

# Primary Used Sand Reclamation Process Efficiency

M. Skrzyński \*, R. Dańko

AGH – University of Science and Technology, Faculty of Foundry Engineering  
 Reymonta 23 Str., 30-059 Kraków, Poland

\* Corresponding author. E-mail address: mskrzyns@agh.edu.pl

Received 23.03.2018; accepted in revised form 31.08.2018

## Abstract

The results of the efficiency of the primary reclamation process as well as the influence of the used sand temperature and other process parameters on it are presented in this paper. A separate stand realized on a reduced scale was built, which is an analogous process of the primary reclamation treatment of spent foundry sands. The used sands were introduced to the crushing process in an agglomerated form in the way typically used in industrial devices. The primary reclamation process was realized on a set of four horizontal sieves with decreasing mesh clearances while maintaining their geometrical dimensions applied in the Regmas industrial device. The model system consists of a vibratory drive mounted on the table, allowing us to control the supply frequency of the vibratory motors within a range of 40-60 Hz as well as the computer system for measuring the vibration parameters and drive power. The used sand on the quartz matrix with the KALTHARZ U404 resin and 100T3 hardener was used in our investigations. The used sand was prepared under the following conditions: cubic-shaped elements made of the applied furan sand was compacted by vibrations then hardened and subjected to heating under controlled conditions (as a “simulation” of the overheating process taking place in the mold after pouring). Time functions of the crushing and sieving process in dependence of the overheating degree of the reference sand samples (100°, 200°, and 300°C) were investigated at various table vibration frequencies and feed loads of the sieve set. The relative index of the crushing ability was determined.

**Keywords:** Spent foundry sands, Mechanical vibratory reclamation, Environmental protection

## 1. Introduction

As it results from the statistical analysis [1, 2], the main wastes of foundry processes are the spent foundry sands. In 2014, their amount constituted 80% of all wastes (fig.1.). The necessity for environmental protection as well as economic reasons cause that foundry plants are more and more often using processes that allow for the reclamation of quartz matrices from the spent sands (mostly by mechanical reclamation methods).

Regardless of the reclamation method chosen, the spent sands are subject to the treatment performed (most often) in the following sequence of operations [3-6]:

- Preliminary separation of mechanical (mainly metallic) contaminations,
- Breaking up caked sands after their knocking-out,
- Sieving of sands and separating grain size ranges for reclamation,
- Repeating separation of metal contaminants,
- Secondary reclamation, liberating the sand grains from the leftovers of the spent binding materials by using ways that allow us to remove binding material coatings from the grain surfaces,
- Removing undesirable reclamation products by dedusting sand grains,

- Separating sand grains of determined sizes and uniformities (classified according to grain size).

The treatment of spent sands based on applying the first four operations is called the primary reclamation process [3]. Its full realization is necessary to perform the further processes of removing the binding material coatings. At that stage, the grains are not yet satisfactorily separated from the binding materials, as this process rather allows for the separation of large grain conglomerates (in effect, reducing the amount of reclaimed material) that can be added to fresh sands for casting production.

Together with the primary reclamation, the secondary 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. The task of more efficiently liberating grains from the base requires more aggressive techniques than the ones applied during the primary reclamation.

In the investigations concerning the devices for spent sand reclamation as well as the process of matrix liberation from used binding materials performed up to now, the focus was placed on the final reclamation result while the primary reclamation related to the crushing of the used sand to an assumed diameter remains omitted and underestimated [7–14]. As it can be assumed, this has been due to the fact that most of the reclamation devices realize both primary and secondary reclamation. Nowadays, the reclamation process is often realized in two separated systems dedicated to primary and secondary reclamation. Obtaining information concerning the influence of both processes on the final effect is important for the development of devices for matrix reclamation as well as for process improvement, in order to achieve a reclamation of a quality similar to that of fresh sands.

## 2. Aim of investigations

During the casting process, molding sand is overheated due to the heat transfer phenomena. Heat is transferred from the casted metal to the mold prepared with molding sand. Molding sand is overheated to various temperatures depending of the distance from the casted element. When a mold is prepared from organic sand, overheating of the sand influences the reclaimability of the sand.

