



Factors influencing selection of effective reclamation techniques and assessment methods of the reclaimed material quality

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Abstract

The paper dealt with such problems of scientific and development research concerning the reclamation of used foundry sands as: management of used sands generated in foundry production, recommendation of selection of effective reclamation techniques and assessment methods of the reclaimed material quality, identification methods and an environmental impact assessment of spent sands from foundry technologies, moulding and core sands of an increased reclamability and a decreased harmfulness for environment.

Keywords: Waste management, Used sand, Reclamation

1. Introduction

Reclamation of used moulding and core sands is defined as a treatment of waste refractory materials allowing to recover at least one component of properties similar to the properties of the new component and to reuse it for casting moulds and core production. Generally applied reclamation procedures comprise practically all used foundry sands with quartz sand grains and some with chromite base. In sands of the so called "new generation" - containing chemically hardened binding materials - the problem of their reclamability is essential. The possibility of easy reclaiming of new moulding sands introduced into foundry industry is a measure of their modernity and industrial attractiveness.

Analysis of data from several countries indicates that from 600 to 1200 kg of fresh sand is used for 1 tonne of ferrous casting alloys. In Poland it is 1000 kg of sand for 1 tonne of castings [28]. Out of this amount approximately 20% of new sand is used for core production and the remaining amount for rebounding moulding sands.

Average charges for disposal of one tonne of moulding sands wastes on dumping yards in Europe are within the range: 12.5 to 61 Eu, which means from 85% to above 400% of purchasing costs of 1 tonne of fresh high-silica sand. The contractual price accepted for such sand in the BREF UE document [13] is 14.56 Eu.

2. Basic sand technologies in Polish foundries

Analysis of data from 20 largest Polish foundries, carried out in 2004 [14] indicates that approximately 50% of waste foundry sands is reclaimed while the rest is directed to dumping grounds. Taking into account all remaining foundries it can be estimated that approximately 250 000 - 350 000 tonnes of waste foundry sands are sent to dumping grounds annually.

Basic kind of a moulding sand is the classic one containing bentonite and coal dust, which is being applied in more than 90% of the

Polish foundries. In cases of producing castings from grey cast iron and nodular cast iron regular classic sands with bentonite are used.

In steel casting facing sands and backing sands containing bentonite are used and also chromite sands on facing layers are applied. Chromite sands most often are applied together with cement, with sands containing water-glass (hardened by organic hardener in the so-called floster technology) or as a mixture of chromite and organic binder (synthetic resins e.g. alkyd, furfuryl, phenolic of low nitrogen content and others). A few large steel foundries apply loose, chemically hardened, sands (floster technology) and self-hardened sands with resins containing furfuryl alcohol (furane sands).

In non-ferrous metals casting technology sands with bentonite and sands with natural binders (semi –strong sands) and also sands with resins as binding material are applied.

Cores are made with practically every kind of available synthetic resins suitable for hardening in the hot-box, cold-box and Croning's processes. The classic Ashland's cold-box technology is applied only in a few larger foundries. Relatively widely applied is a sand technology with strongly basic phenolic resin hardened by CO₂ (Novanol technology and its domestic equivalents).

3. The most effective methods of secondary reclamation

Depending on the applied reclamation method the quality of reclaimed grains can be similar or sometimes even better than the fresh sand quality, which enables foundries to take advantage from all well known values of the reclamation procedure.

The main emphasis of numerous Polish publications [1 - 4, 8 - 9] was placed on the proper selection of kinds and parameters of the reclamation of used sands originated from the most often applied technologies. Research was carried out on experimental test-stands for the mechanical, mechanical-cryogenic and thermal reclamation in different versions of the process.

In foundries producing ferrous alloys castings most often occurs the necessity of reclamation of moulding sands originated from different technologies, which is unfavourable from the point of view of the reclaimed material quality. Mixture of used sands of various chemical character and ways of binding, often not compatible, require a complicated reclamation treatment for obtaining the needed purity of the material. Practice indicates that in many cases – regardless of high costs incurred – the reclaimed sand grains can be used as a substitute of fresh sands in the limited range only.

The secondary reclamation together with the primary reclamation, constitutes the complementary treatment system for cleaning sand grains from the remains of spent binder coatings and from technologically useless fractions of sand bases. A task of more efficient liberating grains of the base requires more aggressive techniques than the ones applied during the primary reclamation.

In Table 1 exemplary systems of mixed sands and the most effective methods of secondary reclamation are listed.

4. Assessment methods of the reclaimed material quality

Assessment of the reclamation effects is a complex problem due to a large number of reclamation methods. Development of a single, universal assessment method of the reclaimed material quality and - indirectly - technological effectiveness of the device, seems not possible and not justified.

Methods listed in Table 2 can be used for an assessment of the reclamation effects of sand grains – intend for making cores. Depending on the requirements for the reclaimed materials only the most important methods can be used.

