Environment Protection Engineering

Vol. 25 1999 No. 3

ECKHART RICHTER*, BERNHARD GEMENDE*,
HERALT SCHÖNE*

TECHNOLOGIES FOR REUSE AND UTILIZATION OF USED FOUNDRY SANDS

There are three general possibilities of handling used foundry sands: the reuse for mould and core production, the utilization as raw material in building industry and the simple disposal in landfills. In this report, the technologies for reuse of used foundry sands and the possibilities of utilization of such materials in other industries are discussed. Both internal and external recycling possibilities and requirements are presented with their technologies. Besides the established regeneration methods, a chemical-biological regeneration approach to resin-bound foundry sands is discussed on the basis of a literature survey and a theoretical feasibility study.

1. INTRODUCTION

In foundries, sand is used to make moulds and cores, which are needed for the casting production. This kind of production is the investment casting with the so-called "lost moulds", because the mould has to be destroyed, while the raw casting is being removed from the moulding box [1].

The foundry sands, i.e. moulding and core sands, consist of three components [2]:

- the sand itself (silica sand is most frequently applied),
- a binding agent,
- additional substances like slurry, which is used to obtain smoother surfaces.

The binding agents pose some technological problems in internal reuse and also in external utilization. In order to demonstrate and evaluate these problems, the binders have to be subdivided into:

1. Binders with physical binding effect.
2. Binders with chemical binding effect.

Bentonite and clay belong to the first type of binders, while all chemical binders – to the second one. The capability of bentonite and clay to bind residual material is of

* Technische Universität Dresden, Institut für Verfahrenstechnik und Umwelttechnik, Mommsenstr. 13, D-01062 Dresden, Germany.

purely physical character, hence they can be regenerated after the casting process by damping the used bentonite or clay-bound foundry sand. Chemical binders (e.g. furan resins, water glass) irreversibly lose their binding capability after each casting process. This fact can be explained by the chemistry of these binding agents: the binder components form three-dimensional interlaced macromolecules in special chemical reactions, e.g. polyaddition and polycondensation. These cross-linked macromolecules coat and bond the sand grains. During the casting process the macromolecule chains are partly cracked and destroyed by thermal and mechanical stresses. Thermal stress is caused by high temperature of liquid metal (e.g. for aluminium up to 800 °C); mechanical stress is being generated, while the raw casting is taken out the moulding box. When the used foundry sand is recycled, fresh binder components have to be added in order to create the binding polymers again [1], [2].

The spent chemical binders are considered to be troublesome agents in the recycling of used foundry sands. Some of them have got a pollutant potential, which has to be considered for utilization in the building industry.

Though there is no negative environmental effect in the bentonite and clay recycling, those binders may cause technological problems in external recycling of used foundry sands (reduced compressive strength in concrete with the addition of bentonite sand) [7].

2. INTERNAL RECYCLING OF USED FOUNDRY SANDS – PROCESSES AND APPLIED APPARATUSES

2.1. COLD-MECHANICAL REGENERATION PROCESS

The principle of this regeneration process is as follows [3], [4]: in order to remove the binding agents from the foundry sand they are pulverised by rubbing and grinding. Thus two mechanisms are involved: on the one hand, the binder-coated sand grains are rubbed against each other and on the other hand, they are rubbed on special parts of the apparatus. As a result the binder is partly rubbed off and pulverized. The generated dust has to be exhausted. In addition an unwanted secondary effect occurs: the abrasion of sand grains, so they become slightly smaller and smoother. This is a kind of downcycling, but it cannot be prevented using this regeneration method (see figure 1).

It can be said that a sufficient embrittlement of binding agents after casting process is necessary for efficient and successful application of cold-mechanical and mechanical-pneumatic regeneration. Therefore these regeneration methods should be applied only to used foundry sands, which have been exposed to thermal stress. At high temperatures the cores are broken and unused moulding sands are not appropriate for a mechanical regeneration.

