

The State of Art of the Mechanical Reclamation of Used Foundry Sands

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Abstract

World production of castings, which in 2011 reached almost 100 million ton [1] is accompanied by large quantities of production wastes, mainly used moulding and core sands. Production of 1 ton of casting from ferrous alloys generates circa 1 ton of waste [4], which due to containing certain amounts of harmful and dangerous compounds [3,6,10] should undergo a reclamation – at least of the main component, which means a moulding sand. One of the barriers blocking more efficient implementation of reclamation techniques is still a lack of elaborate investigations providing scientific data for the selection of the best available technique (BAT) – in accordance with the Directives of the EU [7].

Keywords: reclamation of used foundry sands, moulding sand, environmental protection

1. Introduction

In foundry processes a considerable amount of solid and liquid waste is formed, along with toxic gases emitted to the environment. The solid waste is the best for recycling. The recycling of used moulding sand is now being considered by the Polish foundry industry as a means to solve the technical, economic and, last but not least, ecological problems. And so [2-4]:

- recycling is the factor which creates the advanced technologies of sand recovery from the used moulding and core sand,
- recycling reduces the hazards that the foundry industry creates to its environment,
- in foundry industry recycling is the source of material savings,
- recycling may be great in economical importance.

The currently applied reclamation of waste sands has serious economic and ecologic consequences. Its products is the reclaimed sand suitable for green sand preparation as well as for used sand

rebonding. The resulting advantages have on one hand an economical aspect and on the other they allow to reduce the depletion rate of the existing deposits of sands suitable for the foundry practice. However what is more important, they allow to avoid the formation of waste sand dumps detrimental for soil, underground water and air.

2. Specific features of the sand reclamation process

It is a generally known fact that the reclamation is carried out in order to remove the layer of the used binding material from the surfaces of grains and to restore to a maximum possible degree the primary surface characteristics of the grains. So, this is the process related mainly with the phenomena which take place on the surface of the base sand grains, and as such it is inherently connected with the morphology of the grain surface. In this aspect, an analysis of the quality of base materials used in the sand mixture preparation creates a good background for forecasting an effect of these materials and the potential properties of the base sand recovered in

a given process of reclamation. That the main objective of the reclamation process is „cleaning” of the base sand grains, and as Leidel at al. [8] evidenced the removal through attrition of the surface layer on the grains in the process of, e.g., mechanical reclamation is proceeding on a much more intensive scale when the base sand grains are of an angular shape that when they are rounded. If, in the same installation and under the same operating regime, two different - in respect to their shape - grains are subjected to attrition, then the effects of attrition on their surfaces (the loss of material) will be different. Angular grains give, on an average, a double volume of the dust thus reducing the output of a reclamation unit, which in the mechanical process depends on the type of the base sand rather than on the type of the reclamation unit. This more intensive abrasion of the angular grains of silica has also some positive aspects. The new, clean and active surface of silica is exposed, while rounding of the grains makes a reduction in the binder addition content possible. Good et al. [5] have proved that under the comparable conditions of reclamation, the content of SiO₂ examined in the thin surface layer amounted to 91.9% for angular grains and to 77.2% for rounded grains, although the final content of clay binder was in the sand with angular grains almost 3 times higher and the content of binder in both types of the new sand was similar.

The examinations under microscope of the grains after mechanical reclamation reveal a very rough and folded structure on their surface which enables a conclusion that subjecting of these grains to the treatment which consists in rubbing off from them the envelope of binder results in only a partial cleaning of their surface. A part of the binding material remaining in the depressions and cavities on the grain surface is not exposed well enough to be rubbed off, and because of a difficult access it cannot participate in direct contact with other grains. If, due to technological reasons, two different types of silica sand are used, e.g. in foundries casting bronzes (fine-grained sand for preparation of moulding mixture and coarse sand for the cores), then the effective reclamation of a mixed base sand becomes almost impossible.

The foundries using simultaneously silica, zircon and chromite sands (sometimes olivine as well) should be well aware of what will happen and in what way the quality of castings will be affected when these sands are not properly separated. A mixture of different sands may enter into chemical reaction with liquid metal [4,7], e.g. when the silica sand is a base sand in casting of manganese steel, or a change in the alloy solidification rate may happen when the moulding composition is excessively enriched with chromite sand.

