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ISSN 0543-5846
METABK 50(2) 93-96 (2011)
UDC – UDK 621.741:621.742:502.72:628.54=111

INNOVATIVE DEVELOPMENTS IN SAND RECLAMATION TECHNOLOGIES

Received – Prispjelo: 2010-04-10
Accepted – Prihvaćeno: 2010-08-20
Original Scientific Paper – Izvorni znanstveni rad

Proper sand management and efficient sand reclamation system are two main factors influencing economical and ecological side of modern foundry plant. It is well known fact that the production of 1 metric ton of casting from ferrous alloys generates circa 1 metric ton of waste [1], which due to containing certain amounts of harmful and dangerous compounds should undergo a reclamation – at least of the main component, which means a silica sand grains.
The paper present problems of scientific and development research concerning the innovative reclamation technologies of used foundry sands such as: mechanical-cryogenic reclamation and innovative thermal reclamation.

Key words: innovative reclamation, moulding sand, used sand, waste management, environmental protection

Inovativni razvoj tehnologija regeneriranja pijeska. Odgovarajuće rukovanje i efikasno ponovno iskorištavanje pijeska dva su glavna faktora koji utječu na ekonomsku i ekološku stranu moderne ljevaonice. Poznata je činjenica da proizvodnju 1 t odljevaka na bazi željeza generira cca 1 t otpadnog pijeska [1], koji sadrži određenu količinu štetnih i opasnih spojeva te ga je potrebno ponovno iskoristiti s obzirom na glavnu komponentu, tj. silikatna pješčana zrna.
Rad predstavlje znanstveno i razvojno istraživanje inovatnih regeneracijskih tehnologija korištenja ljevaoničkog pijeska kao što su: mehaničko-kriogena i inovativna toplinska regeneracija.

Ključne riječi: inovativna regeneracija, kalupni pijesak, korišteni pijesak, rukovanje otpatkom, zaštita okoline

INTRODUCTION

Reclamation of used moulding and core sands is defined as a treatment of waste refractory materials allowing to recover at least one component of properties similar to the properties of the new component and to reuse it for casting moulds and core production. In traditional technologies of casting moulds and core production on the basis of high-silica sands with binding agent addition, the reclamation consists mainly of a sand recovery and very seldom of a sand and bentonite recovery. Traditional reclamation technologies are not always enough intensive to liberate silica basis from the envelope of used binding material, thus new innovative methods are investigated to improve the reclamation effectiveness. This methods are: innovative thermal reclamation and innovative mechanical-cryogenic reclamation [1, 2].

INNOVATIVE SAND RECLAMATION TECHNOLOGIES

Innovative mechanical-cryogenic reclamation

The general idea of mechanical-cryogenic reclamation is to use extra-low temperatures as a factor intensifying the process of the waste sand mechanical reclamation. It was assumed that by considerably reducing the temperature at which the process of reclamation is carried out, the envelope of sand binder, present on the surface of the sand grains, should become more brittle, and in the case of bentonite sands, the binding forces which are acting between the sand grains and the envelope of binder present on these grains should be weakened [2, 3]. This should improve the sand reclaimability of the waste sands and release in quite an easy manner the sand grains from the sticking envelope of the used binding material.

Innovative thermal reclamation

Thermal reclamation method is mainly aimed for the reclamation of spent sands containing organic binders [4-6], but is also used for the deactivation of components of sands containing binders in systems, in which the selection of spent sands is not provided.

There are following advantages of the thermal method: accurate removal of binding agent, possibility of utilisation of total reclaimed sand for the production of fresh moulding and core sands and negligible chemical harmfulness of dust for the environment.

In standard industrial thermal reclaimers reclamation is carried out in fluidization bed, where air-gas mix-

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ture is burned to incinerate the used binding material from the sand basis.

The modification of this method is tested at Faculty of Foundry Engineering AGH-UST. Modification consists on usage of sole oxygen or air-oxygen mix tire as a fluidization agent.

TESTS AND EXPERIMENTS

Innovative mechanical-cryogenic reclamation

Laboratory stand

The laboratory test stand is a reduced model of the mechanical reclamation unit with blades acting as a rotating abrasive element [3, 7]. The test reclamation unit enables the reclamation process to be carried out with and without the use of a cooling agent. It has been provided with a feeding system for liquid nitrogen to carry out the reclamation process at extra-low (cryogenic) temperatures.

