M. ŁUCARZ

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SETTING TEMPERATURE FOR THERMAL RECLAMATION OF USED MOULDING SANDS ON THE BASIS OF THERMAL ANALYSIS

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The application of thermogravimetric analysis can be very useful in the method since an extensive range of resins is used in founding. The thermal analysis performed for three different binders indicated the similar destruction mechanism. Along with the temperature increase the mass decrease of samples is related to the organic compounds decomposition and proceeds in a similar fashion regardless of the atmosphere in which the process occurs. However, for each of the tested binders, a certain critical temperature exists, above which - in the oxygen presence - the burning process of the majority of organic compounds forming the given substance occurs.

Key words: foundry, thermal analysis, setting temperature, used moulding sand, sand testing

INTRODUCTION

The reclamation of used moulding or core sands is based on the regeneration of grain matrix bound by an organic binder. When the sand is hardened by an organic binder the most efficient grain matrix regeneration is done by the thermal reclamation. [1–4]. This reclamation is based on the thermal degradation of organic substances forming the binding agent. The destruction process of organic binders is complicated. A majority of organic compounds reveals resistance to oxygen (present in the air) at ambient temperatures and only at increased temperatures they undergo a gradual degradation [5-7] and finally burning. Since the amount of organic resins offered by producers is numerous and their compositions are under patent claims, the determination of the total thermal destruction temperature requires performing laboratory tests, which allow to estimate individual conditions of resin burning. The thermal reclamation is the natural process, supplementing the degradation and destruction effects of binders inside the mould - during making the casting - often at a limited oxygen access, at high temperatures and at the determined heat flow depending on casting dimensions. Thus, endeavours to create the economic thermal reclamation systems, which will fulfill expectations concerning the reclaim quality at simultaneous limiting the realisation costs, should be undertaken. One of the ways of solving this problem is performing the basic research, related e.g. to the total decomposition of resins, which will allow to estimate the minimal temperature requirements to be created in thermal reclaimers [8]. The known burning temperature range of individual resins should contribute to the efficient realisation of the thermal reclamation at the lowest energy consumption.

PURPOSE OF INVESTIGATIONS

The most essential problem of the efficient realisation of the thermal reclamation is determining the temperature, at which not only the resin thermal decomposition occurs (releasing of volatile substances), but also its total burning, which warrants obtaining the reclaim of a quality similar to the one of fresh sand. The laboratory test, based on the thermogravimetric analysis, which - according to the procedure designed by the author - allows the selection of the minimal required temperature, was applied.

MATERIAL AND THE TESTING METHODOLOGY

The thermal analysis carried out in this study was aimed at establishing mass changes of organic binder samples within the temperature range: 20 – 1 000 °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. Thermal investigations were performed at the application of the thermal analyser NETZSCH STA 449 F3 Jupiter®, which allowed the simultaneous performance of TG and DTA. This provided independent signals recorded under the same measurement conditions, it means at the same: temperature increase rate (10 °C/min), atmosphere and gas flow rate (40 ml/min). Measurements were carried out in the oxygen atmosphere (air) and oxygen-free atmosphere (argon). The mass of samples used for thermal analyses

M. Łucarz, AGH University of Science and Technology, Faculty of Foundry and Enginering, Kraków, Poland

Table 1 **Moulding sands compositions recommended by the producer**

Material	Grain matrix	Resin	Hardener/catalyst	Proportion: resin/hardener
Binder I/ Moulding sand I	High-silica sand 100 part by mass	Urea-formaldehyde resin modified by furfuryl alcohol 1,0 part by mass	Mixture of sulphonic and inorganic acids modified by special additives 0,5 part by mass	2
Binder II/ Moulding sand II	High-silica sand 100 part by mass	Urea-furfuryl resin 1,2 part by mass	Hardener based on ammonium 0,12 part by mass	10
Binder III/ Moulding sand III	High-silica sand 100 part by mass	Alkyd resin 1,3 part by mass	Isocyanide catalyst 0,30 part by mass	4,33

TG-DTA was approximately 15 mg. Platinum crucibles, which allowed measurements up to 1 000 °C, were applied.

Three different sets of materials (resin and hardener/catalyst) for preparations of moulding and core sands were used in tests. The resin was mixed with the hardener according to the recommendations of the producer of resins. Individual pairs of materials are presented in Table 1.

In case of binder I, components were mixed under conditions of a fast heat abstraction, due to a highly exothermic reaction of resin with hardener without grain matrix.