3. The principles of proper choice of reclamation processes

The chemical composition of the applied binder determines the choice of the proper reclamation process. If the importance of this factor is not duly appreciated, there is the danger that some of the minerals present in the used sand may change their own chemical composition and structure as a result of the thermal reclamation process which, in turn, will confer to the base sand a higher chemical reactivity in relation to a given binder, thus reducing the sand mixture bench life. The fine particles of the silica dust and of other products are characterised by the specific surface much larger than that of the base sand. Moreover, quite often, they reveal

a strong chemical reactivity. The determination of the admissible ranges of the content in sand of the toxic admixture is not possible without previous determination of its reactivity in respect to various binders which may be used in preparation of the sand with reclaim. This problem is usually neglected in research studies.

Simmons and Leidel [8] have proved that it is fully advisable to carry out the mechanical process of abrasive reclamation only when the reclaim is to be used in preparation of the sand mixture in which the binder will be a phenolic resin added in an amount of 1.26% and hardened with esters, without any special additives. The use in a base composition of the new sand in an amount of 20% and the reclaim in an amount of 80% enables obtaining of the tensile strength equal to 0.607 MPa, i.e. the same as when using the thermally reclaimed base sand. However, in the case of thermal reclamation, the reclaim gives a toxic eluat in water.

In the technology of casting into sand moulds after the casting knocking out used foundry and core sands appear as by-products. This is the main waste of the foundry industry, constituting approximately 80-90% of all foundry wastes. Used sands after being knocked out from moulds, regardless of their further use, should be subjected to treatment processes preparing them for the further application in the casting process, for using outside the foundry industry or just for storing. Possible ways of dealing with used foundry or core sands are schematically presented in Figure 1 [2-4,7,12].

4. Primary reclamation

The reclamation understood as the treatment of used refractory casting materials, allowing the reclamation of at least one of the components of properties similar to the ones of the fresh component and its reuse for the production of moulding and/or core sands, is being done during the final reclamation. This operation, aimed at cleaning sand grains from left-overs of spent binding material coatings and removal of technologically useless matrix fractions, constitutes – together with the primary reclamation – the complex system of the reclamation treatment [2-4,5,7,11,12]. Due to various properties of binding materials applied in casting, achieving an effective liberation of sand grains from coatings of binding materials requires diversified methods of the secondary reclamation, which needs the application of much more intensive techniques than the primary reclamation. The basic classification criterion constitutes the environment in which the reclamation treatment occurs. In this aspect two basic methods – wet and dry – can be distinguished (Figure 2).

5. Secondary mechanical reclamation

Dry mechanical reclamation process is currently the most broadly applied process in the foundry industry. This results from:

- Possibility of sand bases reclamation practically from every spent sands, assuming the limited reclamation degree.
- Possibility of applying relatively simple devices, often of different previous destination (e.g. mixers),
- Lower costs of the process, in comparison with other methods.

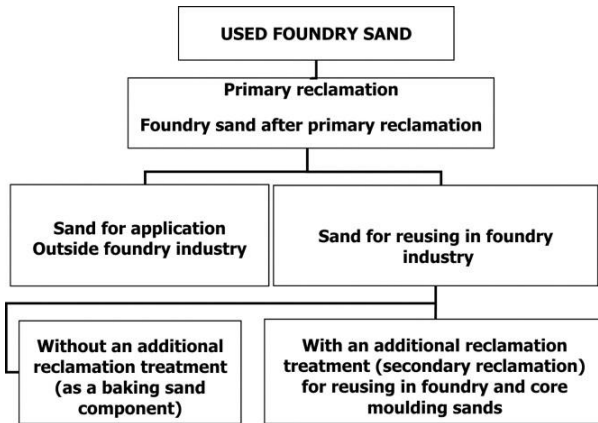


Fig. 1. Ways of management of used foundry sands – prepared on the bases [2-4,7,12]

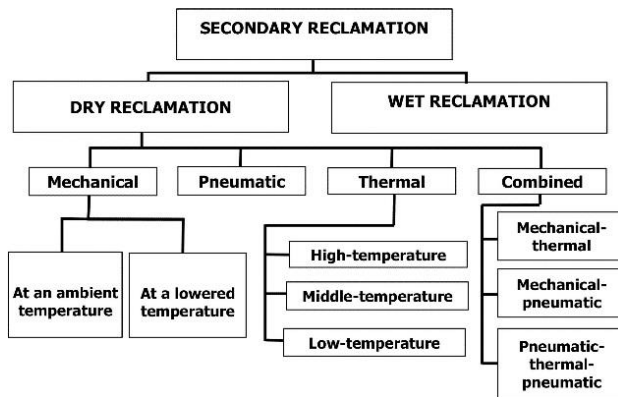


Fig. 2. Schematic presentation of the applied methods of the secondary reclamation [2-4,7,12]

