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Assessment of the Possibility of Using Reclaimed Materials for Making Cores by the Blowing Method

R. Dańko *, J. Dańko, M. Skrzyński

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

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Abstract

The cumulative results of investigations of the possibility of using the reclaimed materials after the mechanical, thermal or mechanical-thermal reclamation for making cores by means of the blowing method in the alkaline CO₂ technology, are presented in the paper. Three kinds of spent sands: with furfuryl resin, bentonite and alkaline phenolic resin, obtained from the foundry, were subjected to three kinds of reclamation: mechanical, thermal and combined mechanical-thermal, applying for this aim adequate experimental devices. The obtained reclaims were assessed with regard to the degree of the matrix liberation from the determined binding material. Reclaims of moulding sands with binders of the form of resin were assessed with regard to ignition loss values and pH reaction, while reclaims of moulding sands with bentonite with regard to the residual clay content and pH value. In all cases the results of the performed sieve analyses were estimated and the average characteristic diameter d_i was determined. The reclaimed matrix was applied as a full substitute of the fresh high-silica sand in typical procedures of preparing core sands used for making shaped samples for bending strength investigations, R_g^u .

Keywords: Moulding sand, Reclamation, Environmental protection

1. Introduction

Making reuses of spent foundry and core sands is a very important problem for foundries from the point of view of the environmental protection and economy, as well as the proper functioning of circulation systems of moulding sands and their matrices [1-4]. Matrix reclamation processes are the most often performed in mechanical and thermal reclaimers. The obtained products are of various properties, and their technological suitability requires each time a verification under the determined application conditions.

Reclaimed materials intended for preparations of core sands should be characterised by the highest quality parameters, as much as possible similar to fresh moulding sands, since conditions of their reusing are very demanding. Cores should be characterised by good strength properties, adequate permeability and knocking out as well as small gas evolution rates [5-7]. They should also satisfy requirements concerning emissions of harmful substances, which are usually more demanding in case of the reclaim applications. In case when the amount of obtainable reclaimed materials in the foundry exceeds possibilities of their usage for making moulding sands, other possibilities are looked for. The simplest way is decreasing the amount of spent moulding

sands intended for the reclamation and sending their part on dumping grounds. More technically advanced way of solving the reclaim excess problem can be based on subjecting this reclaim to additional treatments, aimed at more accurate removal of spent binders from the matrix.

The described situation is very rare in the foundry practice, however from the point of view of the total utilisation of waste materials generated in the casting process, it is desired and expected. Therefore, research leading to the assessment of the possibility of performing the described above process is needed and justified.

Endeavours were undertaken to determine - during the performed investigations - the possibility of utilising reclaimed materials of three different spent moulding sands containing various binders such as: furfuryl resin, bentonite and alkaline phenol resin. These materials were successively subjected to mechanical, thermal and combined two-stage thermal-mechanical reclamation, applying for this aim the proper experimental devices. Then these materials were used as matrix for making cores by the blowing method in the alkaline CO₂ technology, with using the blasting machine PS-1.

2. Materials applied in investigations

Investigations were performed using three kinds of spent moulding sands obtained from domestic foundries:

- spent moulding sand with furfuryl resin (MZ-1),
- spent moulding sand with bentonite (MZ-2),
- spent moulding sand with alkaline phenol resin (MZ-3).

Moulding sands were obtained in a lump form and therefore the first stage of investigations was the primary reclamation process, according to the program schematically presented in Figure 1. In addition, spent moulding sand MZ-2 was dried.

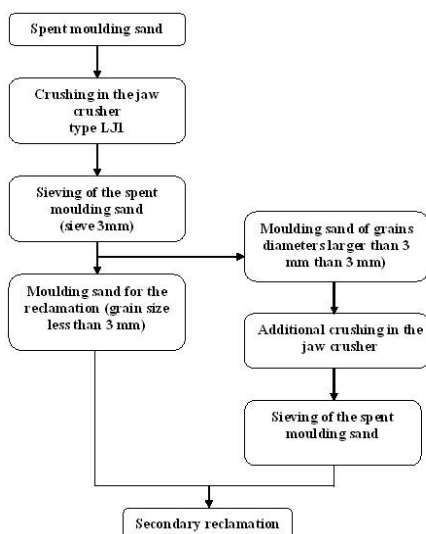


Fig. 1. Proceedings of the primary reclamation process

After the primary reclamation process the obtained materials were characterised by parameters presented in Table 1.

