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RECLAMATION OF USED SANDS IN FOUNDRY PRODUCTION

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The scope and purpose of the present study is to contribute to the research of reclamation processes by investigating factors and conditions allowing replacement of fresh quartz sand consumption in foundry production by the recovered sand. Actually gained experience by the foundries on this field confirmed that reclamation of moulding used sands is regarded as an effective way of saving and protecting of the natural silica sand deposits.

Key words: *foundry used sand, thermal reclamation, mechanical reclamation, sand testing, waste minimization*

Obnavljanje uporabljenog pijeska pri proizvodnji odljevaka. Opseg i svrha ove studije je doprinos razvoju istraživanja procesa obnavljanja pijeska pri pronalaženju okolnosti i uvjeta koji omogućuju zamjenu svježeg kvarcnog pijeska u proizvodnji odljevaka. Na tom polju stvarno stečeno iskustvo u ljevaonicama potvrđuje da se obnavljanje pijeska korištenog za izradu kalupa smatra djelotvornim načinom čuvanja i zaštite postojećeg prirodnog silicijskog pijeska.

Ključne riječi: *rabljeni ljevački pijesak, termičko obnavljanje, mehaničko obnavljanje pijeska, ispitivanje pijeska, minimiziranje otpada*

INTRODUCTION

Existing foundry technologies are main consumers of silica sand used as a basic component of multi-purposed moulding and core sands. Traditional sand technologies still dominate all other manufacture foundry processes. Casting production performed in sand moulds is evaluated as about 80 % of total world casting. Technologies developed in recent time are also applying silica sand as a base material in mould and core processes.

The estimation of used sand quantity generated every year in European foundries shows that during the production of 17 mln metric tons of casts the volume of about 7 mln metric tons of waste is produced [1].

Generally this waste is directed to dump apart the fact, that main component (70 %) is the fully recoverable silica sand proper potentially for further foundry application after being subjected to reclamation process. The waste management has to be considered individually in each foundry, because it is determined as a resultant of many factors eg: foundry location, access to fresh sand sources, waste volume associated with casting volume, costs of waste disposal, costs of reclamation processes and the others [2-5].

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In Poland the one of crucial steps which are expected to be an effective way towards protection of natural silica sand deposits is wide introducing reclamation processes into home foundries.

The aim of this article is to contribute to the research of reclamation processes by investigating of factors and conditions allowing replacement of fresh quartz sand consumption in foundry production by the recovered sand

RESEARCH PROCESSES AND THE EXPERIMENTAL STAND

The objective of the research performed at Faculty of Foundry Engineering, University of Mining and Metallurgy in Cracow was to determine both the possibility of reclamation treatment and the best technological way to achieve the good quality reclaim. Four used sands were tested:

1. Used self-hardened sand with water glass hardened by ester dumped to the dump yard.
2. Used self-hardened sand with water glass hardened by ester after mechanical reclamation treatment in the chosen foundry
3. Used foundry sand with alkyde resin binder dumped to the dump yard.
4. Used foundry sand with furane resin dumped to the dump yard.

Because of the chemical composition of the binder which does not undergo destruction in the process of thermal reclamation used self-hardened sand with water glass hardener was reclaimed by mechanical reclamation carried out in a special disc type centrifugal reclamation unit developed at the Faculty of Foundry. The pilot plant reclaimer is illustrated on Figure 1.

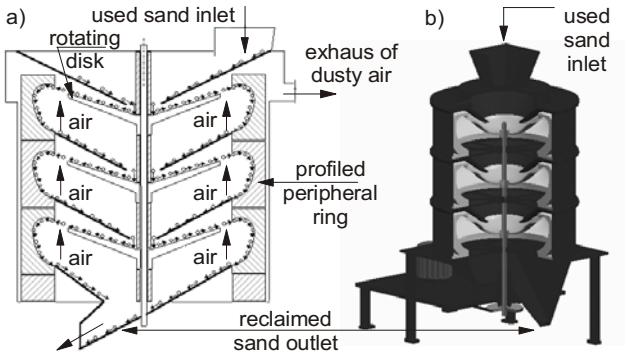

Figure 1. **a) Schematic representation of grain movement phases in a centrifugal reclamation unit with profiled rotating disc and specially profiled peripheral ring, b) general view of a reclaimer**

Slika 1. **a) Shematski prikaz faza kretanja zrnaca u uređaju za centrifugalno obnavljanje s profiliranom rotirajućom pločom i posebno profiliranim perifernim prstenom, b) Izgled regeneratora**

In the case of reclamation of used foundry sands with resin binders additionally thermal reclamation tests were performed. Thermal reclamation was carried out in a pilot reclamation unit, using gas burner directed on the sand bed surface and with fluidizing system engaged periodically to mix the bed of fluidized material. The range of temperatures obtained in the reclamation unit was 750 - 800 °C. The experimental thermal reclaimer is illustrated on Figure 2.