In the presented research, overheating of the molding sand phenomena was simulated by the heating of molding sand samples to the assumed temperatures.

The determination of the influence of the used sand temperature, duration of the crushing process, upper sieve loading conditions, and vibratory engine supply frequency on the crushing and sieving processes realized with the model vibratory stand was the aim of our investigations.

A separate stand realized on a reduced scale was built, which is an analogous process of the primary reclamation treatment of spent foundry sands. The sands were introduced in an agglomerated form, which occurs in the industrial device Regmas [2, 10]

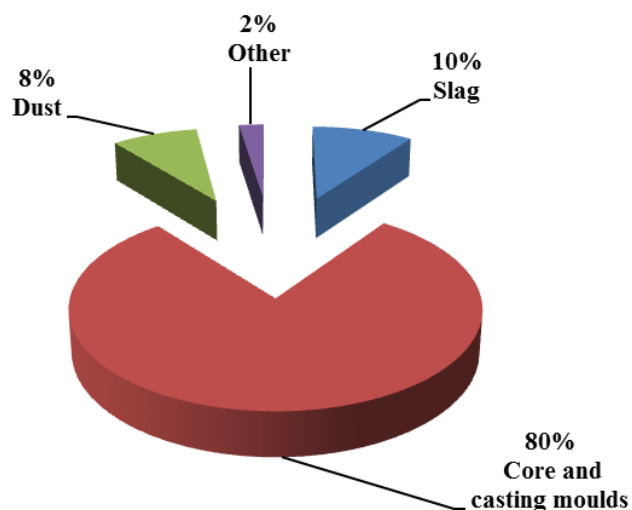


Fig. 1. Amounts of waste from foundry processes during the year 2014 (in percentages) [1-2]

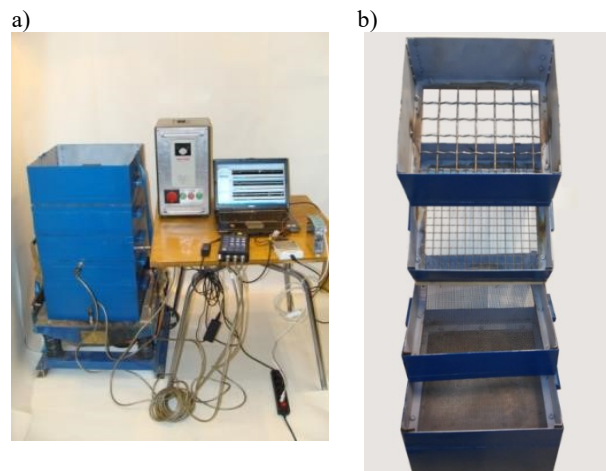


Fig. 2 a) Computer measuring system on research stand; b) Set of model sieves [2]

The model system mounted on the table has a vibratory drive, allowing us to control the vibration frequency within a range of 40-60 Hz, as well as the system for measuring the vibration parameters and drive power. The main components of the stand are presented in Figure 2: a – a computer measuring system for determining the vibration parameters; b – a set of model sieves.

The primary reclamation function is realized in the set of four horizontal sieves of decreasing mesh clearances while maintaining the same geometrical dimensions as applied in the Regmas device [3, 8-9]. The dimensions of the riddle on which the sieves were placed was equal to 400 x 400 mm. The mesh clearance of the sieves (successively from the top) was 50 x 50 mm (wire  $\phi$  4.8 mm), 22.3 x 22.3 mm (wire  $\phi$  2.46), 5 x 5 mm (wire  $\phi$  1 mm), and 1.80 x 1.80 mm (wire  $\phi$  0.4 mm).

In order to avoid the very diversified burning of spent sand obtained from the foundry plant (as it would disturb the clearness of the results), specially prepared model sand based on the fresh

sand matrix was applied in the tests. This sand was marked KWARCOWY PIASEK FORMIERSKI 1K 0.20/0.16/0.32 J89-W<sub>K</sub> 1.26 1400°C acc. PN-85/H-11001), with a KALTHARZ U404 resin added in an amount of 1% as related to the silica weight and hardened by paratoluenesulphonic acid 100T3 (added in amounts of 0.5% as related to the silica sand weight). The additions of the resin and hardener was due to the manufacturer's recommendation.