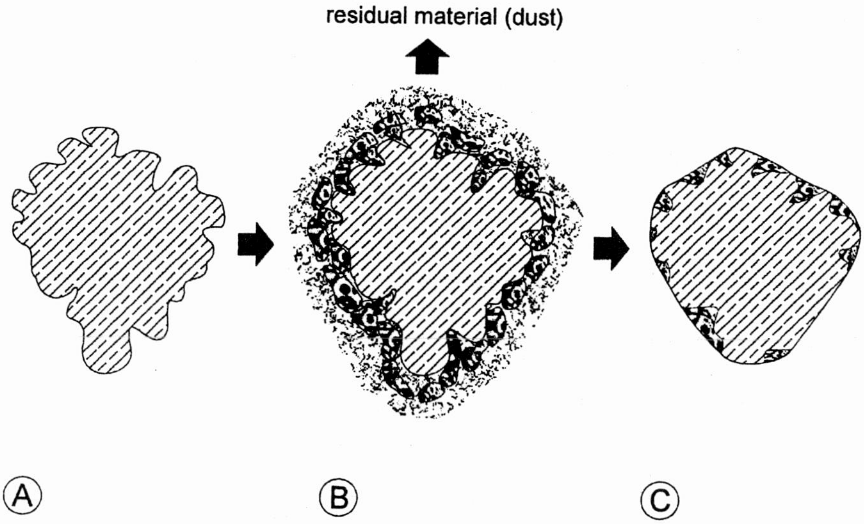

Fig. 1. Sand grain before and after mechanical regeneration
A – grain of fresh sand, B – grain of used foundry sand, C – grain of regenerated sand

The following apparatuses and machines are applied in cold-mechanical regeneration:

• Horizontal rotating grinding roll with a paddle wheel which rotates outside (see figure 2). The paddle wheel transports the treated used foundry sand on a grinding roll, where the binder coatings are ground up. The generated dust is exhausted upwards, the regenerated sand drops downwards.

• Scrubbing drum. In a scrubbing drum, both resin-bound and bentonite-bound sand can be regenerated. In a drum rotating horizontally, the used foundry sand is transported upwards and forced by deflectors against a counter-rotating hammer.

• Centrifugal wheel sand cleaner. By means of a rotor (centrifugal wheel) the sand, fed axially from the top, is accelerated and bounced against the pockets of a stator ring filled with sand. The binder coatings and residues are detached from the sand due to the friction generated between the grains. The rotational speed of the rotor is adjusted to such a level that the sand grains are mainly stressed due to friction and not due to collisions.

2.2. MECHANICAL-PNEUMATIC REGENERATION PROCESS

The principle is quite similar to the cold-mechanical regeneration method [3]: in order to remove the binding agents from foundry sand they are pulverised by bouncing and rubbing. This process is based on two mechanisms: firstly the binder-coated sand grains bounce against special parts of the apparatus, and secondly they are rubbed against each other. Thereby the embrittled binder-coatings are struck off and ground. In addition, they are partly pulverised. The generated dust has to be exhausted. This method of sand cleaning is also associated with the abrasion of sand grains.