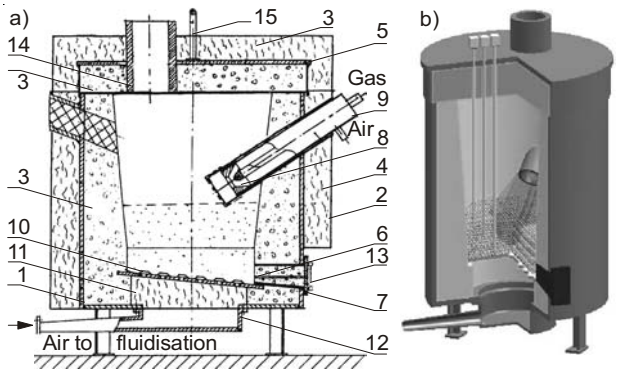

Figure 2. **Experimental thermal reclaimer unit: a) general view of reclaimer: 1- steel casing, 2 - jacket, 3 - refractory lining, 4 - ceramic insulation, 5 - cover, 6 - thermocouple holes, 7 - seal, 8 - burner, 9 - burner casing, 10 - air distributor, 11 - ceramic wool, 12 - air box, 13 - dump hole closure, 14 - stub pipe, 15 - hanging b) scheme of design**

Slika 2. **Eksperimentalni toplinski generator: a) shematski prikaz: 1 - čelična zaštita, 2 - vanjski plašt, 3 - zaštitno vatrostalno zide, 4 - keramička izolacija, 5 - poklopac, 6 - otvor za termopar, 7 - brtva, 8 - gorionik, 9 - zaštita gorionika, 10 - razdjelnik zraka, 11 - mineralna vuna, 12 - zračna komora, 13 - zatvarač otvora za paru, 14 - cijev za šaržiranje, 15 - vješalica b) shema dizajna**

APPLIED METHOD OF RECLAIMED SAND QUALITY ASSESSMENT

A large number of factors characterizing the reclaimed material may be used as the indicators grading of the reclaimed structure.

The diversity of the casting technologies constrain the laboratories to use factors not always corresponding with themselves. The used methods of grading are characteristic for the specific mass.

Depending on the requirements put on the reclaim there may be used either some of the proposed methods of grading or even all of the mentioned methods [9].

Table 1. Purposed reclaim quality index for various used sands. Succession in the brackets given in decreasing importance hierarchy.

Table 1. **Purposed reclaim quality index for various used sands. Succession in the brackets given in decreasing importance hierarchy**

Tablica 1. **Namjenski indeks kvalitete recikliranog materijala za razne vrste rabljenog pijeska. Niz podataka prikazanih u zagradama naveden je redoslijedom od važnijih prema manje važnim**

Reclaim quality index	Waste to reclaim			
	Used sand with			
	bentonite and the coal dust	water glass binder	cement binder	resin binders
Bending strength, tensile strength	(1)	(2)	(1)	(2)
Clay content	(2)	(-)	(2)	(-)
Clay activity	(3)	(-)	(-)	(-)
Loss of ignition (LOI)	(3)	(-)	(-)	(1)
Sieve analyses	(4)	(3)	(4)	(4)
N_2O content	(-)	(1)	(-)	(-)
Surface morphology	(5)	(5)	(5)	(5)
Chemical character (pH, ADV)	(-)	(4)	(3)	(3)

In tests performed in UMM following reclaim quality indexes were applied:

1. Na_2O content for sands 1 and 2 listed below used,
2. Loss of ignition (LOI) and bending strengths for used sands 3 and 4 listed below.

RESULTS AND DISCUSSION

Used sand with water glass binder

Used foundry mixture of known composition was subjected to mechanical reclamation treatment. Following reclaims were obtained:

- R1 - the reclaim after 30 cycles of mechanical reclamation,
- R2 - the reclaim after 30 cycles of mechanical reclamation with preheating up to the temperature of 450 °C for the time of 2 hours,
- R3 - the reclaim after 30 cycles of mechanical reclamation with preheating up to the temperature of 450 °C for the time of 2 hours additionally reclaimed in laboratory batch mixer.

The results of Na_2O content in the reclaims are given on Figure 3. It can be noted that if reclamation scale is higher the process product is better. It is accepted that the limit Na_2O content in the reclaim is 0.2 %. This limit was established as a result of research carried out in Poland in the frame of CIATF commission [10, 11].

