ARCHIVES
of
FOUNDRY ENGINEERING

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

ISSN (1897-3310)
Volume 15
Special Issue
1/2015

131 – 135

27/1

Influence of Thermal Reclamation Temperature on the Strength of the Moulding Sand Made of the Reclaim in the Hot-box Technology

M. Łucarz*, B. Grabowska
AGH - University of Science and Technology Faculty of Foundry Engineering, Department of Foundry Processes Engineering, Reymonta 23, 30-059 Cracow, Poland
*Corresponding author. E-mail address: eumar@agh.edu.pl

Received 28.04.2015; accepted in revised form 05.05.2015

Abstract

The results of the thermal reclamation investigations of the spent moulding sand with the Ekotec 35 binder, are presented in the paper. The reclamation process of the quartz matrix was carried out on the basis of the author,s own method of selecting the reclamation temperature. On the bases of the performed thermo-gravimetric analysis of the binder the temperature range required for the efficient thermal reclamation was indicated. In order to confirm the assumption the thermal reclamations were performed at a temperature determined by the TG and - for comparisons - at a lower and higher temperature. During the reclamation process samples of the reclaim were taken for testing ignition losses in order to determine the process efficiency. The correctness of the assumed method of selecting the temperature range of the thermal reclamation of spent moulding sand with the Ekotec 35 binder was confirmed.

Keywords: Spent sands, Thermal analysis, Thermal reclamation, Thermal reclaimer, Hot-box Technology

1. Introduction

The best method of the grain matrix reclamation from waste moulding sands with organic binders is the thermal reclamation. However, this process is generally considered to be costly due to expenditures related to purchasing an installation and to energy consumption [1]. However, taking into account the current ecological demands, the thermal reclamation process becomes more and more profitable. An application of a mechanical reclamation of waste moulding and core sands, and their multiple usage causes an accumulation of organic binders on grain surfaces [2-3]. In case of core sands the grain matrix should warrant obtaining high quality cores and in consequence high quality castings. Therefore attempts are undertaken to develop efficient structural solutions of thermal reclaimers, in which investment and maintenance expenditures could be limited and simultaneously the reclaimed material would be fully suitable for making cores e.g. in the hot-box technology. One of the ways of limiting costs are operations optimising parameters of the thermal reclamation process. Applying unjustified, too high temperature range or too long process increases costs and makes the thermal reclamation process uneconomical. One of the method limiting the thermal reclamation costs is a determination of the minimal process temperature, warranting obtaining grain matrices of the proper quality and in consequence the cores of the satisfying strength properties. The required reclamation temperature range can be determined by means of the thermal analysis, TG [4-5]. On the bases of binder mass losses at increasing temperatures in the combustion chamber - with and without air - the minimal required temperature of the organic binder destruction can be found [6-9].

2. Investigation Methodology

2.1. Core sand

The core sand prepared for investigations was of the following composition:

– high-silica sand or reclaim - 100 parts by mass;
– urea-furfuryl binder, Ekotec 35 - 1.2 parts by mass;
– hardener AM-G - 10% of the resin.

The core sand was prepared in the rotor mixer according to the following procedure: the hardener was added to the grain matrix and mixed for 2 minutes, then resin was added and mixing was continued for next 3 minutes. The cores of this sand core were made in the universal machine for making test samples and small cores in the hot-box LUT technology. Tests were realised for the shot pressure of 5.2 MPa, shot time - 1 s, blowing time - 2 s. Shaped elements for strength testing were made at a temperature of 220 °C, for holding times: 15, 30, 60 and 120 s. Samples prepared according to the given above way were subjected to bending strength tests in the device LRu-2e for testing moulding sands strength. Tests were performed on hot samples, directly after they were made as well as on cold samples after 24 hours of cooling.

2.2. Thermal analysis

Thermal tests were made by means of the thermal analyser NETZSCH STA 449 F3 Jupiter®, which allows to perform TG and DTG measurements under the same measuring conditions, it means at the same temperature increase rate (10 °C/min), in oxygen (air) and oxygen-free (argon) atmosphere with the same gas flow rate (40 ml/min). The mass of samples subjected to the thermal analysis, TG, was app. 15 mg. Platinum crucibles were used since they allowed measuring up to 1000 °C.