Table 1.

Basic parameters of spent moulding sands after the primary reclamation process

Spent moulding sand	d_{10}	Ignition loss	pH	Clay content
	mm	%	-	%
MZ-1	0.247	2.87	3.53	0
MZ-2	0.236	3.43	10.73	9.58
MZ-3	0.232	2.25	12.15	0

Such characterised materials were then subjected to the secondary reclamation in experimental devices constituting the equipment of the laboratory stands.

3. Laboratory stands

The following laboratory stands were used in investigations:

- experimental mechanical rotor reclaimer,
- experimental mechanical rotor reclaimer with the cryogenic reclamation option,
- experimental thermal reclaimer.

The mechanical reclamation tests were carried out in the experimental device presented in Figure 2. The principle of operation of this reclaimer is based on mechanical grinding of the layer of material bonding moulding sand grains (with a possibility of performing tests at low temperatures).

The thermal reclaimer is schematically presented in Figure 3. In this thermal reclaimer burning of the air-gases mixture occurs inside the furnace on surfaces of spent moulding sands periodically charged into the reclaimer, in batches up to 8 kg.

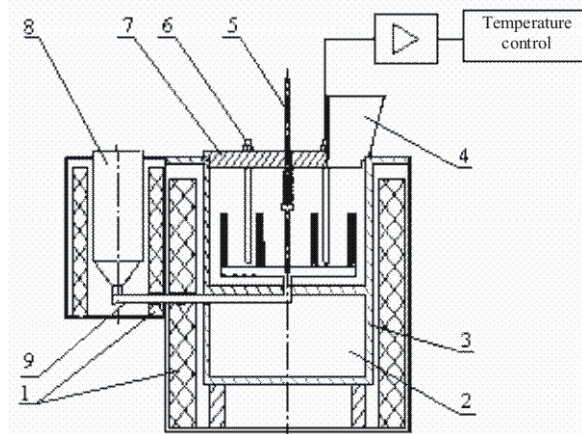


Fig. 2. Schematic presentation of the rotor reclaimer (with the cryogenic reclamation option): 1 - casing with the insulation layer, 2 - air chamber, 3 - main tank, 4 - moulding sand charge, 5 - rotor of the impact-abrasive system, 6 - impact elements, 7 - cover, 8 - nitrogen container, 9 - liquid nitrogen feeder [8]

At each research cycle, at both reclamation processes the same working time (10 min.) of the reclaimer was applied. In case of the mechanical reclamation the rotational speed of the reclaimer rotor system being 460 rot./min, was applied. In case of

the thermal reclamation [2-4], in order to improve heat exchanges in the material being reclaimed, a periodical fluidised mixing of this material bed - every 30 seconds for 10 seconds - was applied. The combined reclamation was the thermal-mechanical reclamation. After the thermal reclamation carried out for 10 minutes the material was cooled and subjected to the mechanical treatment (of 10 min. duration) in the device presented in Figure 2. The example of the reclaimed material temperature obtained during the reclamation of spent moulding sand with bentonite MZ-2, is presented in Figure 4.

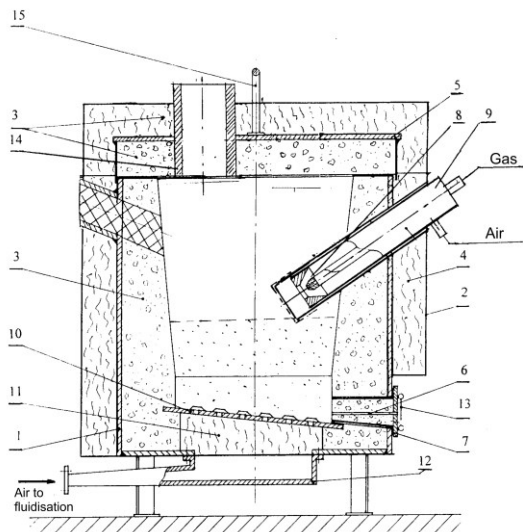


Fig. 3. Scheme of the experimental thermal reclaimer: 1 – steel casing, 2 – mantle, 3 – refractory concrete, 4 – insulation of ceramic fibres, 5 – cover, 6 – thermocouple opening, 7 – asbestos sealing, 8 – burner, 9 – burner casing, 10 – perforated bottom, 11 – ceramic wool, 12 – air box, 13 – outlet closing, 14 – outlet ferrule, 15 – suspension [8]