The possibility of conducting in the same equipment either the mechanical reclamation alone, or a combination of the mechanical and cryogenic reclamation provides an excellent tool for comparison of the real efficiency of the reclamation process obtained in both examined cases.

The testing procedure

Within the research described in this paper some tests have been made to improve the effectiveness of a mechanical reclamation process as applied to the most used type of the waste moulding sands typically produced during castings manufacture, namely:

– the used sand with bentonite,

The process of the proper reclamation of the sand grains was conducted under the following operating parameters of the reclamation unit: rotational speed of the impeller blades - 300 rpm, time of reclamation - 1, 3, 5, 10 and 15 min, successively. A sample of the determined waste sand was subjected to reclamation at ambient temperature (mechanical reclamation - MR); the second analogical sample was reclaimed in temperature reduced to about -70°C (mechanical-cryogenic reclamation - MCR).

The effectiveness of releasing the sand grains from the envelope of the used binding material was evaluated by means of the tests below which, were considered to be the tools reliable enough in evaluating the degree of the examined waste sand reclamation:

– clay binder content in bentonite reclaim,
– value of pH of the reclaim,
– compressive strength and permeability of the sand prepared with bentonite reclaim,
– reclaims morphology.

The results of the tests

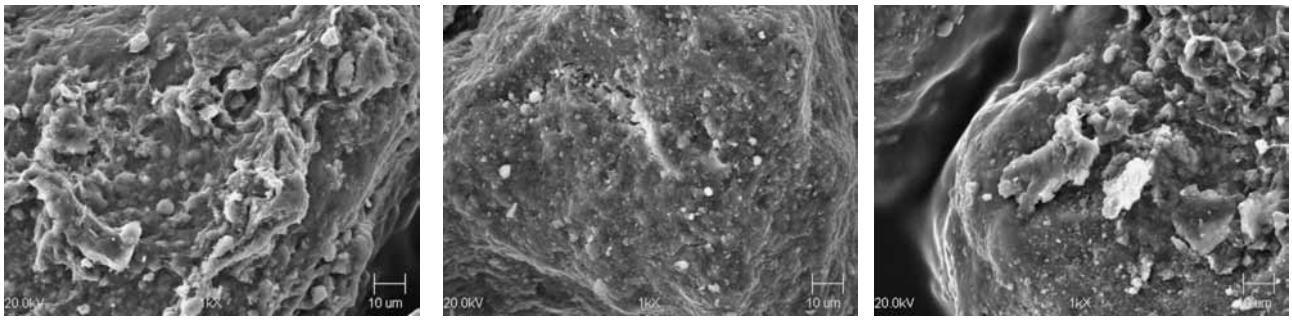
The results of tests for the waste sand with bentonite are presented in combined diagrams (Figures 1 and 2) and in Table 1. The analysis of the obtained data is given below.

In evaluating the effectiveness of a reclamation process of the waste sand with bentonite, as a main indication of the effectiveness of this reclamation has been adopted the content of the clay binder present in reclaim.

After reclamation treatment, the content of the clay binder in the sand drops to a value of 4,20 % and 3,5 % for, respectively, the mechanical and mechanical-cryogenic reclamation conducted for a time of 15 minutes (Table 1). The chemical analysis of reclaim also indicates a high degree of removal of the used binder from the sand grains; in the case of mechanical-cryogenic reclamation this effect is even more pronounced.

SEM micrographs of the waste moulding sand and its reclaim at a magnification of 1000x are presented in Figure 1.

Figure 2 shows the results of testing the compressive strength and permeability of sands prepared with the obtained reclaims. In these studies the obtained reclaim was treated as a replacement of the new sand. The sand composition included 7 % of Zebiec bentonite and 3,5 % of water content.