In case of binder II the resin, after mixing with a hardener, was placed for 1,5 minutes into the furnace heated to 220 °C (hot-box process). Binder III after mixing its components was left for binding.

Materials after hardening were crushed and samples for thermogravimetric analyses were prepared. Moulding sands, according to compositions presented in Table 1, were also prepared. Moulding sand I and III, after mixing, were left for hardening, while from moulding sand II (after mixing) cores in the hot-box technology were made by means of the experimental shooting machine LUT-c. This device was shooting the moulding sand into the core box heated to a temperature of 220 °C and holding there for 90 s. The obtained moulding sands were crushed in the jaw crusher, sieved and roasted in the silite furnace at various temperatures. The presented results are average values from two samples. In each case moulding sands were heated in the furnace for 2 hours at a temperature of 950 °C.

ANALYSIS OF THE RESULTS

The results of investigations of the thermal destruction of binder I in the oxidising atmosphere (air) are presented in Figure 1. It was found that the tested sample was completely burned at temperatures above 800 °C.

The results obtained when binder I was subjected to the temperature influence in oxygen-free atmosphere (argon), are shown in Figure 2. In view of a lack of oxygen, which is necessary in the burning process the sample only degraded in 50 % (in the tested temperature range).

Similar analyses were performed for the remaining binders. Figures 3 and 4 present results obtained for binder II. In the presence of oxygen, from the air, material II was burned in 100 % at a temperature of app. 700 °C (Figure 3), while in the argon atmosphere the tested