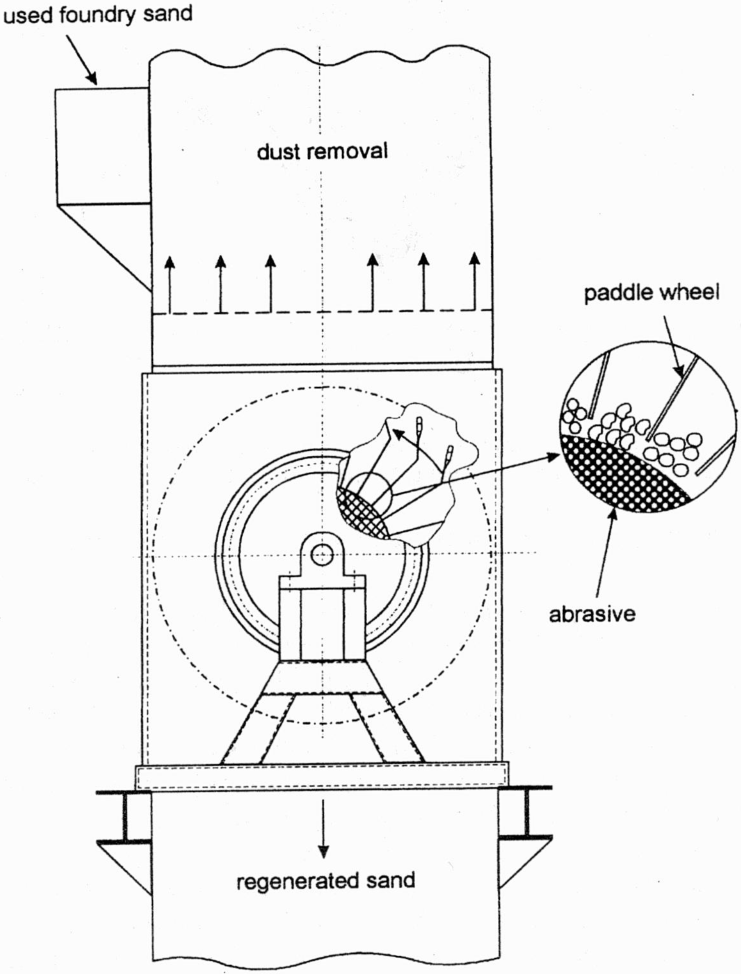

Fig. 2. Apparatus for cold-mechanical regeneration of foundry sand (rotating grinding roll) [2]

The process of mechanical-pneumatic regeneration can be described generally as follows: the used foundry sand is fluidized by compressed air and then it is accelerated in order to bounce at high velocity against one or more barriers. The compressed air nozzles, the acceleration section and the barrier(s) are constructed and shaped differently.