2.3. Thermal reclamation

Cores made of a fresh sand, after strength tests were crushed in the jaw crusher and sieved through 0.8 mm mesh sieve. The material obtained in such way was subjected to thermal reclamation operations.

The thermal treatment of a spent moulding sand was performed in the experimental thermal reclaimer, which operation principle was presented in other papers [10-11].

When the reclamation chamber was warmed to the required temperature of the operation and the fluidisation air (bed mixing) obtained 50 °C, the spent sand was charged into the chamber. The spent sand (charge of 10 kg) was reclaimed at temperatures: 400, 525, 680 °C, with the bed mixing acc. to the sequence: 5s_5s_5s. During the reclamation process small portions of the reclaim were taken out (after 2.5, 5, 7.5, 10, 15, 20, 25 and 30 min.) to be used for determining ignition losses. Samples of the grain matrix, after the determined reclamation times, were roasted in the silite furnace. The results presented in this paper are average values of two reclaim samples, which were heated for 2 hours in the furnace at a temperature of 950 °C.

3. Analysis of the results

The thermal analysis is a method allowing to determine the material thermostability, which is often essential under conditions of the material treatment and usage. The performed thermal analysis was aimed at finding the mass change of the sample of the bound organic binder (acc. to recommended proportions) in the temperature range 20-1000 °C, under oxygen and oxygen-free conditions as well as obtaining its thermal characteristic needed to perform optimisation of the thermal reclamation conditions of waste moulding sands. TG curves are presented in Figure 1 and the methodology of determining the required reclamation temperature in papers [6-9].

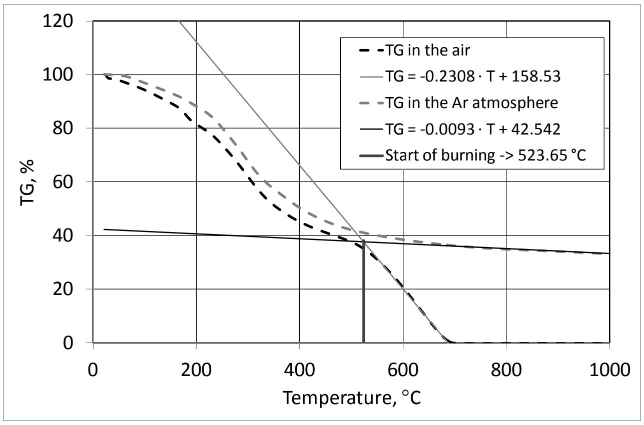

Fig. 1. Selection of the combustion temperature of Ekotec 35 binder

Analysing the obtained TG results it can be stated that a binder subjected to the temperature influence - at its certain range - undergoes degradation being a decomposition of organic substances and formation of volatile (gaseous) compounds which effect is a mass loss of the sample. This process proceeds to a certain moment only and at the lack of the atmosphere containing oxygen stops or significantly slows down.

It was noticed that both in the oxygen and oxygen-free atmosphere rectilinear segments occur on the thermal analysis curves. Linear functions were fitted to these data ranges and it was assumed that their point of intersection determines the temperature, at which the binder combustion or pyrolysis process starts. The above considerations are - for the tested binder - presented graphically in Figure 1, where the temperature of 523.7 °C was determined as the one from which the combustion process starts.

Simultaneously it can be seen that up to a temperature of 400 °C the process of the mass degradation was intensive, while much less intensive at higher temperatures. In view of this observation, this temperature value was assumed as suitable for testing the thermal reclamation for the first time. The subsequent operation of the thermal treatment of the waste moulding sand was performed at a temperature of 525 °C, negligibly higher than the one determining the start of the combustion (destruction) of binder residues.

The data shown in Figure 1 indicate that the total combustion of the sample occurs at a temperature of app. 680 ºC. Therefore the subsequent investigations of the thermal reclamation of the spent core sand were carried out at this temperature.

The results of ignition losses of samples taken out during the reclamation process, in dependence on the reclamation time and temperature, are presented in Figure 2.