Cubic shaped elements with sides of 80 mm and weighing 0.8 kg were formed from the prepared sand. The size of the sample was due to the analysis of the mold knock-off process presented in [2]. The analysis showed that more than 80% of the sand after knocking out the cast (before primary reclamation) is characterized by agglomerate sizes between 60 and 100 mm. Next, the samples were compacted by vibrations up to an apparent density of 1.56-1.57 g/cm<sup>3</sup> then hardened and subjected to heating under controlled conditions. The hardened samples were divided into four groups. The first group (not heated) was treated as the reference group (marked MR). The remained three groups were heated for approx. 4 hours. The heating was performed at temperatures of 100°, 200°, and 300°C.

The heating temperature was chosen in accordance to the research [14] in which it was stated that, in traditional casting systems, over 90% of sand in the mold is overheated to a temperature below 300°C.

The groups were marked as follows: 100°C – Sand 1; 200°C – Sand 2; and 300°C – Sand 3. The sand samples intended for bending-strength tests were prepared in a similar fashion.

The time functions of the crushing and sieving process were tested for the model set of prepared samples of the reference sand at various overheating degrees, applying three different supply frequencies of the vibratory drive motor at various feed loads of

the sieves. The total program of the investigations of the primary reclamation on the experimental stand is shown schematically in Fig. 3.

The upper sieve was loaded by various feed weights in individual investigation stages. Three increasing load degrees were assumed. Assuming that the dimensions of the sieve surface allow the theoretically tight placement of 20 shaped elements (100%), the following loading degrees were used in our investigations: 5% (which means 1 shaped element), 45% (9 shaped elements), and 85% (16 shaped elements). The view of the upper sieve with 1 and 16 shaped elements is presented in Figure 3.

The investigations described in this paper were performed at vibration frequencies of 40, 50, and 60 Hz, and the arbitrary loading degree of the model sieve with the feed equals N(5%) (1 sand sample x 0.8 kg). The applied frequencies of the vibrations were chosen due to the engine's specifications.

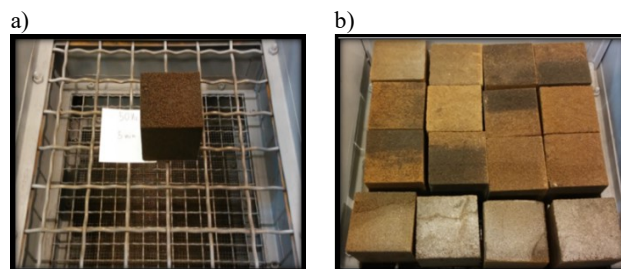


Fig. 3. Examples of loading degrees of upper sieve: a) 5% (0.8 kg); b) 85% (12.8 kg)

