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Research on Reclamation and Activation of Moulding Sands Containing Water-Glass Hardened with Microwaves

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Abstract

Presented are results of a research on usability of an innovative reclamation process of microwave-hardened moulding sands containing water-glass, combined with activation of binder. After each subsequent stage of reclamation, quality of the reclaimed material was determined on the grounds of measurements of permeability and results of screen analysis. The reclaimed material was next used again to prepare new moulding sand. The sandmix based on high-silica sand prepared with water-glass grade 145, was subject to the following cyclical treatment operations: mixing components, consolidation, microwave hardening, cooling, heating the mould up to 800 °C, cooling to ambient temperature, mechanical reclamation dry and wet. It was found that the used-up and reclaimed sandmix containing water-glass is susceptible to the applied activation process of thermally reacted film of binder and, in addition, it maintains good quality and technological properties of high-silica base. Observations of surfaces of reclaimed high-silica grains with activated film of reacted inorganic binder were carried-out using a scanning microscope. Thanks to properly selected reclamation parameters, the high-silica base can be reused even five times, thus reducing demand for fresh aggregate and inorganic binder.

Keywords: Foundry technique, Water-glass, Reclamation, Microwaves

1. Introduction

The foundry industry belongs to those industries where significant quantities of natural raw materials are consumed. Thus, this industry strongly influences the environment and often causes its degradation resulting in irreversible changes. The group of natural raw materials used in masses for manufacture of castings includes moulding and core sands. Loose self-hardening moulding sands commonly used in foundry technique, including those containing water-glass, are prepared on the base of high-silica sand. For economical reasons, used-up sandmix is replaced with new mixture, prepared of fresh components. The so created wastes are not subjected to energy-consuming reclamation processes, consisting mostly in restoring original properties of the base. Resigning the reclamation processes contributes to degradation of the environment.

In the case of new generation of sandmixes, i.e. those where the binding process is dominated by chemical reactions, refreshing of the sand is excluded, as it is in traditional sandmixes based mainly on natural components. However, Lewandowski [1] indicates that the binding materials in that no chemical reaction occurs during hardening and that do not become deactivated as a result of overheating by the solidifying casting, can be suitable for repeated use. Among physical methods used for hardening the binding materials, considerably reducing crosslinking chemical reactions, can be numbered the innovative microwave heating that guarantees high quality of moulds and cores [2-4]. This is the method that can be successfully used for hardening moulding

sands containing water-glass [5] to guarantee high repeatability of finally obtained mechanical and technological properties. Inorganic binders hardened this way include water that intensively absorbs microwave energy at ambient temperature [6]. A sandmix with the binder hardened by dehydration can be highly susceptible to secondary hydration (rehydration) [5] of films of glassy sodium silicate. An example can be unfavourable influence of moisture present in atmospheric air on stored casting cores hardened in the CO_2 process. However, no positive examples can be found in literature for practical utilization of this phenomenon. Each of physical methods used for hardening hydrophilic binders, including water-glass, requires individual determination of possibilities and scope of actions that consist in reversing the results of dehydration hardening, e.g. in the process of reclamation of binders [1].

Nowadays, carried-out are intensive works on improving methods of recovery and repeated utilization of, first of all, high-silica base [7] and sometimes also of chromite base. These methods are jointly named the reclamation process that consists in separating the binding material (binder) chemically and thermally reacted to a different degree from base grains of used-up moulding sand.

The research works are mostly aimed at determining parameters of the methods guaranteeing effective separation of the film of hardened and overheated binding material that is still present on the surface of base grains [7-10]. From among the so-far developed recovery methods of sand base of moulding sands, the most commonly applied are: mechanical, pneumatic, thermal, wet and combined reclamation [11]. However, it is difficult to find in literature information about possibilities to run reclamation process of the binder, in particular water-glass, in such a way that a sandmix with this kind binding material has features of a durable sandmix [8] or, at least of a multiple-use material. This inorganic binder used for many decades in foundry industry is characterised by low cost and low harmfulness for the environment and humans. Therefore, research works on practical possibilities of activation [12] in the reclamation process of used-up, reacted water-glass seem to be an interesting direction of developing this technology of moulding and core sands.