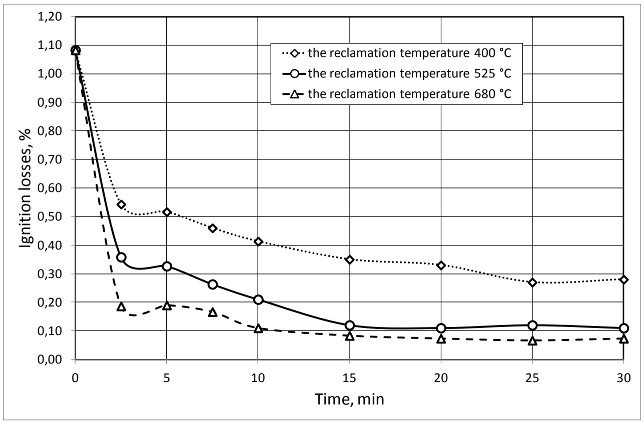

Fig. 2. Ignition losses of samples of materials in dependence on the reclamation time and temperature

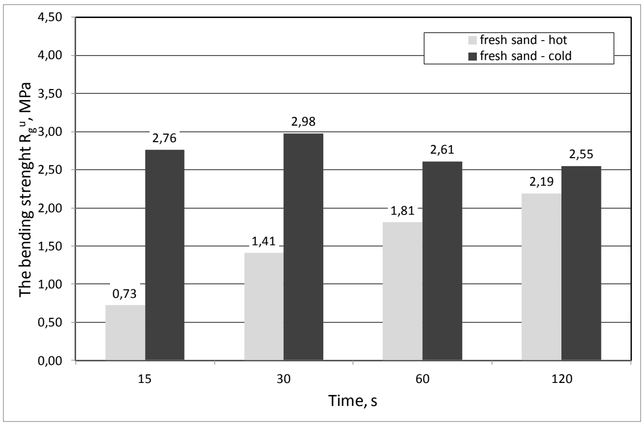

Fig. 3. Results of the bending strength of shaped elements made of the fresh sand, directly after being made and after cooling

It was found that a temperature of 400 ºC was too low for the efficient cleaning the grain matrix from the spent binder. It was also noticed that the higher reclamation temperature the faster resin combustion process, and due to that in shorter time lower ignition loss values were obtained. Whereas from the 15-th minute of the process similar ignition loss values were obtained for the determined temperature and for the maximal one at which the total binder destruction occurred. Ignition loss values at the level 0.1% are due to mixing of the bed and uneven binder combustion on grain surfaces in this mixed bed.

Core sands of the same composition were prepared on the grain matrix obtained after individual reclamation operations and on the fresh sand. Shape elements made of these moulding sands were used for the assessment of the reclaim quality and for the verification of the methodology of determining the minimal required reclamation temperature.

The results of strength tests of shaped elements made from moulding sand on the fresh sand grain matrix are presented in Figure 3. It was found that the highest strength of 2.98 MPa, was obtained - after cooling - by shaped elements heated for 30 s in the core box.

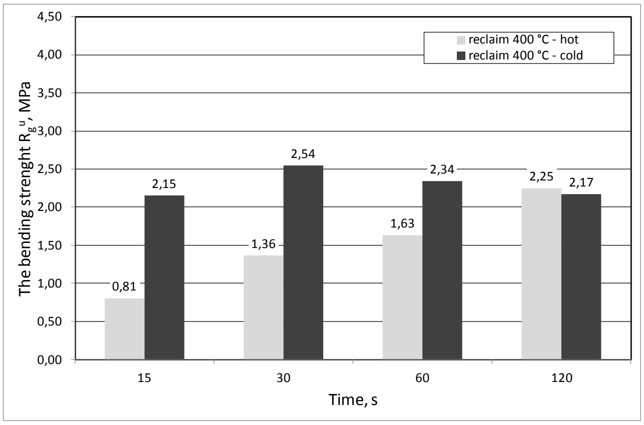

Fig. 4. Results of the bending strength of shaped elements made of the reclaim (thermal reclamation at 400 ^{o}C, 30 min.), directly after being made and after cooling

Subsequent strength investigations were performed on moulding sand samples prepared in the hot-box technology on the grain matrix of the reclaim obtained in the reclamation process at a temperature of 400 ºC (Fig. 4). For the shaped elements heated for 30 s in the core box the highest strength was obtained, however lower than for the elements prepared on the fresh sand. Simultaneously the binding process was faster since higher values of the bending strength were achieved for samples directly after being made (hot).

