

Thermal Reclamation Process of the Spent Moulding Sand with the Polymer BioCo2 Binder

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Abstract

The results of the thermal reclamation investigations of the spent moulding sand with the polymer BioCo2 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 basis 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 polymer BioCo2 binder was confirmed.

Keywords: Spent sands, Polymeric binder BioCo, Thermal analysis, Thermal reclamation, Thermal reclaimer

1. Introduction

The thermal reclamation of moulding sands with organic binders is considered - from economic and ecological reasons - the costly process [1]. However, this is the only one treatment method warranting a complete removal of binding materials from grain surfaces. An application of the mechanical reclamation, cheaper in respect of investment and management, does not warrant the efficient grain matrix purification from a left-over binder. In the majority of cases the application of the mechanical reclamation of spent sands with organic binders is reduced to effective moulding sands fragmentation. Multiple use of matrices reclaimed in such way indicates an accumulation of organic resins on grain surfaces [2]. The reclaim obtained by mechanical way is the most often used for preparations of backing sands. In case of

core sands the grain matrix must warrant high-quality cores, which will meet the casting quality requirements. Therefore looking for efficient solutions of thermal reclaimers structure, in which investment and maintenance expenditures can be limited, while the obtained reclaimed material will be fully suitable for making cores e.g. in the hot-box technology, seems essential. One of the ways leading to limiting costs are operations optimising the thermal reclamation process parameters. The thermal treatment realisation is related to obtaining the determined reclamation temperature. The application of the unjustified too high temperature range or too long time, increases process costs and makes the thermal reclamation treatment uneconomic. Undertaking investigations concerning various resins used for core productions aimed at finding satisfying conditions of the thermal reclamation is one of the ways, which can allow to reduce costs of this process. The hereby study is a continuation of

research concerning the optimisation of realisation conditions of the thermal reclamation process of spent moulding sands with organic binders with the application of the thermal analysis method (TG). The new polymer BioCo2 binder [3], which as a fully organic material should warrant obtaining the reclaim of needed properties, was subjected to the thermal analysis and then to the thermal reclamation.

2. Experimental

2.1. Polymer binder BioCo2

The binder subjected to the thermal analysis was BioCo2 [4], a new polymer binder in the form of a water-based PAA/D polymer composition, namely a mixture of a synthetic polymer, poly(acrylic acid) (PAA by BASF) and a modified biopolymer: potato dextrin (D, by Fluka). The polymer composition contained 60% of water. The weight ratio of the PAA : D polymers was 7 : 8.

2.2. Preparing sand

Moulding sand was prepared in the following with (parts per weight):

- mineral matrix, namely the moulding quartz sand BK D 0.16 – 0.32 mm from SIBELCO EUROPE - 100.0;
- polymeric binder BioCo2 - 3.0.

Moulding sand after 3 minutes of mixing in the rotor mixer was placed for 1 hour in the drier - warmed to 120 °C. After drying and cooling the bound moulding sand was crushed in the jaw crusher and sieved through the sieve of 0.8 mm. The material obtained in the described way was subjected to the thermal reclamation procedures.

2.3. Thermal analysis methods

The thermal examinations were carried out by using a NETZSCH STA 449 F3 Jupiter® thermal analyser, which supports simultaneous TG and DSC measurements, thus providing two independent signals recorded in the same measurement conditions, namely at the same rate of temperature increase (10K/min), atmosphere and gas flow rate (40 ml/min). The measurements for the hardened thermally (thermal crosslinking: temperature 120 °C, holding time 30 min) sample BioCo2 were taken in an oxygen atmosphere (synthetic air) and an oxygen-free one (argon). The sample undergoing the thermal analysis weighed approximately 15 mg. Platinum crucibles were used, as they allowed measurements up to 1000 °C.

2.4. Thermal reclamation

The thermal treatment of used moulding sands was performed in the experimental thermal reclaimer. Operation principles of this device were presented in other publications of the author [5 - 7]. The spent sand was charged into the reclamation chamber, when this chamber was heated to the required temperature and the fluidizing air (mixing the deposit) achieved a temperature of 100 °C. Spent core sands (charge of 10 kg) were reclaimed at temperatures: 400, 510 and 700 °C, with the deposit mixing acc. to the sequence: (5s_5s_5s). During the reclamation process (after 1, 2, 4, 8, 16 and 32 minutes) small portions of the reclaim were taken in order to determine ignition losses. Samples of grain matrix, after the determined reclamation times, were roasted in the electric furnace. The results presented in this paper are average from two reclaim samples, heated in the furnace for 2 hour at a temperature of 950 °C.