Certain notions relevant for the comparative assessment of sand susceptibility for the reclamation were defined in several papers [3, 8 10, 14]. The notion „reclaimability” understood as a susceptibility of the given used moulding sand to liberation of sand grains from coatings of binding agents – at the determined way of the reclamation treatment – was introduced by D. Leidel [8]. Recent publications emphasise the need of determining the reclaimability of used sands in dependence of their kind and chemical composition.

In the Polish papers the previous notions: „susceptibility” and „ability” were substituted by „reclaimability” by Lewandowski and other authors [3, 11, 14], in respect to the determined kinds of used sands.

5. Identification methods and an environmental impact assessment of spent sands from foundry technologies

The development of analytical investigation methods gave rise to research linking problems related to assessment the impact of used foundry sands on the natural environment. Papers [11 - 12] present procedures applied to spent sands in the USA. Used sands are classified there according to strictly specified standards concerning toxicity of disposed wastes and leached of hazardous substances [11] (mainly heavy metals). According to the binding standards of EPA (Environmental Protection Agency) used sands are classified for disposal on dumping grounds, characterised by different protection degrees and isolation of stored materials from the surroundings. Similar, very rigorous, standards are in force in Germany. Concentrations of hazardous chemical substances, which might be leaching from particular dumping grounds, decide on the class of those grounds and on the related to it storage costs of waste materials.

The task of systematising regulations and standards concerning the management of wastes and used foundry products - being in force in Poland - was undertaken in paper [5, 13]. Regulations being in force in Poland were compared to the ones in other European Union countries.

Table 1.
Reclamation methods recommended for various systems of mixed sands [12]

Kind of sand	Reclamation method	Dominating elements of reclamation	Usage of reclaimed material	Initial conditions	Minimal yield (t/h)
Mixture of sands containing organic binders	Mechanical	Pneumatic abrasion, Centrifugal abrasion, Impact,	Sand substitute for core production (participation of the reclaimed material: 50-100%)	Sole mechanical reclamation only when coatings of the binding material became brittle due to their partial overheating,	0.75
	Thermal	Turbulent bed (jet), Fluidised bed, Impulse mixed bed, Rotary furnace,		Periodical checking P ₂ O ₅ , PbO and other harmful elements content in sands.	
	Combined	Abrasion by rotor in a heated or fluidised bed, Impulse mixed heated bed,		Establishing the required purity degree of the reclaimed material. The achieved quality should be similar to that of the fresh sand. Reuse of dusts from thermal reclamation.	
Mixture of sands containing bentonite and cores from sands containing organic binders	Mechanical	Pneumatic abrasion, Centrifugal abrasion with and without impacts, Abrasion by rotor,	Sand substitute for rebounding the sand in the circulation	Preliminary drying of sands to 150 - 200°C required, preliminary and final dedusting.	0.75
	Combined	Abrasion by rotor in a heated or fluidised bed, Impulse mixed heated bed.	Sand substitute for core production (participation of the reclaimed material up to 50%)	Necessity of removal of active bentonite. Periodical checking the oölitisation degree. Reuse of dusts.	

Table 2
Proposed assessment methods of the reclaimed material from various kinds of used sands. The order of the diminishing hierarchy of importance is given in brackets (1-5) [3, 10, 14]

Recommended assessment method	Kind of spent moulding sand				
	Sand with bentonite and coal dust	Sand with water-glass hardened by CO ₂	Sand with water-glass hardened by esters	Sand with cement	Sand with synthetic resins
Strength of sand containing the reclaimed material	(1)	(2)	(2)	(1)	(2)
Binding agent content	(2)	(-)	(-)	(2)	(-)
Binding agent activity	(3)	(-)	(-)	(-)	(-)
Ignition loss (LOI)	(3)	(-)	(-)	(-)	(1)
Sieve analysis	(4)	(3)	(3)	(4)	(4)
N ₂ O content	(-)	(1)	(1)	(-)	(-)
Surface morphology (microscope)	(5)	(5)	(4)	(5)	(5)
Chemical reaction of sand grains (pH, Z _K)	(-)	(4)	(5)	(3)	(3)

6. Moulding and core sands of an increased reclamability and a decreased harmfulness for environment

Much attention has been given in recent years to preventing the generation of large amounts of wastes. On account of that, the optimisation of utilised binding agents, aimed at decreasing their participation in moulding and core sands, is being done together with looking for substitutes or new additives making binding agents more “environmentally friendly”.

Development directions of moulding and core sands containing inorganic binding agents, in respect of meeting the environment protection requirements are discussed in paper [5, 11]. It was stated, that further work on this topic should be pointed towards improving known inorganic binders (on sodium silicate or phosphate basis) or towards developing completely new binders, not hitherto applied in the foundry engineering.