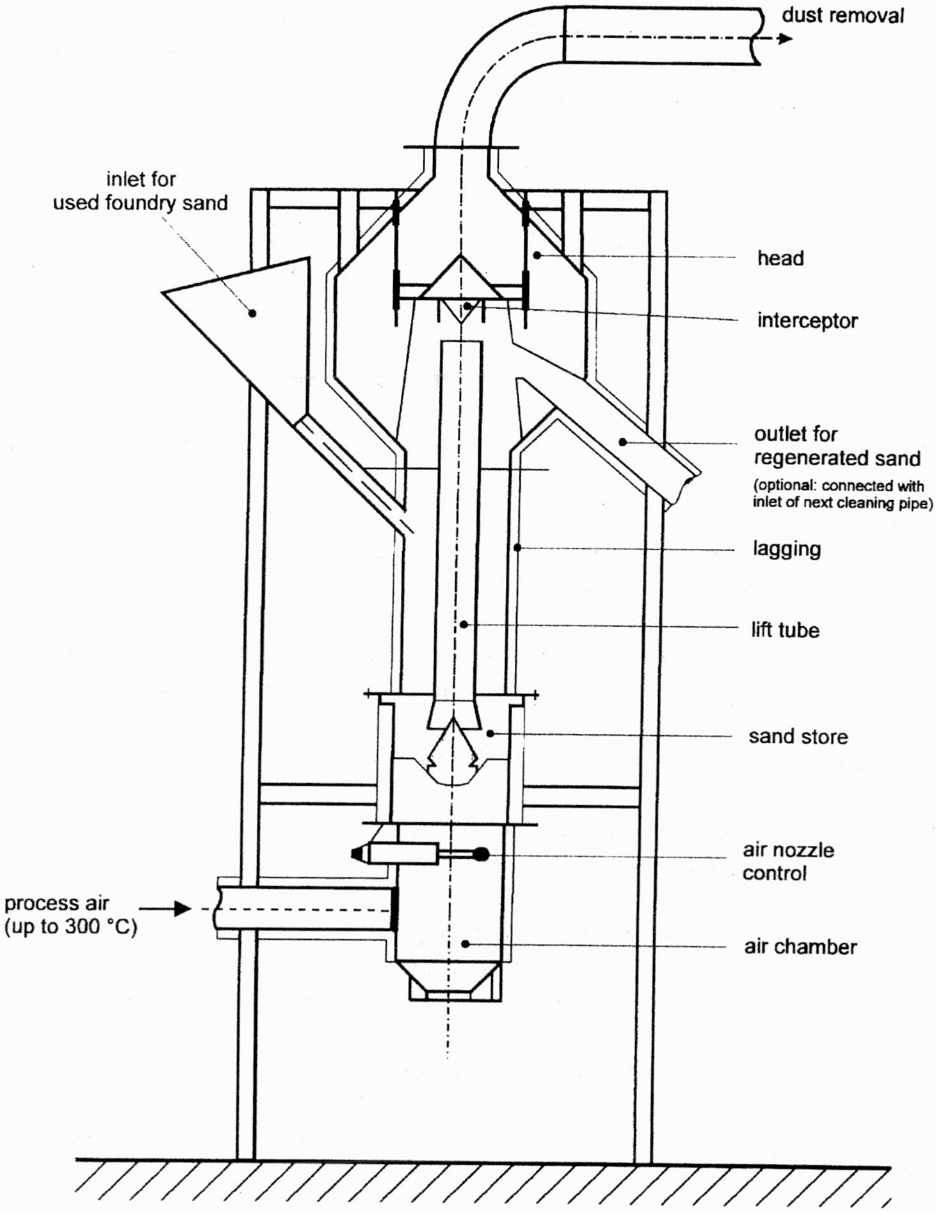

Fig. 3. Apparatus for pneumatic regeneration
of foundry sand (pneumatic cleaning pipe) [3]

The following apparatuses and machines are applied in order to realize the mechanical-pneumatic regeneration of used foundry sands:

• Pneumatic cleaning pipe with bouncing bell (see figure 3).

• Bouncing jet mill. From two compressed-air nozzles, located on the opposite sides and directed to each other, the sand-grain jets are blown down horizontally towards each other.

• Lift tube with cylindrically shaped separator for regeneration of dried and pre-cleaned used foundry sands.

• Fluidized bed cleaner. The used foundry sand is mixed with air and fluidized. In the fluidized bed, metal rods are moved. The cleaning is accomplished by grinding up the binder coatings.

2.3. THERMAL REGENERATION PROCESS

This regeneration process is based on the incineration of binding agents [3]–[5]. The sand itself is not destroyed, it has to be cooled down after thermal regeneration.

Generally, this cleaning method is suitable for resin-bound foundry sands. These sands can almost perfectly be cleaned, because the organic binders are totally burnt. So the regenerated sands can have a quality as fresh sand. The thermal treatment of resin-bound sands requires an incineration temperature of about 500 °C. But in this case, an afterburning of the generated gas mixture with high organic content is necessary.

For bentonite-bound foundry sands the thermal regeneration is disadvantageous because [4]:

• High temperatures are required (up to 900 °C).

• At these high temperatures the active bentonite is changed into hardened bentonite or mullite. These substances adhere to sand grains very strongly and therefore their removal is very difficult. Besides, it is possible to recycle the active bentonite and graphite as it is done in mechanical regeneration.

The thermal regeneration process has the following technological advantages compared to the mechanical regeneration method [4], [5]:

• a higher cleaning efficiency (the so-called "degree of regeneration") can be reached, because binding agents, which are situated in grooves, are removed, too;

• at similar degrees of regeneration there is less abrasion of sand grains than in mechanical regeneration.

The following apparatuses are applied in order to realize the thermal regeneration of used foundry sands:

• fluidized bed furnace (different constructions, heated with natural gas or electrically; see figure 4),

• cylindrical, rotary kiln,

• shaft furnace.