In order to find out whether the assumed methodology of selecting the required reclamation temperature is correct and warrants obtaining the reclaimed material of properties similar to the fresh sand, the strength tests of samples made of the moulding sand on the reclaimed grain matrix obtained in the reclamation process performed at a temperature of 525 ºC, were carried out (Fig. 5). The obtained results confirmed that the method of the reclamation temperature selection by means of own methodology is the correct one. The moulding sand prepared on the reclaimed grain matrix has the bending strength by 0.3 MPa higher than the moulding sand with the fresh sand.

The results of the strength of the moulding sand made of the reclaim obtained after the thermal treatment at the highest temperature (out of the ones applied in tests) are presented in Figure 6. The obtained results of performed tests did not indicate a significant effect of the reclamation at the high temperature on the quality of the moulding sand strength properties.

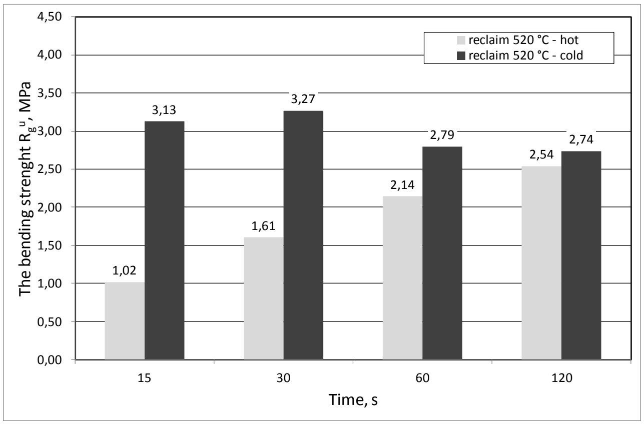

Fig. 5. Results of the bending strength of shaped elements made of the reclaim (thermal reclamation at 525 ºC, 30 min), directly after being made and after cooling

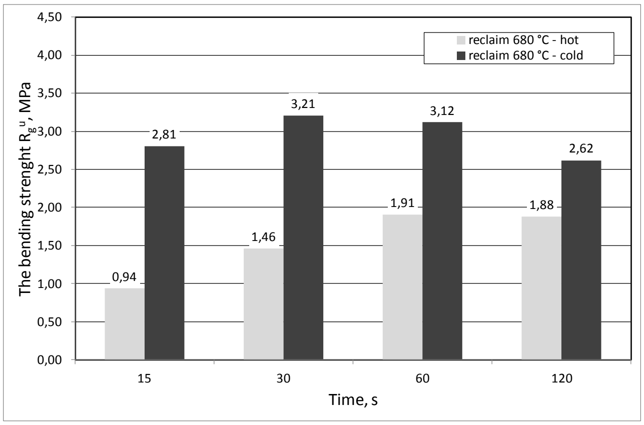

Fig. 6. Results of the bending strength of shaped elements made of the reclaim (thermal reclamation at 680 ºC, 30 min), directly after being made and after cooling

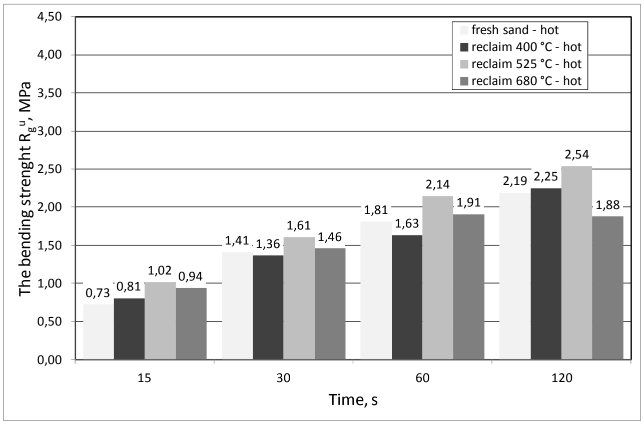

Fig. 7. Comparison of the bending strength of samples in the hardened state directly after being made of the fresh sand and of reclaimed materials

The overall results of the bending strength tests of shaped elements directly after being made (hot), prepared on various grain matrices, are presented in Figure 7. The strength of the tested samples indicates that the core sand prepared on the reclaim faster obtains higher bending strengths. This can shorten the core preparation time and increase the production efficiency.

Listing the bending strength values after cooling (Fig. 8), indicates that samples made from the grain matrix after the reclamation at a temperature of 525 ºC, after shorter holding time reach higher strength than shaped elements prepared from the fresh sand.