Part of the research concentrates [6, 7] on searching for new additives to improve parameters of sands containing water-glass, which are relatively cheap and ecologically neutral ways of producing moulding sands. Perspective investigations should concern the improvement of their knocking out properties and reclaimability.

An ideal solution, from the point of view of the reclaimability, would be the creation of the self-reclaiming binding agent. It means such material, in which after filling the casting mould with liquid metal and a solidification of casting the self-degradation of binding agents – under the influence of a high temperature – and the liberation of sand grains will occur. Such used sands would later require only a separation of self-destruction products from sand grains base.

7. Conclusions.

Further significant progress in the reclamation is related to several factors, which should be considered. The most important are:

- basic research, supportive to searching for the sands, which would be the reclamation friendly and neutral for the natural environment,
- striving to achieve the compatibility of mould and core technologies substantiated by the possibility of the common reclamation of spent sands in the system of mixed sands and allowing to utilise the specialist reclaimers of much simpler construction instead of very costly universal ones,
- application of the proper material management in the range of moulding and core sands leading to diminishing the number of sands being used in the foundry,
- optimisation of the existing reclamation methods by introduction of improvements and new solutions to the process, especially by adapting reclaimers to the binding mechanism characteristic for the given binding agent, in order to increase quality and yield of the reclaimed material.

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References

- [1] Dańko J., Dańko R., Holtzer M.: Reclamation of used sands in foundry production. *Metallurgy*, vol. 42, br. 3, Zagreb, (July/ September) 2003, pp. 173 – 178.
- [2] Dańko J., Dańko R.: Low temperature reclamation treatment of water-glass bonded sands. *Archives of Foundry*. 2004, vol. 4, No. 11, pp.102-107. (in Polish).
- [3] Dańko R.: Theoretical and technical backgrounds of optimum choice of the dry reclamation process for used moulding sands. PH. D. Thesis, Department of Foundry Engineering, AGH, Kraków 2006.
- [4] Dańko J., Holzer M., Kargulewicz I., Lewandowski J. L., Zapalski A.: Możliwość wykorzystania metody określania zapotrzebowania na kwas (Zk) do oceny jakości regeneratu z mas z cementem. *Acta Metallurgica Slovaca*. nr 4, Special issue 2/1998, pp. 136-140.
- [5] Holzer M.: Trends in sand molds and cores with inorganic binder to reduce harmful impact an environment. *Archives of Foundry*, 2002, vol. 2, No 3, 2002, pp. 50-56. (in Polish)
- [6] Jelinek P.: *Pojivove soustavy slevarenskych formovačich smesi*, ISBN 80-239-2188-6, 2004.
- [7] Johnson J.A. Lister D.R.: Recent developments in the sodium silicate (water glass) process including high level sand reclamation. International Conference “The reclamation of used foundry sand” (Czech Republic), 16-17. 04. 2002, pp. 53 – 72.
- [8] Leidel D.S.: The influence of sand and binders on reclaimability. *Foundry Trade Journal*, Issue 3497, v. 168, 1994, pp. 384-387.
- [9] Łucarz M., Dańko J., Dańko R.: Influence of non-organic impurities on sand properties prepared on reclaimed sand basis; *Acta Metallurgica Slovaca*, Košice, Ročník 8, t. (1/2), No 2, 2002, pp. 87 – 92.
- [10] „Badania zmierzające do optymalizacji parametrów regeneracji różnych rodzajów masy w regeneratorsze odśrodkowym o zmniejszonym efekcie udarowym oraz do optymalizacji konstrukcji regeneratorów tego typu”. Research Project KBN, No 7T08B 004 14. Department of Foundry Engineering, AGH, Kraków 1998-1999.
- [11] Holtzer M., Kargulewicz I. Leaching of Cd, Cu, Pb, and Zn from used sands as a criterion for estimate harmfulness. III International Conference “Modern Foundry Technologies – Environmental Protection, Kraków, 7-9 September 2000, pp. 87-92.
- [12] Integrated Pollution and Control. Reference Document on the Best Available Techniques in the Smitheries and Foundries Industry. European Commission, July 2004.
- [13] Lewandowski J.L., Dańko J., Dańko. R.: Selection of waste sand at the Odlewnie Polskie SA Foundry in Starachowice. *Przegląd Odlewnictwa*, 2004, Vol. 54, No 2, pp. 120-126.
- [14] Holtzer M.: Problems of environment protection in the foundry industry after Poland's joining to European Union. *Przegląd Odlewnictwa*, 2004, Vol. 54, No 4, pp. 314-321.
- [15] Dańko J., Holzer M., Dańko R.: Reclamation of Used Foundry Sands – Study of Scientific Problems and Development Research, rozdział monograficzny w książce “Research in Polish Metallurgy at the Beginning of XXI Century. Committee of Metallurgy of the Polish Academy of Sciences, ISBN 83-910159-3-9, Kraków 2006, pp. 219-237.