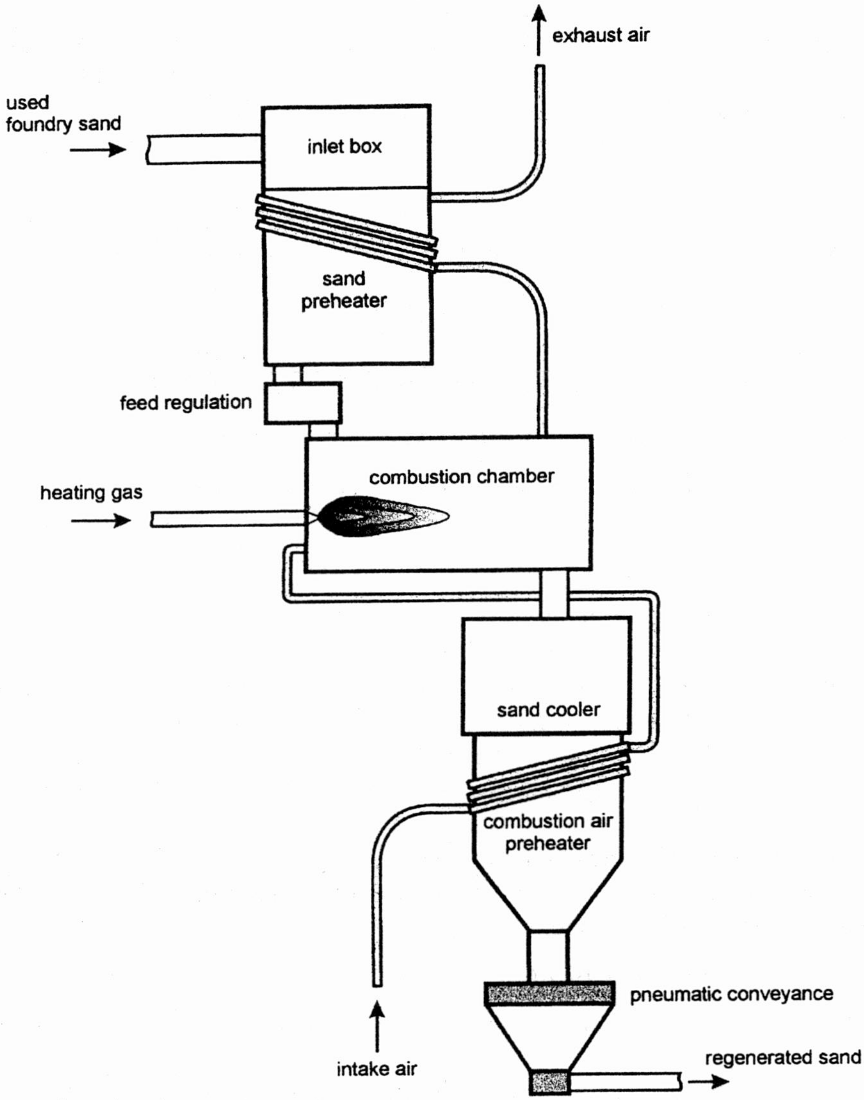

Fig. 4. Plant for thermal regeneration of foundry sand
(fluidized bed furnace) [4]

3. EXTERNAL RECYCLING OF USED FOUNDRY SANDS

The external recycling of used foundry sands is equivalent of the utilization of these materials in such industries, where different kinds of sand are applied [6], [7],

[9], [10]. So the used foundry sands are mainly utilized in building industry. The other mineral materials can partly be substituted. If used foundry sand shall be applied as substitute material for fresh sand, binders have to be considered as troublesome agents with regard to both technological and ecological aspects. That is why the possibilities for utilization of foundry sands strongly depend on the kind of binding agent. In many cases, the amount of contained binder must be reduced because of technological and/or ecological requirements. They have to be removed to the levels prescribed by legislative limits (e.g. in Germany by the LAGA guideline for the reuse of mineral residues [8]).