3. Results and discussion

The thermal analysis is a method allowing to determine the material thermostability, which is often essential for its treatment and application. Thermostability measurements are performed by means of thermoanalytical methods thermogravimetric (TG). The thermal analysis carried out in this study was aimed at establishing mass changes of organic binder samples within the temperature range: 20 – 1000 °C, under oxygen and oxygen-free conditions as well as at obtaining the binder thermal characteristic essential for optimisation conditions of the thermal reclamation process of used moulding sands.

Figure 1 shows the TG results of the measurement of the sample BioCo2 in an oxygen atmosphere. It was found that the tested sample was nearly completely decomposed (app. 95 %) at a temperature above 550 °C.

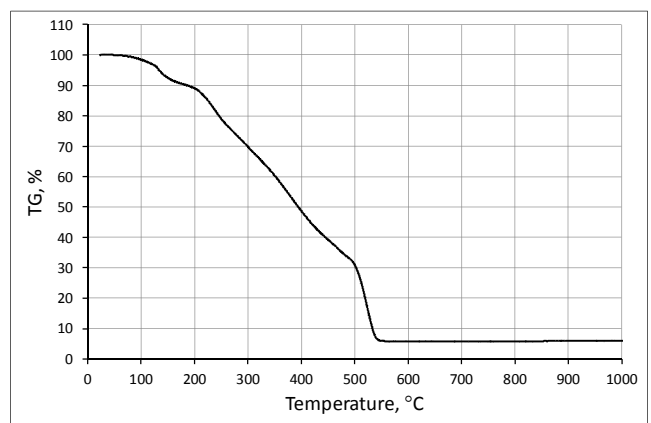


Fig. 1. TG- curve of the binder BioCo2 in oxygen atmosphere

Figure 2 shows the TG results of the measurement of the sample BioCo2 in an oxygen-free atmosphere. Since there was the lack of oxygen - necessary for a burning process - the sample, within the tested temperature range, was degraded in 75% (pyrolysis), the remained part constituted app. 25%.

The remaining part of the BioCo2 sample mass which has not decomposed up to the temperature of 1000 °C in oxygen and oxygen-free conditions probably mainly contains carbonised carbon [8, 9].

On the bases of the obtained results TG, it can be stated that the binder subjected to the temperature influence, at its certain range, undergoes degradation, being the decomposition of organic compounds and formation of volatile substances (gases), which - in effect - cause decreasing of the sample mass. This process proceeds only to a certain moment and at the lack of oxygen stops or significantly slows down.

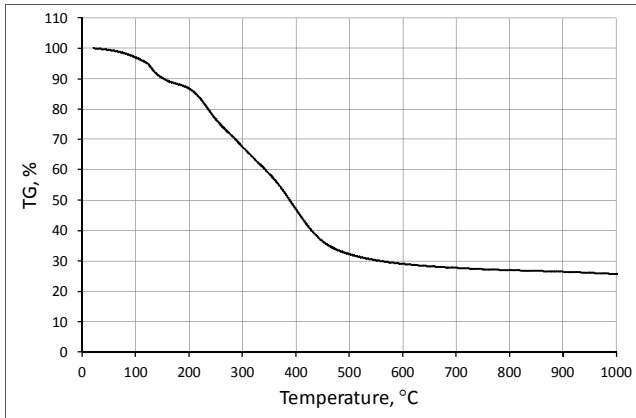


Fig. 2. TG-curve of the binder BioCo2 in oxygen-free atmosphere

It was noticed in the oxygen atmosphere as well as in the oxygen-free one - that rectilinear segments occur in the obtained TG diagrams. Linear functions were selected for these data ranges and assumed that their point of intersection determines the temperature, at which the binder burning process starts. These considerations, in relation to binder BioCo2, are presented in Figure 3 and the temperature of 505.7 °C was determined as the one, at which the burning process starts.