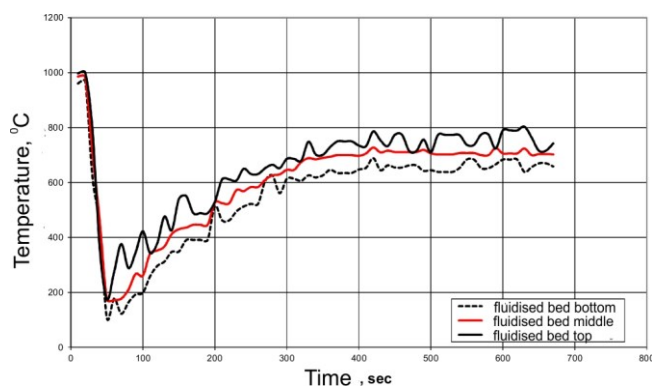


Fig. 4. Temperature time function at various bed levels of the moulding sand being thermally reclaimed

4. Investigations results

For each kind of spent moulding sand, MZ-1÷MZ-3, three kinds of the reclaimed material were obtained:

RM – reclaim after the mechanical reclamation;
 RT – reclaim after the thermal reclamation;
 RK – reclaim after the combined thermal-mechanical reclamation. Instrumental tests were performed for all reclaimed materials. Their ignition losses, clay content, pH reaction and the average characteristic diameters d_l (in a sieve analysis) were obtained. The results are presented in Table 2.

The obtained reclaims were used for preparing moulding sands. The following compositions of core sands were used:

Matrix (high-silica sand, reclaim) 100 parts by mass
 Resin, Carbophen 5692 3 parts by mass

Core sands were prepared in the typical laboratory ribbon mixer. Mixing time was equal 4 minutes.

Shaped elements for bending strength tests R_{gu} were made on the table of the blasting stand PS-1. Cores were made at the shoot pressure being 0.6 MPa (5atm). After shooting the cores were blown through by CO_2 for 20 seconds.

Fresh sand FS was applied, for comparing reasons, as the matrix of moulding sands. For each tested reclaim the following mixtures were prepared:

- 70% fresh sand + 30% reclaim (M-1),
- 50% fresh sand+ 50% reclaim (M-2),
- 30% fresh sand + 70% reclaim (M-3).

Cores bending strength was determined after 1 hour of sand maturing.

The obtained results are listed in Table 3 and graphically presented in Figures 5-7.

Table 2.
 Tests results of the obtained reclaims

Spent moulding sand	d_l mm	Ignition loss %	pH -	Clay content %
MZ-1 (RM)	0.240	2.43	3.87	0
MZ-1 (RT)	0.233	0.46	6.11	0
MZ-1 (RK)	0.229	0.37	6.16	0
MZ-2 (RM)	0.227	3.03	9.83	6.58
MZ-2 (RT)	0.221	1.06	8.28	5.34
MZ-2 (RK)	0.214	0.78	7.95	2.89
MZ-3 (RM)	0.222	2.02	11.65	0
MZ-3 (RT)	0.217	0.46	8.03	0
MZ-3 (RK)	0.214	0.35	7.97	0

Table 3.
 Results of the bending strength of cores made of tested reclaimed materials

Reclaim	Bending strength, R_{g^u} , MPa			
	FS	M-1	M-2	M-3
MZ-1 (RM)		0.45	0.2	0
MZ-1 (RT)		0.78	0.56	0.42
MZ-1 (RK)		0.92	0.68	0.55
MZ-2 (RM)		0.42	0.18	0
MZ-2 (RT)	1.56	0.59	0.39	0.23
MZ-2 (RK)		0.78	0.53	0.39
MZ-3 (RM)		0.79	0.60	0.42
MZ-3 (RT)		1.21	1.02	0.89
MZ-3 (RK)		1.38	1.13	0.94