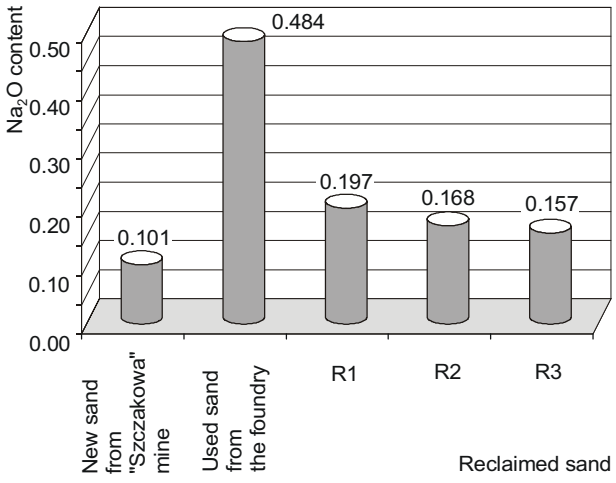

Figure 3. **Na_2O content in tested reclaims**
Slika 3. **Sadržaj Na_2O u testiranom recikliranom materijalu**

Used sand with water glass binder reclaimed in the foundry

The aim of the research was to determine the efficiency of the reclamation system installed in the foundry. The new installed system is destinated for the waste with water glass binder. In the foundry the waste is reclaimed in the mechanical centrifugal reclaimer. At the Faculty of Foundry Engineering the reclaim obtained in the foundry was tested in aspect of increasing of its properties by 1, 5 and 10 reclamation cycles treatment in the laboratory reclamation unit. Loss of ignition and Na_2O content were used as a reclaim quality indexes. Results of the conducted tests are shown on Figure 4.

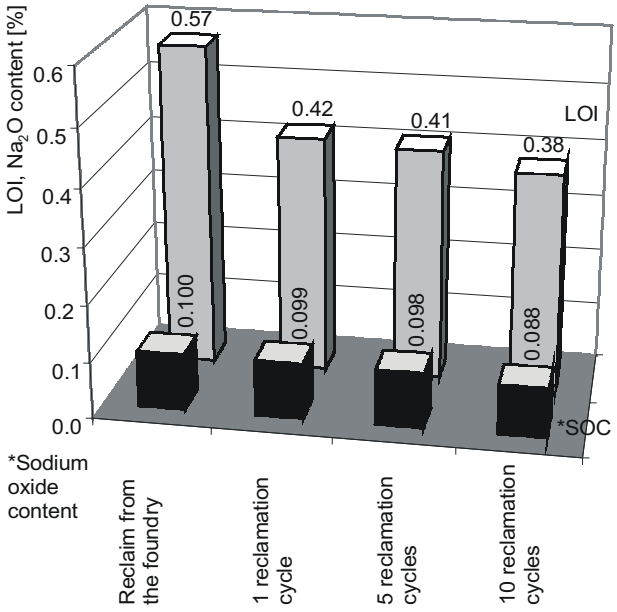

Figure 4. **Ignition loss and Na_2O content after determinition of stage of reclamation treatment**
Slika 4. **Gubitak žarenjem i sadržaj Na_2O nakon određivanja koraka postupka recikliranja**

Used foundry sand with alkyde resin

The comparative studies of the reclaim obtained by mechanical and thermal reclamation performed on the equipment operating in the examined foundry and that available at the Faculty of Foundry Engineering, University of Mining and Metallurgy in Cracow, included determination of the loss of ignition and testing the mechanical properties of foundry mixtures prepared with the reclaimed sand. The loss of ignition was determined by the method of heating the sand samples at a temperature of 850 ± 20 °C for the time of 2 hours. The research was conducted on three types of the used sands with alkyd resin, including:

1. Weakly burned out lumps of the sand with alkyd resin (designated as "Sand 1");
2. Heavily burned out sand directly adjacent to the casting surface (designated as "Sand 2");
3. Mixture of used sands, containing about 60 % of the weakly burned out sand and 40 % of the heavily burned out sand (designated as "Sand 3");
4. Reclaim obtained in an installation for mechanical reclamation (designated as "Sand 4");
5. Reclaim obtained in an installation for thermal reclamation (designated as "Sand 5").

Sands with the alkyde resin are now considered as-out-of date sands and technologically unmodern. This is the reason why the researches aiming to maximize the ef-

fectiveness of their reclaim capability are not recently conducted in many research centers. Technologies causing the generation of the spent masses of this kind are used mainly with the steel casting demanding specific technological conditions which are demanded especially because of the requirements of the casted alloy. This is the reason why those sands considered to be out-of-date, and useless by the cast iron technologies requiring the high flexibility predispose the technologically out-of-date sands [12].