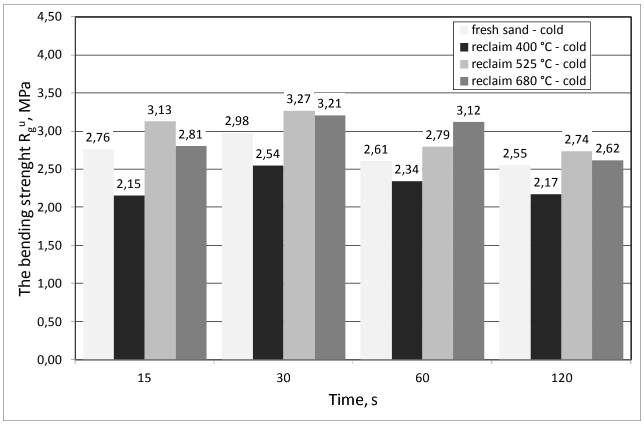

Fig. 8. Comparison of the bending strength of samples in the cold hardened state (after 24 h) made of the fresh sand and of reclaimed materials

4. Conclusions

On the basis of the thermal analysis and TG curves - in oxygen and oxygen-free atmosphere - it is possible to determine the conditions of the thermal reclamation realisation. The performed tests of ignition losses and bending strength of moulding sands confirm the rightness of the assumed methodology of the temperature selection for the core sand reclamation performed in the hot-box technology.

The cores made on the grain matrix of the reclaim - obtained in the process performed at the selected temperature of 525 ºC - achieved the bending strength comparable with the ones on the fresh matrix.

Too low temperature of the grain matrix reclamation process does not remove completely the organic binder from grain surfaces, but only causes its degradation. Not fully realised destruction of the bound resin decreases the quality of the cores made on the reclaimed grain matrix.

The obtained investigation results confirmed the expectations that the application of economically unjustified too high temperature of the thermal reclamation is groundless since it only increases costs without significant quality effects of the made cores.

Acknowledgements

This work was elaborated under AGH research and development study no 11.11.170.318, task2.

References

[1] Danko, J., Dańko, R., Łucarz, M. (2007). *The processes and equipment for the regeneration of used foundry sands warp*. Kraków, Wydawnictwo Naukowe AKAPIT (in Polish).

[2] Łucarz, M. (2006). The Condition of Silica Sand Grains Surface Subjected to Reclamation Treatment. *Metalurgija* Volume 45 Issue1, 37 – 40.

[3] Łucarz. M. (2015). Thermal Reclamation of the used Moulding Sands. *Metalurgija* Volume 54 Issue1, 109 – 112.

[4] Grabowska, B. (2013). *New polymer binders in form of aqueous compositions with poly(acrylic acid) or his salts and modified biopolymer for foundry practice applications*. Kraków, Wydawnictwo Naukowe AKAPIT (in Polish).

[5] Łucarz. M., Grabowska. B. & Grabowski, G. (2014). Determination of parameters of the moulding sand reclamation process, on the thermal analysis bases. *Archives of Metallurgy and Materials.* Volume 59, Issue 3, 1023-1027.

[6] Łucarz, M. (2015). Setting temperature for thermal reclamation of used moulding sands on the basis of thermal analysis. *Metalurgija* 54 (2), 319 – 322.

[7] Łucarz, M. (2015). Ecological aspects of the performed thermal reclamation. *Archives of Metallurgy and Materials.* Volume 60, Issue 1, 329-333.

[8] Łucarz, M. (2014). Influence of the Thermal Reclamation of the Spent Core Sand Matrix on Its Reuse. *Archives of Foundry Engineering.* 14 (1), 27-30.

[9] Łucarz, M. (2010). Study of thermal reclamation of used hot-box sand. *Archives of Foundry Engineering.* Volume 10, Special Issue 2/2010, 99-102 (in Polish).

[10] Łucarz, M. (2012). Ecological installation of the thermal reclamation of used foundry sands. *Archives of Foundry Engineering.* Volume 12, Special Issue 1/2012, 125-130 (in Polish).

[11] Łucarz, M. (2013). The influence of the configuration of operating parameters of a machine for thermal reclamation on the efficiency of reclamation process. *Archives of Metallurgy and Materials.* Volume 58, Issue 3, 923-926.