2. Objective of the research

The preliminary research was aimed at developing a methodology of reclaiming moulding sands containing water-glass, hardened with microwaves, that would consist among others in disintegration of lumpy sandmix and activation of the film of binding material remaining on base grain surfaces. Results of the reclamation processes will be evaluated on the grounds of selected qualitative and technological criteria of the newly prepared sandmix, as well as of the material reclaimed from used-up medium-size high-silica base. It was assumed that the used-up sandmix will be subject to the process of mechanical reclamation, with additional elements of wet reclamation, aimed at weakening cohesive and adhesive bonds of glassy film of hardened and overheated binder.

3. Methodology

It was fixed on the grounds of previous examinations that content of binder grade 145 in fresh moulding sand will be 1.5 %. In addition, to improve spreading the binder on surface of base grains, 0.5 % of water was added to the first sandmix used in a given cycle during preparing it in a laboratory ribbon mixer (Fig. 1, Stage I). Of so prepared sandmixes were made cylindrical test samples in a mould specially adapted to work in electromagnetic field (Stage II) and casting moulds (Stage III) that were hardened by the innovative microwave heating. Next, the moulds cooled-down after hardening were poured with molten alloy at 800 °C (Stage IV). This way reached was a determined degree of thermal load (overheating) of the sandmix. After cooling-down the moulds to ca. 40 °C, the used-up and preliminarily disintegrated sandmix (Stage V) was subject to actual mechanical reclamation by means of a disintegrating and grinding device with continuous controlled removing of powdery fractions (Stage VI).

During cyclically realised stages shown in Fig. 1, determined was permeability of moulding sand made of the reclaim (Stage II), analysed was its granularity and observed was topography of its surface (Stage IV). On the grounds of these results, an attempt was made to determine the number of reclamation cycles during which possible was activation (rehydration) of the reacted binder, effective in the given conditions.

4. Results

Figure 2 shows changes of distribution of fractions of reclaimed high-silica base. Examinations were carried-out on sieves No. 0.40; 0.315; 0.20; 0.16; 0.10 and bottom. The results in Fig. 2 consider total percentage of individual fractions. In the same diagram shown are measurements of permeability of microwave-hardened sandmixes whose base consisted in 100 % of reclaimed material. Each time, permeability was measured on three cylindrical samples using the apparatus LPiR-3. The cycle "0" (Figs. 2 and 4) marked on abscissa describes parameters of fresh, microwave-hardened sandmix prepared of medium high-silica sand with addition of 1.5 % of hydrated sodium silicate grade 145.

It was found on the grounds of screen analysis of the reclaim, carried-out after actual mechanical reclamation (Stage VI), that size distribution of grains making the high-silica base proceeds along with subsequent reclamation cycles. Loss of percentage of grains is visible, first of all, on the screens No. 0.10, 0.16 and 0.20. On subsequent screens No. 0.32 and 0.40 observed was increasing part of fractions with bigger grains. This increase corresponds with measured values of permeability. With each subsequent cycle observed was describable linear increase of permeability, see Fig. 2. The additional portion of water-glass grade 145, cyclically introduced to the sandmix at Stage I (Fig. 1), probably led to creation in the reclaim and growth of conglomerates of lumped base grains. It is supposed that this can result from inefficiently or too shortly run process of dry mechanical reclamation. In addition, excess quantity of binder, cyclically introduced to the reclaim, could be also a cause of the

observed strength increase of the reclaimed sandmix [12] in comparison to that prepared of fresh components only.

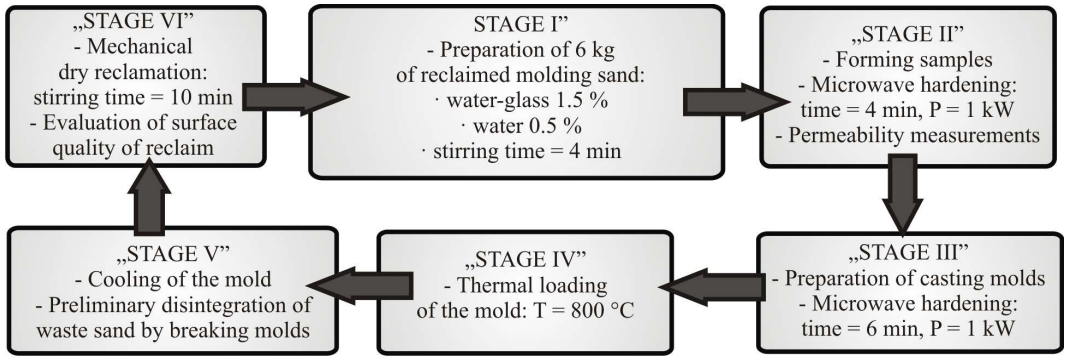

Fig. 1. Schematic presentation of reclaiming process of used-up moulding sand containing water-glass, hardened with microwaves