Analysis of the assortment of devices for the dry mechanical reclamation produced by 35 known European and American manufacturers indicates that the interest of reclamation of spent resins bonded sands (25 manufacturers) is the same as of spent sands containing bentonite (24 manufacturers), while sands with water-glass hardened by CO₂ or ester hardeners incite less interest (17 manufacturers). Only 9 producers offer reclamation devices for all three kinds of spent sands.

Regardless of an extremely wide offer and constructional variety of reclamation devices, systems of the dry mechanical reclamation are applying solutions in which liberating of grains from the coatings of binding material is being done by a combination of the following elementary operations: rubbing, abrasion and crushing of binding material coatings from the sand surface [37, 40].

Identification of active forces dominating in known devices for the secondary reclamation process allows to indicate the following methods and techniques of liberating sand grains from coatings of spent binding material:

- intensive mechanical influence of internal and external friction forces, when the process is carried on at various temperatures: ambient, increased and cryogenic,

- violent momentum change of sand grains or of the sand-air jet occurring most often in pneumatic or centrifugal reclaimers,
- thermal influence either individual or combined with an intensive mechanical influence occurring mainly in the fluidisation systems or in thermal-mechanical reclaimers with rotors,

Intensive mechanical influences of internal and external friction forces, when the process is carried on in a water medium.

Low effectiveness of the classic mechanical reclamation of used sands, especially sands with water-glass requires looking for new, more intensive processes to improve effects of the reclamation procedures.

Most of these systems relied on impact of the sand grain in different variations from the ‘hammer’ mill to impact plate and sand upon sand collision. Although binder was removed, the parameters controlling the rate of binder removal and the option to lessen the impact and subsequent damaging of the sand where just not there.

In more recent times a method defined as ‘rotary reclamation’ has been developed, this system relies on a sand-to-sand ‘rubbing’. Primary disintegrate sand enters the chamber where it falls under gravity on a fast rotating disc. The sand when in contact with the disc is immediately thrown to the outside due to centrifugal force. The sand is retained in the peripheral wall of the disc by a retaining ring allowing a tumbling/rubbing action to take place as further sand enters the chamber.

The system works well with ‘hard’ sand such as Furan/Phenolic Acid cured due to the brittle nature of the resin bond. However for other processes such as Alkaline Phenolic and Silicate the rate of binder removal is lessened due to plasticity of binder material and content of water in this hygroscopic materials.

A novel method has been introduced into the reclaimer to overcome above problems, it allows a more intensive scrubbing action, yet at the same time reduce the formation of fines or degrade the sand. This is accomplished by two ceramic discs positioned internally and pushing against the sand to increase significantly the level of sand-to-sand contact (rubbing) and hence the binder removal with full control of intensity of process.

The overview of 2nd stage reclamation unit the ‘USR’ secondary reclaimer is presented on figure 3.

Complete secondary reclamation plant consist following elements:

1. Primary reclaimed sand silos above reclaiming station
2. Vibratory pan feeder – to supply unified stream of sand
3. Magnetic drum separator to remove metal particles (optionally with rare earth magnet if chromite sand is present in sand)
4. USR ceramic rollers unit for actual secondary reclamation process
5. Fluid bed for fines and dust removal.
6. Cooler classifier to reduce sand temperature.



Fig. 3. USR Type reclaimer test station based in Omega Peterborough

In actual reclamation process sand falls into the rotating drum and is pressed against the sides of the drum by centrifugal force. Ceramic squeeze rollers then push against the sand causing the sand grains to rub together. Rubbing efficiency removes the binders that have adhered to the sand.

Reclamation process sand falls into the rotating drum and is pressed against the sides of the drum by centrifugal force (fig. 4). Ceramic squeeze rollers then push against the sand causing the sand grains to rub together. Rubbing efficiency removes the binders that have adhered to the sand (fig 5).

What make this method superior to previous systems are the various parameters that can be altered in order to hone and refine maximum binder removal without degrading the sand.

The following parameters can be altered to suit:

1. Sand feed rate
2. Disc speed
3. Retaining ring size to increase/decrease retention time of the sand
4. Pressure of the ceramic wheels on the sand.