A) B) C)

Figure 1 SEM micrographs of grain surfaces morphology: A – waste sand with bentonite before the reclamation, B – reclaimed material after 5 minutes of the mechanical reclamation, C – reclaimed material after 5 minutes of the mechanical-cryogenic reclamation

Table 1 **Clay content and pH value in the reclaim after reclamation processes**

Reclamation time/min	Clay content/%	pH value		
	MR	MCR	MR	MCR
0	7,80	7,80	10,46	10,46
3	6,39	5,88	9,82	9,39
5	5,57	4,85	9,50	8,97
10	4,60	3,90	9,11	8,65
15	4,20	3,16	8,91	8,49

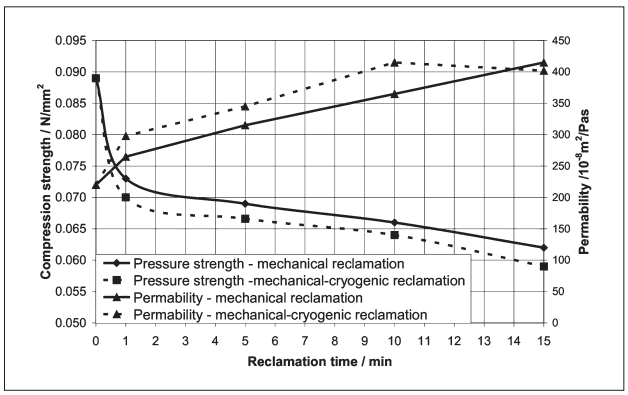


Figure 2 Compressive strength and permeability of foundry sand prepared from reclaimed bentonite sands after various reclamation time subjected to mechanical or mechanical-cryogenic treatment

In the case of the sand with bentonite, raising the time of reclamation makes the value of the compression strength decrease due to removal from the sand grains surface of a portion of the still active binder. The permeability of those sands increases along with the longer time of reclamation. In the case of mechanical-cryogenic reclamation one can observe a drop of permeability in the sand prepared with reclaim processed in a reclamation unit for a time longer than 10 minutes. This is due to the effect of the sand grains being crushed, which is observed after this time and proved by the successively made screen analyses.

Innovative thermal reclamation

Laboratory stand

The laboratory stand is thermal reclaimer unit [7] with fluid bed mixing system. The mixing (fluidising) agent can be air, oxygen, or a mixture of these two, introduced in various ratios to the bed at intervals of every 1 minute. The time of feeding the fluidising agent was 10 seconds.

Test parameters

In the present study attention was focussed on an assessment of the reclamability of the sand used in the technology of loose furan self-setting mixtures. The trials were made on the sand which was not burnt down, considering this type of sand much more difficult for reclamation than the burnt down material.

The following techniques of reclamation were used in the study:

I. Mechanical reclamation carried out in a test unit [7]. Operating parameters of the reclamation process: time - 3 minutes, 5 minutes, 10 minutes, reclaim R1.
II. Thermal reclamation with periodical fluid bed mixing carried out in an experimental thermal reclaimer unit [7]. The time of reclamation process - 3 minutes, 5 minutes, 10 minutes, reclaim R2.
III. Thermal reclamation with preheating the surface of a steady bed of the used sand for a time of, respectively, 3 minutes, 5 minutes, 10 minutes, followed by additional blowing of the sand with oxygen for a time of 1 minute – reclaim R3.
IV. Thermal reclamation with periodical fluid bed mixing The time of reclamation - 3 minutes, 5 minutes, 10 minutes, respectively. The fluidising agent – air + oxygen in ratio 1 : 1, reclaim R4.
V. Thermal reclamation with periodical fluid bed mixing The time of reclamation - 3 minutes, 5 minutes, 10 minutes, respectively. The fluidising agent – air + oxygen in ratio 1 : 2, reclaim R5.

The output of the reclamation process was evaluated measuring the following factors : loss on ignition (LOI), bending strength of specimens prepared from the reclaim after the time of 1, 4 h and 24 h, and pH value.

Analysis of results

Examining the results of the tests it can be noted that the loss on ignition of the reclaim obtained by the mechanical technique of reclamation differs quite considerably from the level obtained in the case of thermal reclamation carried out in its different variations. High values of the loss on ignition of reclaim R1 indicate weak effect of the rubbing-abrading action provided by the used mechanical reclamation unit as well as the fact that in the case of sands with organic binders the thermal reclamation is much more effective in removing the coating from the base sand grains.