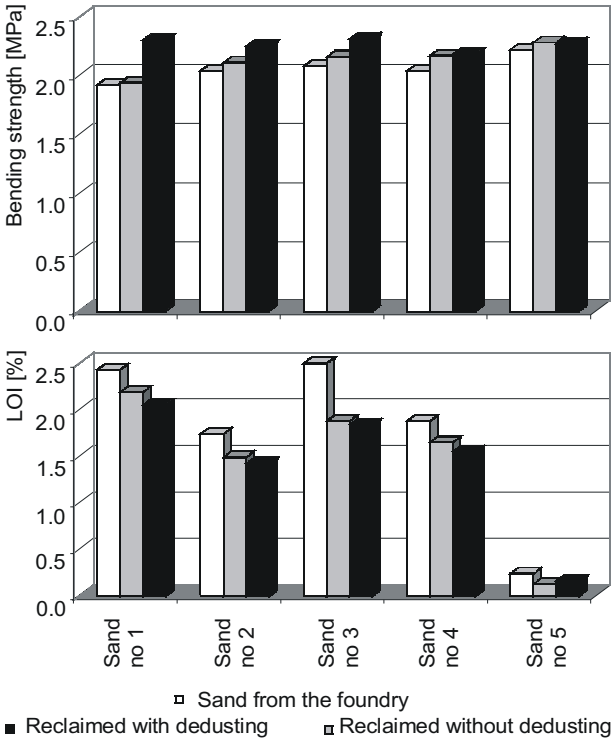

Figure 5. **Bending strength and loss of ignition of reclaims from used foundry sands with alkyde resin after reclamation treatment at the UMM**
Slika 5. **Čvrstoća na savijanje i gubitak materijala žarenjem rabljenog ljevačkog pijeska s alkidnom smolom nakon recikliranja tretiranjem u UMM**

In terms of the quality of the obtained reclaim, the system of thermal reclamation is functioning correctly. The loss on ignition of the reclaim amounting to less that 0.1 % is lower than in the case of new silica sand from Wiślak (0.53 %) and Grudzeń Las (0.11 %).

Examining extensively the effect of the mechanical reclamation cycles on the reclaim quality measured by the loss of ignition it can also be observed that in many cases the number of the additional cycles of the reclamation process is less effective than the dedusting of sand done before and after the reclamation process. Hence a conclusion follows that the existing system of vibration reclamation conducted in a Vibrader equipment is acceptable, but more attention should be paid to dedusting of the reclaim and specially to keeping the level of dust content stable, i.e. the lowest possible, since on this value depend the mechanical properties of the sand mixture. In this aspect one can observe a considerable increase in permeability of all the types of the base sand grains resulting from its effective (additional) dedusting.

Used foundry sand with furane resin

Used foundry sand with furan resin binder was tested.

Figure 6. shows the results of testing realized within the 5 performation statuses which means mechanical and thermal reclamation processes exerted upon reclaimed sand. Bending strength tests and loss of ignition tests were carried out on:

- used moulding sand supplied from the foundry (1st stage of tests),
- used moulding sand supplied from the foundry after pneumatic classification in cascade classifier (2nd stage of tests),
- used moulding sand supplied from the foundry after dry mechanical reclamation process carried out in mechanical centrifugal impactless reclaimer (3rd stage of tests),
- used moulding sand supplied from the foundry after thermal reclamation process carried out in experimental thermal reclaimer (4th stage of tests),
- used moulding sand supplied from the foundry after thermal reclamation process carried out in experimental thermal reclaimer and additionally subjected to dry mechanical reclamation in mechanical centrifugal impactless reclaimer (5th stage of tests).

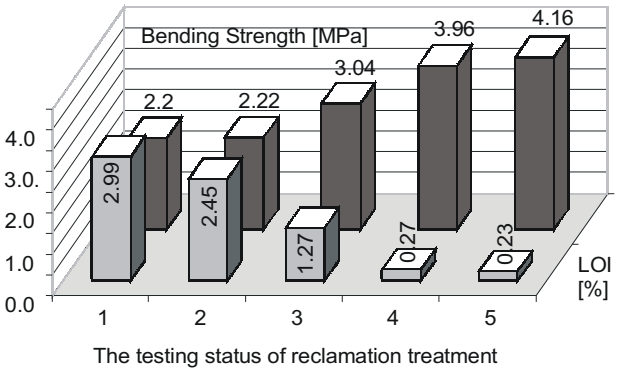

Figure 6. **Results of testing realized within the 5 performation statuses of mechanical and thermal reclamation processes**
Slika 6. **Rezultati testiranja dobiveni u okviru 5 izvedenih mehaničkih i toplinskih procesa recikliranja**

The two main properties of reclaimed sand are highlighted. The Bending Strength [MPa] of sand mixture prepared on reclaimed sand basis, and the percentage Loss of Ignition (LOI) [%].The specimens for strength testing were prepared in hot box process holding them for 40 seconds in a core box preheated up to a temperature of 220 °C. Before strength testing, the specimens were stored for 1 hour.