6. Preliminary tests

Preliminary tests were performed in USR reclaimer. The used sand with a alkaline phenolic resin, characterized by loss of ignition of 2.2% and Potassium content of 0.16% was subjected to the two cycles of reclamation. The result of this tests are presented on figure 6.

Basing on the results of the loss of ignition and potassium content in used sand and in reclaims after 1st and 2nd reclamation cycle it can be seen that the best results are achieved after 2nd cycle when the used sand was subjected to reclamation treatment twice.

The view of the sand surface before and after reclamation treatment are presented on figure 7 and 8.

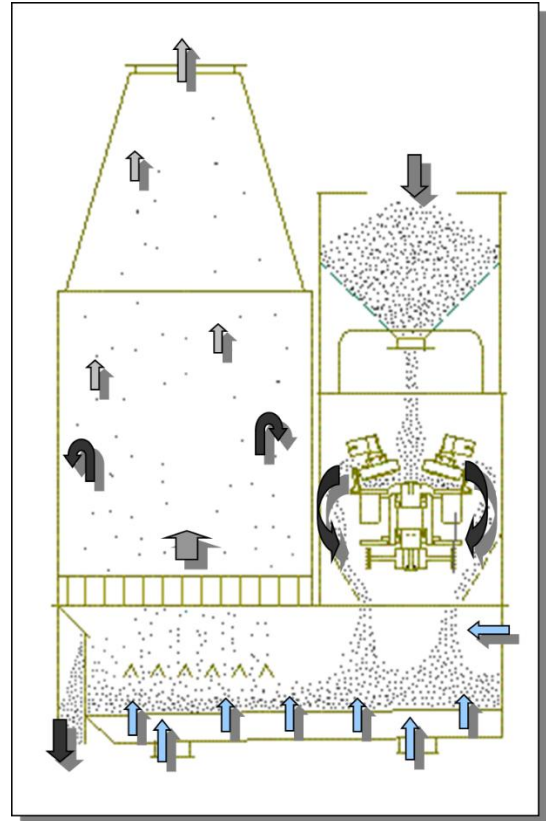
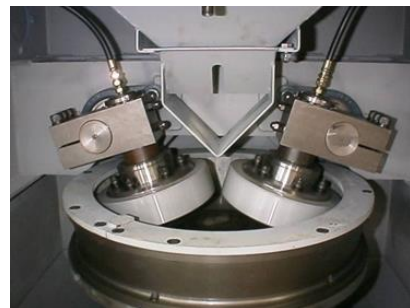


Fig. 4. USR Type reclaimer work diagram

a)



b)

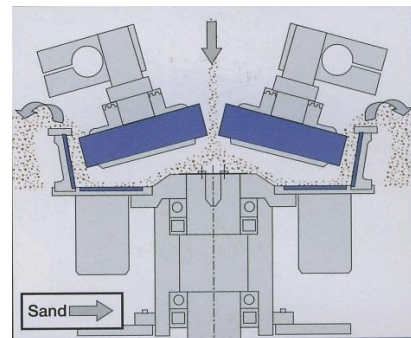


Fig. 5. USR Type reclaimer attrition cell with ceramic intensifying wheels a – general view, b-scheme

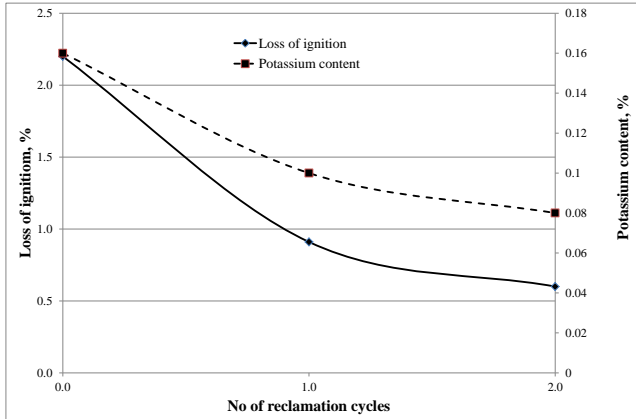


Fig. 6. Loss of ignition and potassium content in reclaim after reclamation in USR reclaimer

The results of the compression strength of the moulding sands prepared with reclaim are presented on figure 9.