The removal of binders to the required level is carried out either before or during their utilization. The following demands have to be considered if used foundry sands shall be utilized in the mentioned branches of building industry [7,] [10]:

Utilization in earthworks and road construction

- The suitability of used foundry sands has to be proved by eluate and solid analyses.
- Maximum permissible values, in Germany prescribed by LAGA [8], must be kept.

Utilization as raw material for cement production

- It is possible to utilize the used foundry sands, which consist of silica sand and are not treated with the binding method using water glass and CO_2.
- Used foundry sands are appropriate to be substituted for pit and river sands.
- If resin-bound sands are used, the exhaust flue gas with a high content of organic substances is generated because of the slow temperature rise (from 100 up to 850 °C) during the process. It should be burnt in an afterburner! This can be realized through:

  direct feed of used foundry sand to kiln,

  separated thermal pre-treatment of used foundry sand in a cylindrical rotary kiln using hot exhaust gas of the cement kiln.

Utilization as raw material in ceramic production

- Substitution of river sands, which are applied as amendment up to 20 mass-%, is possible.
- Tunnel kilns have to be equipped with the facilities allowing the exhaust gas re-circulation in order to burn organic content.
- Technological requirements are:

  maximum particle size: 1 mm,

  used foundry sand has to be free of metal parts.

Utilization as additive material in concrete production

- Used foundry sands substitute for fine-grain material, which must be added to the concrete mixture.

• Addition of resin-bound sands is possible without negatively affecting the concrete quality (measured as compressive strength).

• Addition of bentonite-bound sand is questionable, because its negative influence on compressive strength has been proved.

Utilization as additive material for asphalt production

• Used foundry sands substitute for fine-grain material, which must be added to the asphalt mixture.

• In a mixture, the ratio of fresh sand to used foundry sand should be about 1 : 1 if we want to improve the grading curve.

4. DISCUSSION OF CHEMICAL-BIOLOGICAL TREATMENT OF RESIN-BOUND FOUNDRY SANDS

The study was made to investigate the possibility and feasibility of a chemical-biological cleaning/regeneration process of furan-resin bound foundry sands [11]. The main objective of this study was to check whether it is possible to remove alternatively furan binder residues by means of chemical and/or biological treatment. The study was based mainly on literature and discussions with experts. Potential advantages would be the reduction in the energy consumption compared to the thermal regeneration processes and the reduction in mechanical stress exerted on the sand grains compared to mechanical treatment inducing reduction of sand grain size and roughness. Thus, a better recyclability and an improved reuse could potentially be achieved.

Especially a two-step process was carried out for the furan resin removal.

(A) In a first step, the furan resin polymers should be destroyed into smaller biologically degradable molecule segments.

(B) A subsequent biological degradation of the smaller segments should follow the destruction step. Because of the properties and stability of the furan resin, the first destruction step has also to be accomplished by two subsequent treatment actions.

(A1) The furan resin is dissolved by a suitable solvent (e.g. tetrahydrofuran, dibenzofuran).

(A2) The furan resin is broken by an acid (ring cleavage at the oxygen position).

Problems have mainly been encountered in the following issues:

Characteristics of troublesome agents in the foundry sands as a multicomponent mixture of organic and inorganic compounds. Foundry sand contains both organically and inorganically bound carbon. The binder polymers are thermally destructed at high moulding temperatures by pyrolysis. Thereby they are transformed into coke, i.e. into inorganic carbon. However, that inorganic carbon cannot be degraded by microorganisms. A very large inorganic carbon portion may render the chemical-biological method inefficient and obsolete. Thus, for such an approach the mass ratio of organically and inorganically bound carbon is important. For an intrinsic investigation, this ratio has to be determined by certain chemical analyses (thermogravimetric analysis, pyrolytic chromatography, possibly after sequenced extraction methods with different selective solvents [12]).

A further problem will stem from the bioavailability of the binder by suitable solvents and splitting agents and the finding of appropriate microorganisms, which are able to metabolize the binder in a mixture of (possibly biotoxic) solvents and splitting agents.

