthetic resins in an aspect of the of the integrated matrix recycling process*. Gliwice. Archives of Foundry Engineering Publishing House, 193 pages.

[2] Dańko, R. (2013). Assessment method of overheating degree of a spent moulding sand with organic binder, after the casting process. *Archives of Foundry Engineering*. 13(2), 11-16.

[3] Łucarz, M. (2013). Utilisation of the reclaim from the cold-box technology in the core sands production. *Archives of Foundry Engineering* 13(spec. 3), 107-112.

[4] Izdebska-Szanda, I., Pezarski, F. & Stępniewski, K. (2008). Application of design Project developer by Foundry Research Institute in Krakow in construction of integrated stand for processing and reclamation of moulding sands. *Archives of Foundry Engineering*. 8(1), 133-138.

[5] Dańko, J., Holtzer, M. & Dańko, R. (2010). Problems of scientific and development research concerning the reclamation of used foundry sands. *Archives of Foundry Engineering*. 10(4), 29-34.

[6] Boenisch, D. (1995). United States Patent No. 5 439.044. Washington, D.C.: U.S. Patent and Trademark Office.