The results of the loss of ignition and pH values measurements are shown in Table 2. In the case of reclaim R1, the removal of the remaining resin from the sand grains was unsatisfactory even after 10 minute process duration. In the case of other reclaims, the effects can be considered satisfactory already after 5 minutes of the process duration.

Basing on the changing values of the loss on ignition in function of time in different techniques of the reclamation process it has been noted that the most effective is reclamation R5, which uses a 1 : 2 ratio mixture of air and oxygen for mixing of the fluidised bed. The next in

Table 2 **Loss of ignition and pH value in the reclaim after reclamation processes**

Reclamation time/min	Loss of ignition/%					pH value				
	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
0	1,56	1,56	1,56	1,56	1,56	2,3	2,3	2,3	2,3	2,3
3	1,39	0,88	0,60	0,36	0,19	3,2	3,7	3,8	4,0	4,2
5	1,32	0,43	0,33	0,24	0,10	3,4	4,4	4,5	4,8	4,9
10	1,22	0,22	0,10	0,06	0,04	3,7	6,2	6,35	6,6	6,6

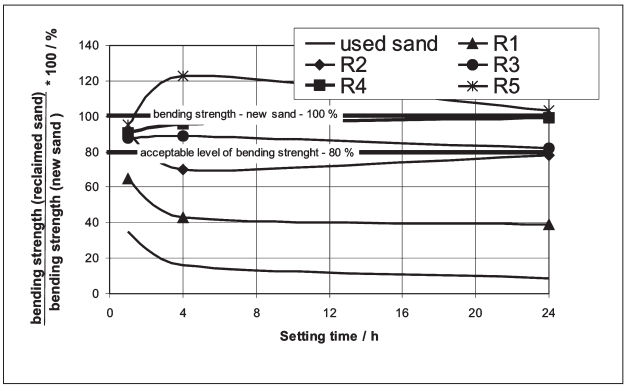


Figure 3 Bending strength vs setting time for samples made from the sand subjected to various techniques of reclamation (with total reclamation time - 10 minutes)

respect of its effectiveness is reclamation R4, followed by similar, as regards output, reclamations R3 and R2.

During the present studies also changes in chemical reaction (pH) have been examined. The results of this investigation are shown in Table 2.

Examining the results one can observe a very high level of acidity in the tested used. The value of pH increases with increasing rate of reclamation, reaching a maximum value of 6,6 (7,07 for the new sand), obtained in reclaim R5.

Figure 3 shows the relationship between bending strength of samples made from the reclaimed sand and time of their setting using various techniques of reclamation, referred to samples prepared from the new sand. The diagram also includes a plotted level of 80% strength value of the sand mixture prepared from new components, which can be used as a criterion for evaluation of the reclaim and its applicability in being re-used as a base material in core sands.

Basing on the collected data it can be stated that reclaims R2÷R5 satisfy the imposed requirements and can be re-used in core sands. Reclaim R2 approaches the limit value and in the case of less responsible cores its re-use as a base material can be taken into consideration. Under industrial conditions, reclaim R1 is suitable in preparation of the backing sand or as an additive to the new sand.

CONCLUSIONS

It can be stated that the currently used processes of reclamation with application of extra- low temperatures are the only ones, which among all other well-known techniques of the reclamation can effectively utilise the hygroscopic behaviour of moulding sands as a factor intensifying the process of releasing the sand grains from a binding material. The presence of a "freezing" agent changes the volume of both binder and sand grains, leading to increased stresses on the grains surface and inside the grains, combined with higher brittleness of the binding material.

The conducted studies confirm that the core sand-to-core sand reclamation creates a lot of technical problems. So far, to perform this process, mainly thermal reclamation has been used, which in industrial plants can last from about 25 to 30 minutes. The application of oxygen enables this time to be shortened quite considerably (by even as much as 60%), not deteriorating in any way the reclaim quality. This can be of particular importance for foundries which face some problems with throughput of the already existing thermal reclamation units, which can easily be improved without high investment outlays. At the same time, it creates the possibility of extending further the range of reclamation units which use the oxygen-enriched air to perform an even more efficient process.

Scientific paper financed by the scientific grant in years 2008-2011 as a Research Project No N N507369735

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Note: The responsible translator for English language: "ANGOS" Translation Office, Krakow, Poland.