The composition of the applied moulding sands was as follows:

- matrix 100 parts by weight,
- binder 2.4 parts by weight,
- activator 0.38 parts by weight.

It can be stated that if the cleaner is reclaim the better are properties of the moulding sand.

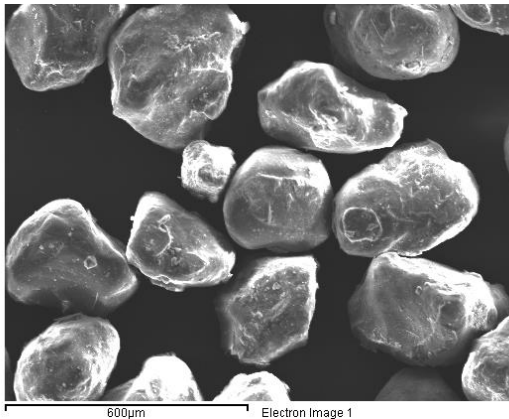


Fig. 7. Used sand prior to secondary attrition

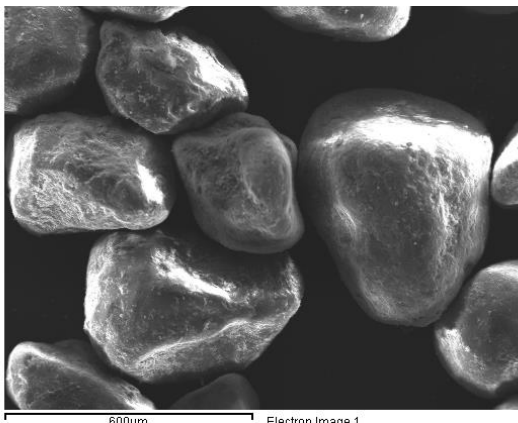


Fig. 8. Used sand after secondary attrition

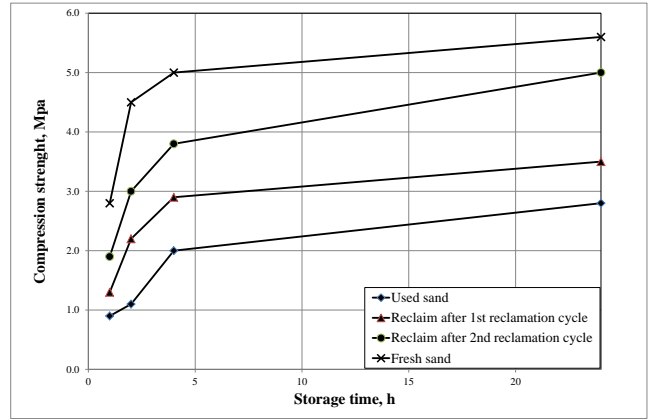


Fig. 9. Compression strength of the moulding sand prepared with reclaim after different reclamation treatment

5. Conclusions

The performed investigations allow to present the following. It won't be possible to achieve 100% sand reclamation (even with thermal) due to losses on the system such as fines removal etc. These normally equate in the range of 4-7%. However it has been proven that foundries normally operating on single stage attrition and with alkaline Phenolic have increased their reclamation levels from 60% to 90% with the associated cost savings that go with this

The use of this type of reclamation offers the foundry an affordable opportunity to maximize the reclamation levels to that approaching thermal yet with a much lower capital investment and subsequent running costs. Also due to the fact that there is no thermal calcination of the binder means that hard to reclaim inorganic or semi-inorganic binder systems can be effectively reclaimed using this method.

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Stan wiedzy w zakresie regeneracji mechanicznej zużytych mas odlewniczych

Streszczenie

Światowa produkcja odlewów, która w roku 2011 osiągnęła poziom prawie 100 mln ton, jest przyczyną powstawania dużej ilości odpadów, głównie zużytych mas formierskich i rdzeniowych. Szacuje się, że produkcja 1 tony odlewów ze stopów żelaza powoduje powstanie około 1 tony odpadów [4], które ze względu na zawartość w nich substancji niebezpiecznych [3,6,10], powinny podlegać procesowi regeneracji - szczególnie dotyczy to zużytych mas formierskich i rdzeniowych. Jedną z przyczyn ograniczonego wprowadzania procesów regeneracji do praktyki odlewniczej jest niepełna wiedza dotycząca tego procesu, umożliwiającą dobór najlepszych dostępnych technik (NDT) jego realizacji, zgodnie z dyrektywami Unii Europejskiej [7].