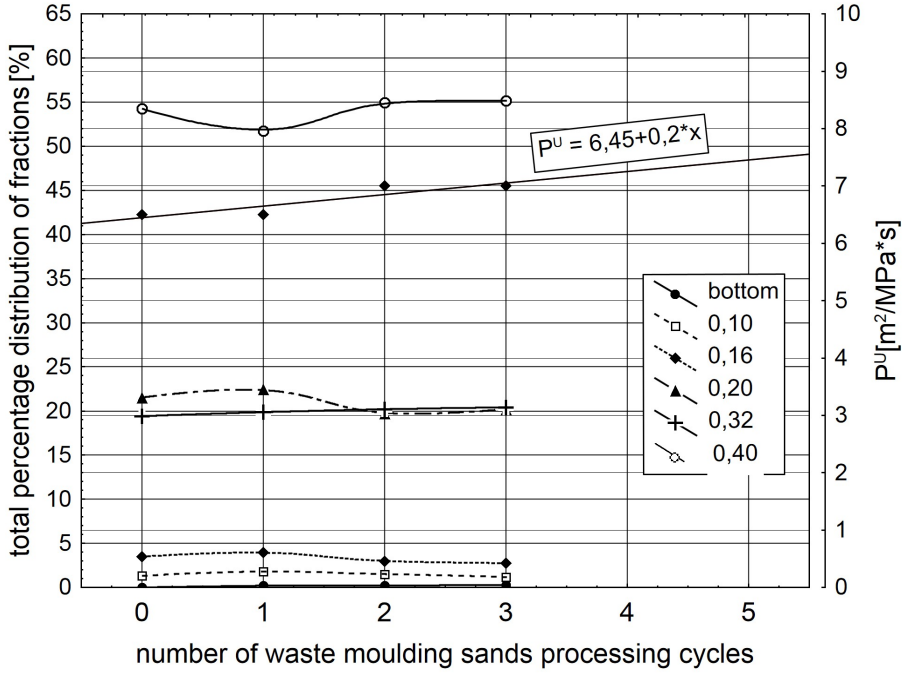

Fig. 2. Changes of percentage distribution of fractions of cyclically reclaimed high-silica base and changes of permeability of the sandmix prepared entirely of reclaimed material

On the grounds of the above-mentioned results, an attempt was made to eliminate the process of creating conglomerates in the reclaim. To this end, an additional processing Stage VII (Fig. 3) was introduced to the chart shown in Fig. 1. During its realisation, a small quantity of distilled water was added during stirring in order to "activate" the film of reacted binder left on the grain surfaces. Moreover, quantity of fresh binder added during stirring at Stage I (Fig. 3) was reduced to that guaranteeing stabilisation of mechanical properties of the sandmix, obtained after hardening [12]. Changes of quality of the reclaim and of the sandmix each time prepared entirely of it are shown in Fig. 4. The examinations were completed with SEM observations of morphology and surface topography of the cyclically reclaimed sand base, see Fig. 5.

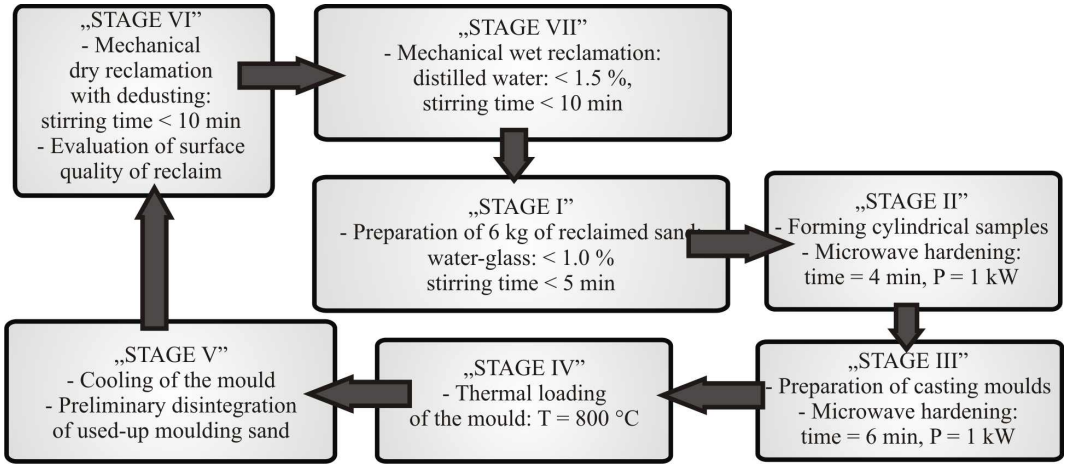

Fig. 3. Schematic presentation of reclaiming process
of used-up moulding sand containing water-glass, hardened with microwaves