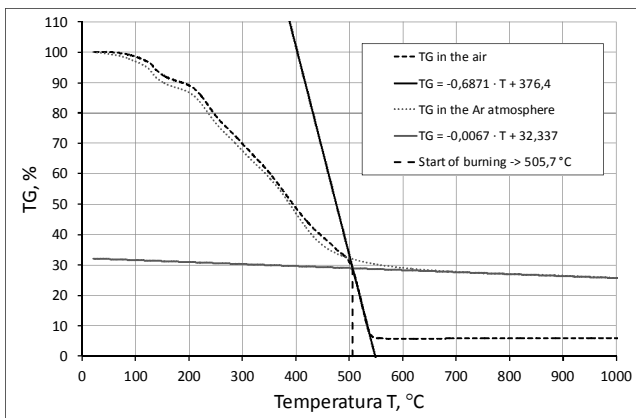


Fig. 3. Selection of the burning temperature – binder BioCo2

The temperature pathways in the selected points of the thermal reclaimer for the assumed process temperature, being 400 °C, are presented in Fig. 4. Simultaneously, during the whole process the

gas consumption was recorded. For 32 minutes of the reclaimer operation it was app. 1 m³.

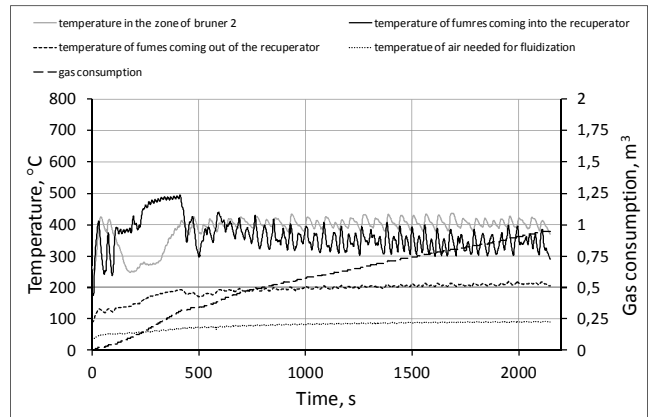


Fig. 4. Recorded temperatures and gas consumptions during reclamation procedures, at a temperature of 400 °C, mixed by the air from the recuperator

The recorded parameters of the operation at a temperature of 510 °C are presented in Fig. 5. Within the same time the gas consumption increased by 25% as compared to the lower temperature.

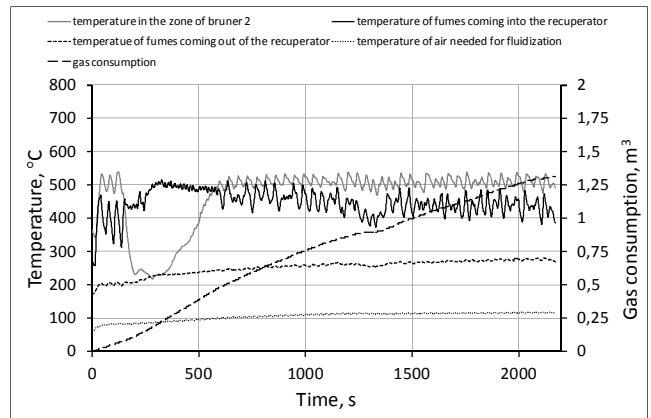


Fig. 5. Recorded temperatures and gas consumptions during reclamation procedures, at a temperature of 510 °C, mixed by the air from the recuperator

The reclaimer operational parameters were also recorded for a temperature of 600 °C (Fig. 6). It was noticed that in the device applied for tests, operating with the determined intensity and functionality, increasing the reclamation temperature by the successive 100 °C causes increasing the gas consumption by next 25%.

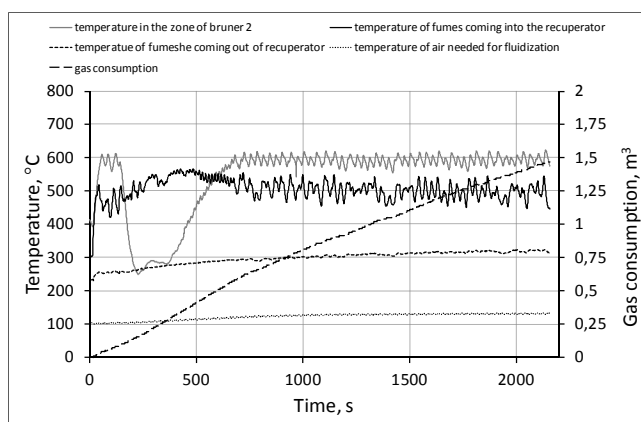


Fig. 6. Recorded temperatures and gas consumptions during reclamation procedures, at a temperature of 600 °C, mixed by the air from the recuperator