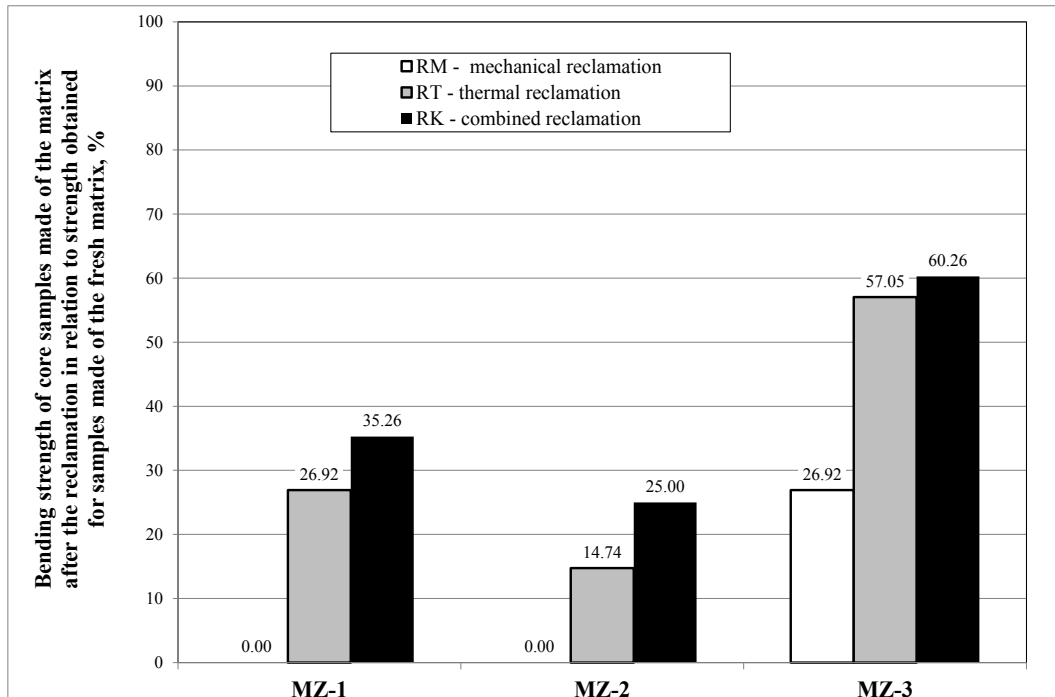


Fig. 5. Bending strength of core samples made of the matrix after the reclamation in relation to strength obtained for samples made of the fresh matrix. Matrix: reclaim 70% - fresh sand 30%

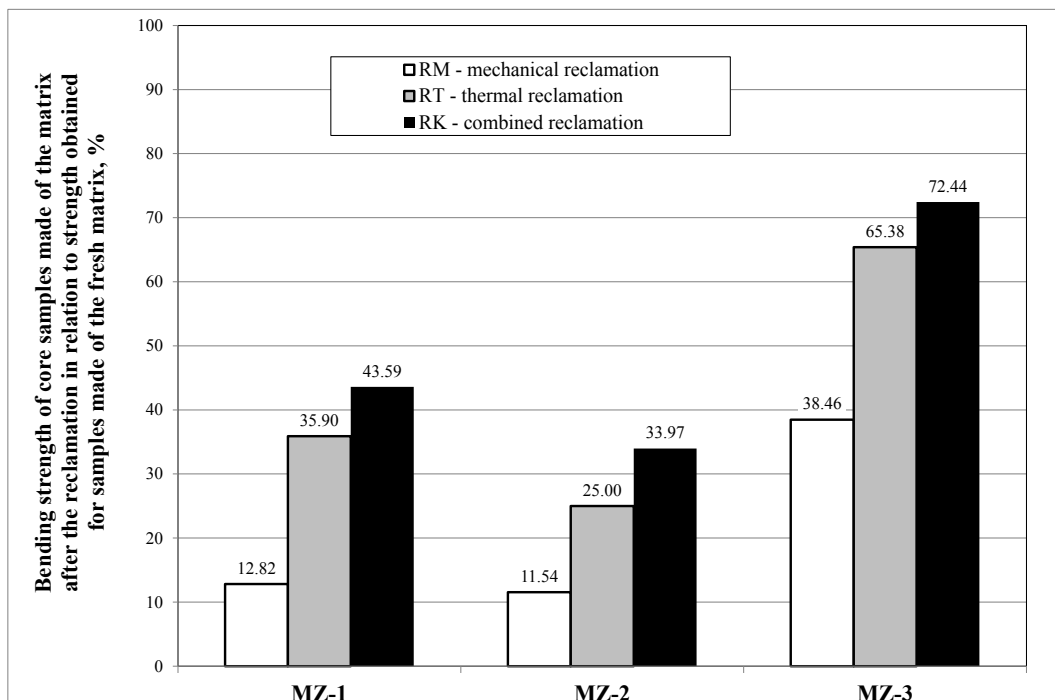


Fig. 6. Bending strength of core samples made of the matrix after the reclamation in relation to strength obtained for samples made of the fresh matrix. Matrix: reclaim 50% - fresh sand 50%