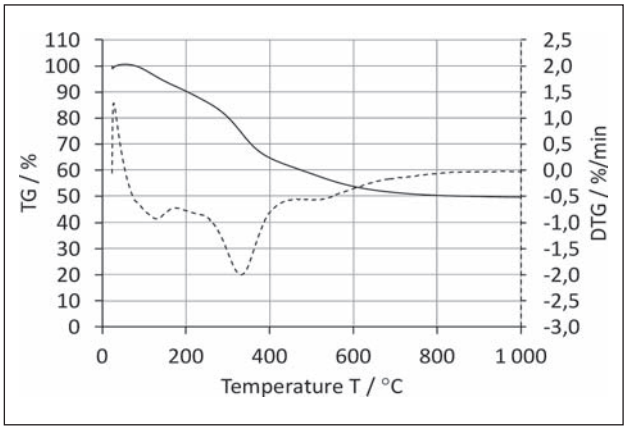

Figure 2 Thermal analysis in the oxygen-free atmosphere (argon) – binder I

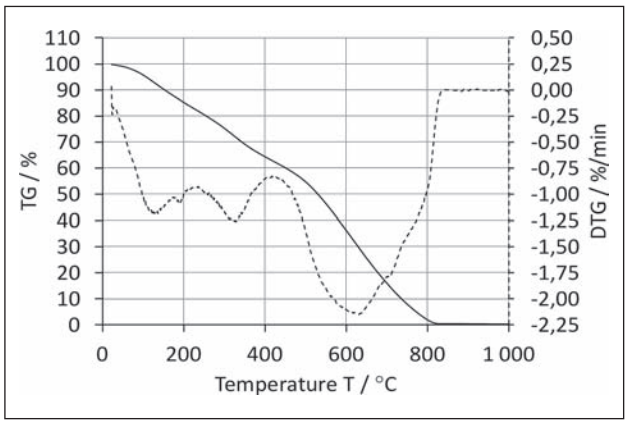

Figure 1 Thermal analysis in the oxygen atmosphere (air) – binder I

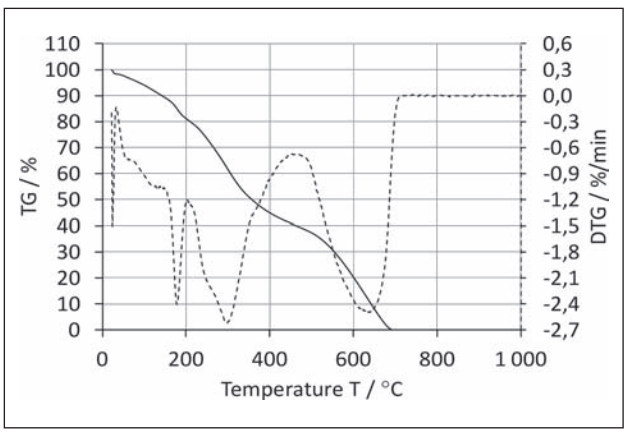

Figure 3 Thermal analysis in the oxygen atmosphere (air) – binder II

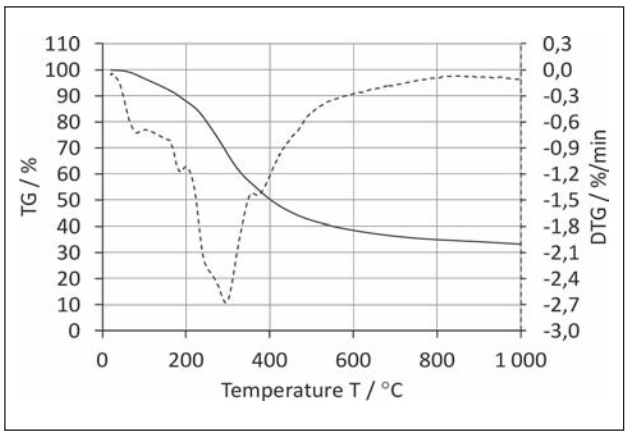

Figure 4 Thermal analysis in the oxygen-free atmosphere (argon) – binder II

resin was degraded only at the level of 30 % of its initial mass. The thermal analysis results for binder III are presented in Figures 5 and 6 100 % binder destruction occurred in the presence of oxygen (at app. 650 °C), while in the oxygen-free atmosphere, approximately 12 % of the sample mass remained.

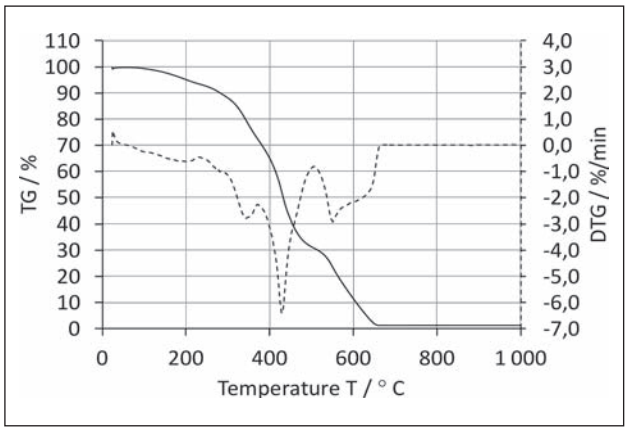

Figure 5 Thermal analysis in the oxygen atmosphere (air) – binder III

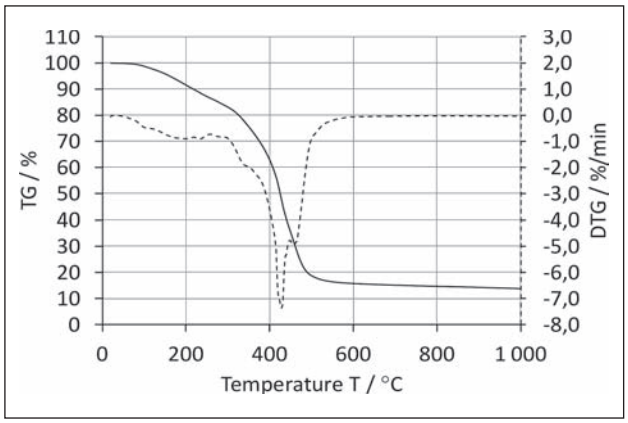

Figure 6 Thermal analysis in the oxygen-free atmosphere (argon) – binder III

On the bases of the obtained results, 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.

It was noticed in all analysed cases - in the oxygen atmosphere as well as in the oxygen-free one - that rectilinear segments occur in the obtained TG diagrams.