Examining obtained data one can observe that the bending strength noticeably increase with more advanced rec-

lamation treatment exerted upon used sand during reclamation process. The top value of bending strength (4.16 MPa) was obtained for combined thermal and mechanical reclamation process (testing status no. 5), while sole thermal reclamation gives value of 5 % lesser. In this order mechanical reclamation enables to obtain only 75 % of full bending strength range.

It is worth to emphasize that the used sand supplied from the foundry was primarily reclaimed in vibration reclaimed and dedusted in the foundry. In this light the effect of this primarily reclamation treatment has to be considered as a highly insufficient and unsatisfactory for further foundry application.

The bending strength has inverse manner to loss of ignition. The practical value that could be accepted as a sufficient for foundry practice is approx. 1 %. It means that it is located between 3 and 4 treatment status of reclamation rather more close to status 4, where thermal combustion of residual resin on grain surface allows to rapid decrease of LOI.

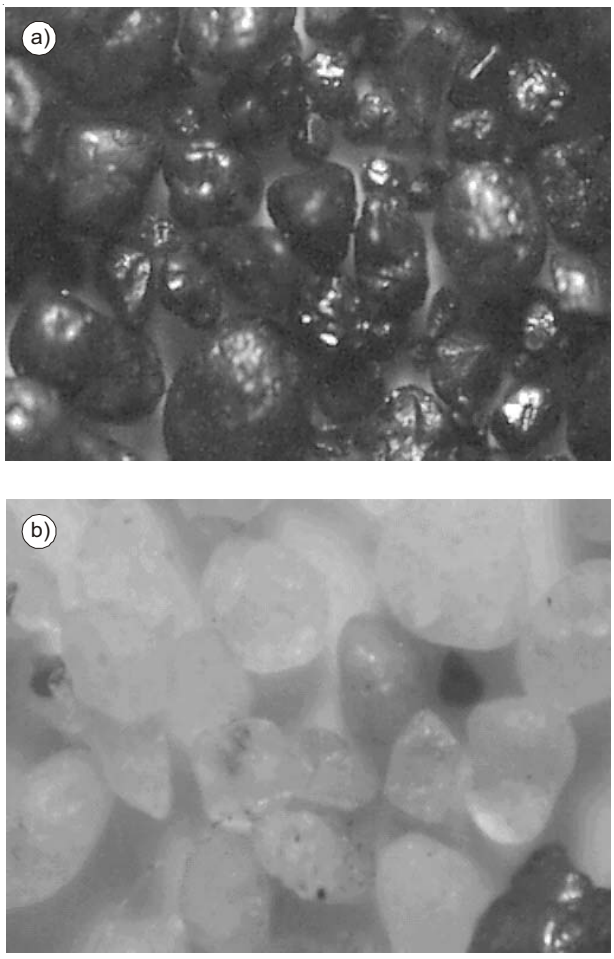

Figure 7. **Difference of surface appearance after 1st (Figure 7.a) and after 5th (Figure 7.b) stage of tests**
Slika 7. **Razlika u izgledu površine nakon 1-vog (Slika 7.a) i nakon 5. (Slika 7.b) 5-tog stadija pokusa**

As it mentioned above the reclamation process is carried out in order to remove the layer of the used binding material from the surfaces of grains. Figure 7. shows the difference of surface appearance after 1st (Figure 7.a) and after 5th (Figure 7.b) stage of tests. The highest level of the sand grains cleaning process is achieved after both thermal and mechanical regeneration.

CONCLUSIONS

It is possible to entirely eliminate and reduce to a generally acceptable level the toxic effect of all side-products of reclamation that are harmful to the soil, underground water and air.

In foundries the best for recycling is the solid waste from which the recovery of moulding sand is fully recommended.

The currently applied reclamation method of waste sands ensures the high effectiveness of reclamation processes, and at the same time allows for other specific features inherent in every method of reclamation and importance of the process performance under optimum conditions.

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