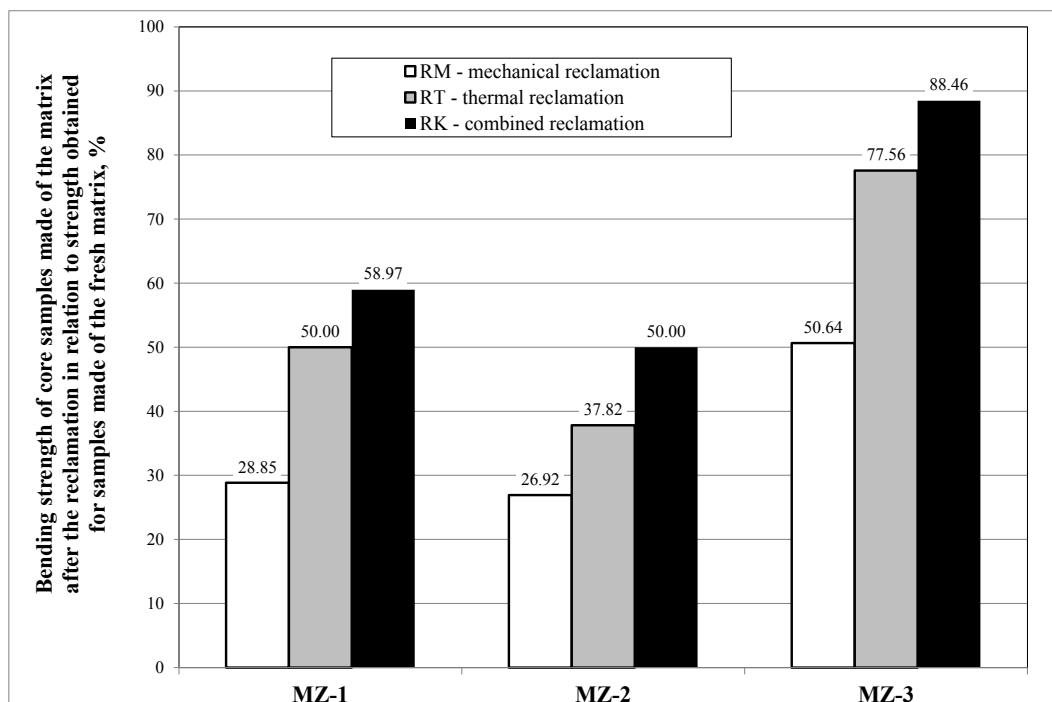


Fig. 7. Bending strength of core samples made of the matrix after the reclamation in relation to strength obtained for samples made of the fresh matrix. Matrix: reclaim 30% - fresh sand 70%

On the basis of the obtained results analysis, especially concerning the bending strength of cores made in the CO₂ technology, it can be noticed that the obtained reclaimed materials are not of a satisfactory quality. The best approximation degree of the strength properties of samples made of the fresh sand mixed with the reclaim to the properties of samples made of fresh components was obtained for the reclaim originated from the spent moulding sand with alkaline phenol resin. This is due to the chemical similarity of this type of moulding sand to the core sand made in the technology of phenolic resol resin, hardened by CO₂. Worse results were obtained in the reclamation of spent moulding sands with furfuryl resin and with bentonite. In the first case, it is caused by a different chemical character of the spent moulding sand and the reclaim, while in the second case by the presence of certain amounts of a retained clay in the reclaim. The highest strength parameters were obtained for samples (of all tested spent moulding sands) with matrices after the combined thermal-mechanical reclamation process.

5. Summary

The final conclusions, drawn on the bases of the performed tests, are listed below.

1. The reclaim application for making cores in the blowing technology requires very strict control of the reclaim quality with regard to its purification from the spent binder remains and with regard to the chemical character.
2. A very essential element of the proper reclaim application constitutes its chemical similarity to the technology of moulding or core sands, in which it is to be used.

3. Core sands should be prepared of reclaimed materials of properties like the fresh sand properties, it means they should be originated from combined reclamation systems, the most often thermal-mechanical, allowing the maximum purification of the matrix. A complete purification of spent sands is often too costly to be applied in foundries.
4. Very high, positive influence on strength properties of samples has an increased fraction of the fresh sand in the matrix, which determines the range of the real reclaim addition - as the fresh sand substitute - at the level not exceeding 50%.

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