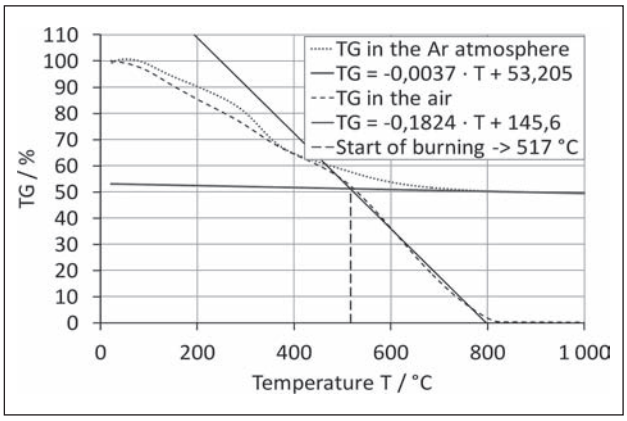

Figure 7 Selection of the burning temperature – binder I

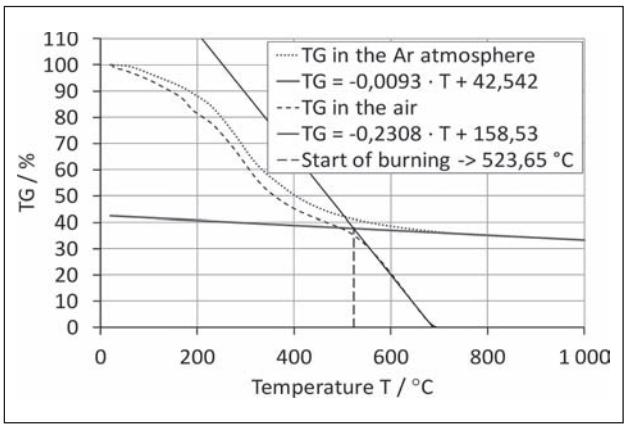

Figure 8 Selection of the burning temperature – binder II

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 I, are presented in Figure 7 and the temperature of 517 °C was determined as the one, at which the burning process starts. The same analyses were performed for binder II (Figure 8) and binder III (Figure 9) determining temperatures of 523,65 °C and 576 °C, respectively.

In order to verify the assumed model the loss on ignition of used moulding sands - prepared according to compositions given in Table 1 - were measured. The ignition loss was tested at a temperature of 950 °C and at the individually determined burning temperature for each moulding sand. The obtained results are presented in Figure 10. In case, when the difference between ignition losses of pure high-silica sand at 500 °C and 950 °C equals 0,05 %, it can be assumed that the applied method is the proper one.

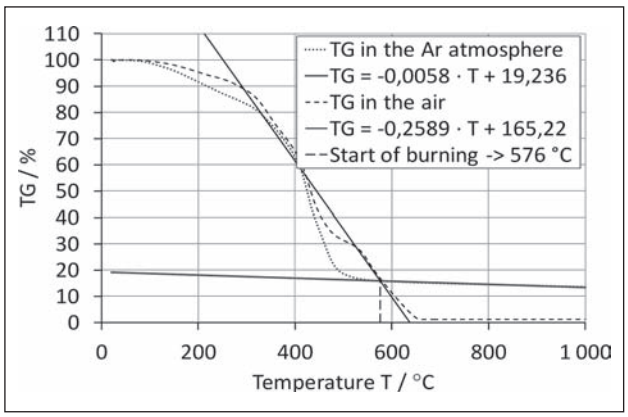

Figure 9 Selection of the burning temperature – binder III

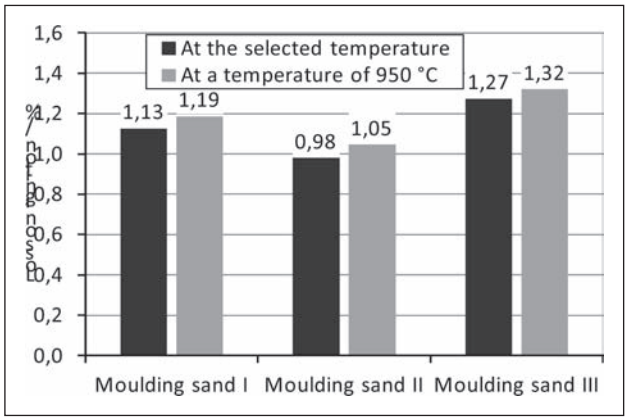

Figure 10 Loss on ignition in dependence of a temperature

CONCLUSIONS

The thermal analysis performed for three different binders indicated the similar destruction mechanism. Along with the temperature increase the mass decrease of samples is related to the organic compounds decomposition and proceeds in a similar fashion regardless of the atmosphere in which the process occurs. However, for each of the tested binders, a certain critical temperature exists, above which - in the oxygen presence - the burning process of the majority of organic compounds forming the given substance occurs. The obtained in this way the temperature range can be implemented for the determination of the required thermal reclamation temperature of the given used moulding sand.

Acknowledgements

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Note: The responsible translator for English language is J. Pawlikowska-Czubak, Kraków, Poland