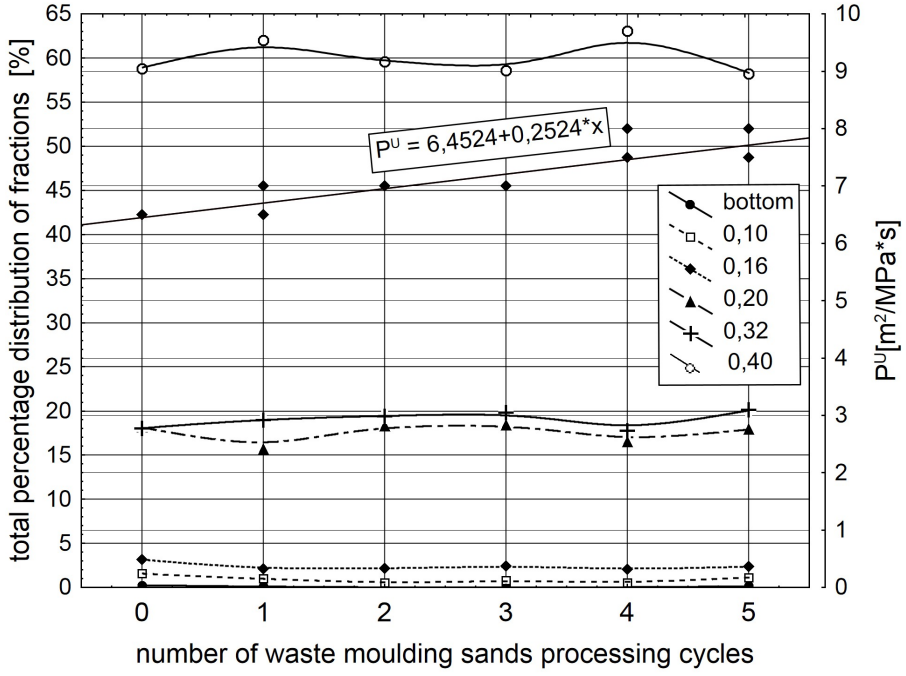

Fig. 4. Changes of percentage distribution of fractions of cyclically reclaimed high-silica base and changes of permeability of the sandmix prepared entirely of reclaimed material

It was found on the grounds of SEM photographs that the applied 7-stage reclamation method combined with dedusting the released powdery fractions permits effective disintegration of lumped moulding sand in course of at least 3 times repeated reclamation process. Observations of surface morphology of the reclaim performed after the fourth processing cycle revealed larger number of conglomerates in the next, fifth cycle. Observed were also concentration places of binder in cavities present on the surfaces of base grains, see Figs. 5e and 5f.

Introducing to the sandmix in stages VII and I small quantities of fresh components (water and binder) intensified the process of binder reclamation consisting, among others, in secondary hydration of sodium silicate film, designated by the authors as the operation of "activation".