REFERENCES

[1] Fachausschuß Fertigungsverfahren und -einrichtungen im VDG, *Gießereitechnik 1993/94: Form- und Kernherstellung – Verbreitung und Trends*, Giesserei, (1994), 81, No. 11, p. 324 ff.

[2] RÖTH G., *Untersuchungen zur Verträglichkeit regenerierter organisch und anorganisch gebundener Produktionssande mit verschiedenen Kunstharzbindersystemen sowie zur Regenerierbarkeit von Gießereireststoffen*, Düsseldorf, June 1997.

[3] GÄRTNER-KAUFMANN C., *GIFA 94: Anlagen zur Regenerierung von Mono- und Mischsandsystemen*, Giesserei, (1994), 81, No. 18, p. 637 ff.

[4] WELLER E., *Möglichkeiten und Grenzen bei der Regenerierung von Gießereialtsanden*, Giesserei, (1989), 76, No. 10/11, p. 350 ff.

[5] FRANKE R., *Thermische Regenerierung von Gießereirestsanden und Inertisierung von Stäuben*, Giesserei, (1994), 81, No. 4, p. 85 ff.

[6] BRADKE H.-J., HANSONIS-JOULEH H., *Untersuchungen zur umweltrelevanten Beurteilung von Formstoffen für die Form- und Kernherstellung in Gießereien: Teil III der Untersuchungen Deponieverhalten und Verwertung von Gießereisanden*, investigation by Institut für gewerbliche Wasserwirtschaft und Luftreinhaltung e.V. (IWL), ordered by Industrieverband Gießerei-Chemie e.V. (IVG), Köln 1993.

[7] Materialien zur Abfallwirtschaft 2/97, *Stofffflußwirtschaft der sächsischen Gießereiindustrie. Erfassung und Bewertung bei der Gußteilfertigung*, research report by Technical University of Freiberg and SLG mbH, ordered by Sächsisches Staatsministerium für Umwelt und Landesentwicklung.

[8] Länderarbeitsgemeinschaft Abfall (LAGA), *Anforderungen an die stoffliche Verwertung von mineralischen Reststoffen/Abfällen – Technische Regeln*, March 1994.

[9] REGAN R.W. Sr., PALETSKI W., MASSELL R., *Environmental Issues: Beneficial Use of Spent Foundry Sand from Multiple Sources*, Proceedings of the 48th Industrial Waste Conference, Purdue University, May 1993.

[10] REGAN, R.W. Sr., BATCHEV E.S., VOIGT R.C., *Beneficial Use of Foundry Excess Systems Sands for Construction Products*, Proceedings of the 52nd Industrial Waste Conference, Purdue University, May 1997.

[11] RICHTER E., *Verwertungsmöglichkeiten für die Gießereirestsande einer Aluminiumgießerei, einschließlich eines Ansatzes für die chemisch-biologische Behandlung von organisch gebundenen Restsanden*, study, Technical University of Dresden, Institute of Process and Environmental Engineering, September 1998.

[12] Personal information by Mr. Vogts, Institute of Polymer Research, Dresden, 14.7.1998.

TECHNOLOGIE UMOŻLIWIAJĄCE RECYKLING I UTYLIZACJĘ ZUŻYTYCH MAS FORMIERSKICH

Istnieją trzy możliwości zagospodarowania zużytych mas formierskich: recykling w technologii produkcji form i rdzeni odlewniczych, wykorzystanie w budownictwie lub bezpośrednie składowanie na

wysypiskach. W przedstawionej pracy omówiono możliwość recyklingu i utylizacji zużytych mas formierskich w różnych dziedzinach przemysłu, a także warunki zewnętrznego i wewnętrznego recyklingu oraz wymagania stawiane poszczególnym technologiom. Oprócz znanych metod regeneracyjnych omówiono na podstawie literatury chemiczno-biologiczną metodę regeneracji żywicznych mas formierskich.