Ignition losses of spent sands for various reclamation temperatures are presented in Fig. 7. Performing the operation at a temperature of 400 °C, even for the longest of the tested reclamation times, did not warrant a good matrix purification, leaving more than 0.40% of not burned resin. The reclamation performed at a temperature of 510 °C (determined on the basis of the thermal analysis) caused the spent binder removal to a level of 0.10%. Increasing the reclamation temperature to 600 °C, did not cause essential mass losses for the longest of the used reclamation times. However, at the higher reclamation temperature the binder was faster decomposed. Ignition losses were the same after 16 minutes of the reclamation procedure at temperatures of 510 °C and 600 °C.

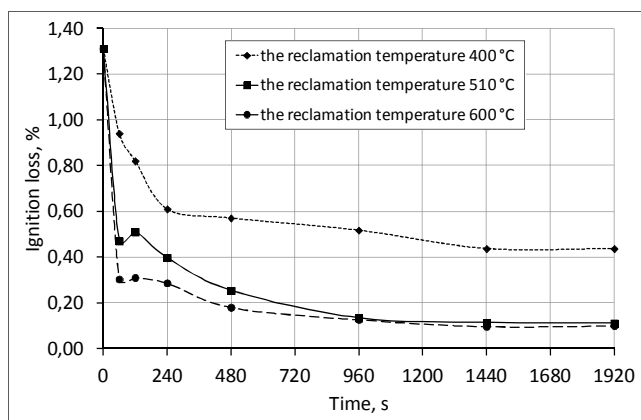


Fig. 7. Ignition loss of the reclaim in dependence of the reclamation temperature and the thermal treatment time

To compare the reclamation results in the thermal reclaimer the ignition losses were measured at the determined temperature of 510 °C and in a temperature of determining ignition losses, being 950 °C. The obtained results are presented in Figure 8.

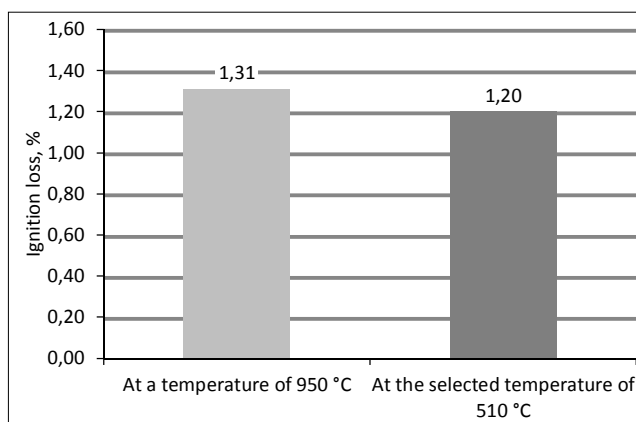


Fig. 8. Ignition loss values of the spent sand in dependence on the temperature

The comparable results of ignition losses as for the investigated thermal reclamation process, performed in the laboratory device were obtained. If, additionally, it will be taken into account, that the difference in ignition losses of pure high-silica sands equals 0.05% between temperatures: 500 °C and 950 °C, it is justified to assume that the presented method of selecting the reclamation temperature is the proper one. Simultaneously it can be stated that the device operates with a high efficiency.

4. Conclusions

The performed investigations indicate that the developed method of the reclamation temperature selection on the bases of the TG curve - in case of the tested organic binder - is the proper one. The reclamation process performed at the determined temperature is efficient and optimal, which is seen when the obtained results are compared with the results obtained at the application of lower or higher reclamation temperatures. The application of a higher reclamation temperature, is unjustified for economic reasons, since increasing the temperature raises the reclamation cost (the higher gas consumption) not providing better purification effects. In turn, the application of the lower than the determined reclamation temperature does not warrant the satisfactory binder removal.

It was found in investigations, that the process of releasing volatile parts from the binder occurs very fast already during heating of the spent moulding sand bed after its charging into the reclaimer. The observed effect corresponds with changes in the TG curve in the oxygen atmosphere, and especially in oxygen-free one, where - regardless of the lack of oxygen - the sample decreased its mass. These indicates a decomposition of organic compounds into volatile substances and formation of a lot of gases. In case of the tested binder it constitutes 70% of the initial sample mass.

Acknowledgements

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