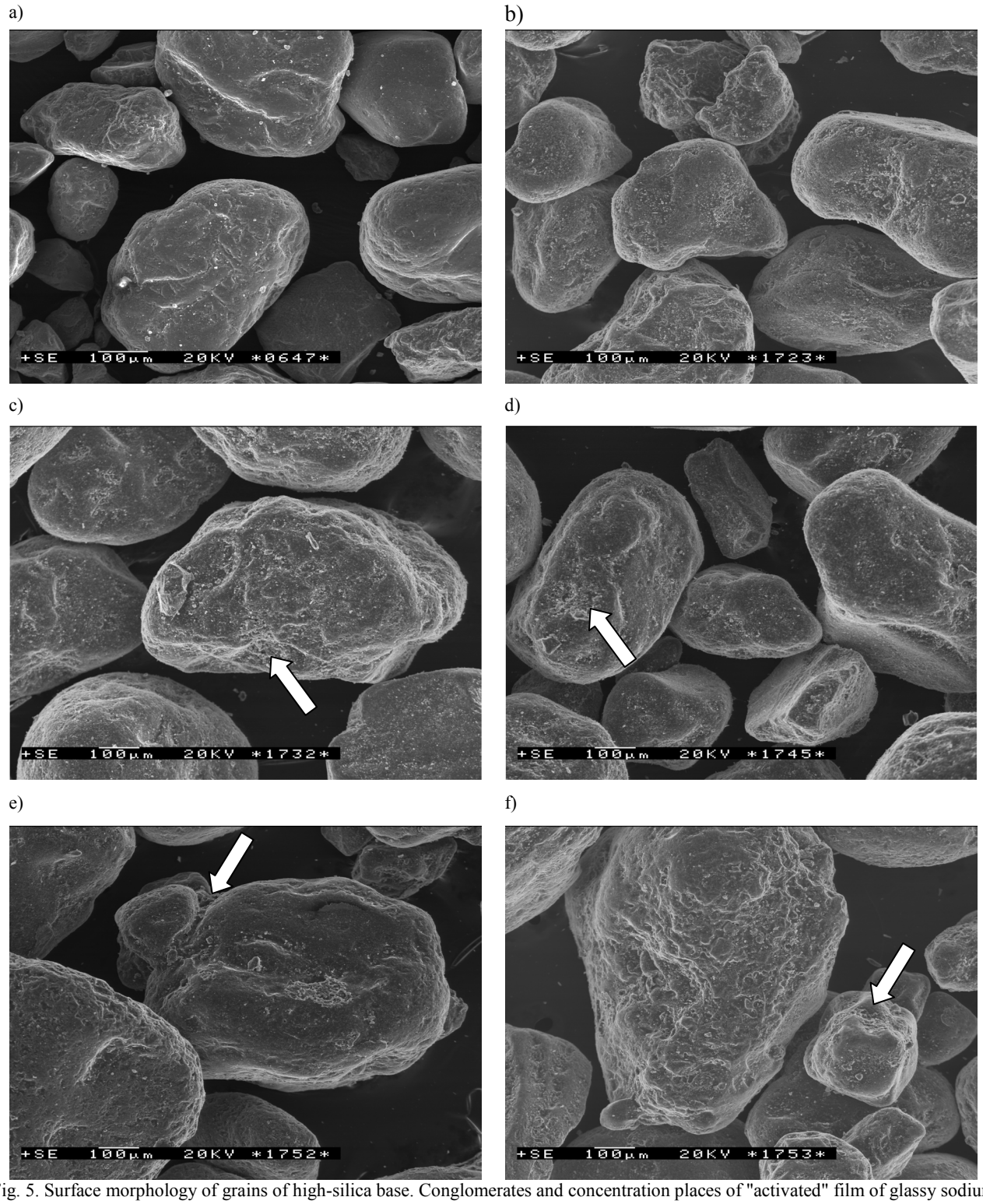

Fig. 5. Surface morphology of grains of high-silica base. Conglomerates and concentration places of "activated" film of glassy sodium silicate are marked with arrows: a) fresh high-silica sand; b) after first cycle; c) after second cycle; d) after third cycle; e) after fourth cycle; f) after fifth cycle of reclamation

5. Conclusions

Analysis of the results of laboratory research on possibility of reclamation of used-up microwave-hardened moulding sands containing water-glass with use of available equipment for preparation and testing moulding and core sands leads to the following conclusions:

- Possible is even 5-time "activation" of reclaimed binder with hydrophilic properties, as is hydrated sodium silicate, in a sandmix unequally overheated to 800 °C, consisting in selecting proper sequence and parameters of dry and wet mechanical reclamation.
- Introduction of small quantity of fresh "activating" components makes it possible to maintain qualitative and technological parameters of reclaimed sandmix during 5 cycles of its processing.
- Cyclically prepared moulding sand does not require introducing fresh high-silica sand, because obtained quality of the reclaim (base and binder) permits its 100-% utilisation for manufacture of next moulding sands.
- Operations of preliminary reclamation, connected with controlled removing the powdery fraction, should be carried-out only to the moment of disintegration of used-up moulding sand, lumped after the knocking-out operation.
- Operations of actual reclamation, following the preliminary operations, should be carried-out on the high-silica reclaim wetted with small amount of distilled water, subject to intensive crushing combined with grinding.
- The research should be extended by subsequent cycles of processing sandmixes, during which controlled would be also pH of the reclaim and its abrasion resistance.
- Examinations of possibilities of reclaiming overheated binder by its "activation" should be continued for other grades of sodium water-glass and for bigger thermal load of casting moulds and cores.

Acknowledgements

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