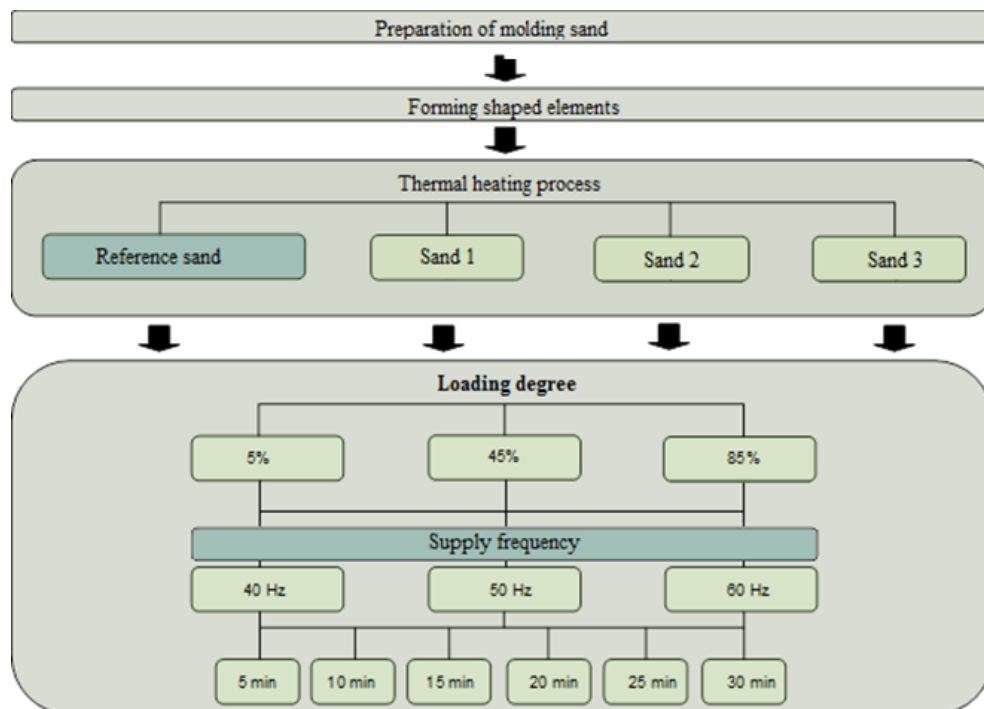


Fig. 4. Schematic presentation of investigating primary reclamation on experimental stand

### 3. Results of investigations

The first element of the research was to investigate the bending strength of the moulding sand with a Kaltharz binder and 100T3 hardener in its initial stage and after heating it to temperatures of 100°, 200°, and 300°C. Before being subjected to heating and after mixing and vibration, the molding samples were held at a temperature of 20°C for 24 hours. These holding conditions guaranteed that the samples attained their final strength. The bending strength pathways as heating time functions are presented in Figure 5 together with the bending strength  $R_{g^u}$  change of the reference sand samples held at the ambient (20°C) temperature (AMB).

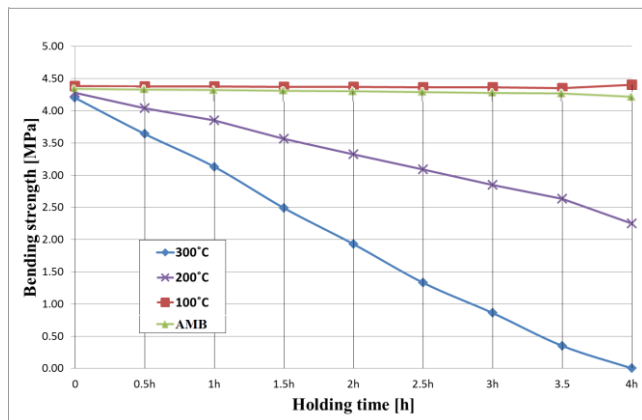


Fig. 5. Bending strength pathways as heating time function of samples in furnace of temperatures of 100°, 200°, and 300°C; also, bending strength  $R_{g^u}$  change of reference sand samples hardened at ambient temperature (AMB)

This shows that heating of the sand at a temperature of 100°C does not cause any decrease in the sand bending strength as related to the reference sand strength hardened before the heating process. This bending strength is even higher by 8.3%. Heating at higher temperatures causes - adequate to a temperature - a decrease in the bending strength  $R_{g^u}$ , which is of a linear character. The data indicates that, at a temperature of 300°C, the final bending strength after 4 hours of heating is zero (an average decrease was 0.525 MPa in 30 min.). Analogous data for the heating temperature of 200°C is as follows: the final strength is lower by approx. 50%, with an average decrease of 0.24 MPa for each 30 minutes of heating.

In successive Figures 6, 7, and 8, the pathways of the crushing process of the shaped elements at the apparent loading of the upper sieve being 5% (a single element of a weight of 0.8 kg) - obtained at three different temperature values of heating the test shaped elements - are presented. The comparison of the obtained results for Sand 1 (Fig. 6) allows us to notice minus mesh amounts very similar to the reference sand (MR) values. The final increase of the sand minus mesh was also similar. It confirms the observations resulting from the data in Fig. 6 that sand subjected to heating at a temperature of 100°C (Sand 1) retains still strength properties similar to the initial sand (MR). After heat treatment, the sand is relatively resistant to crushing, since 60 to 87% of the feed still remains in the upper sieve after 30 minutes of sieving.

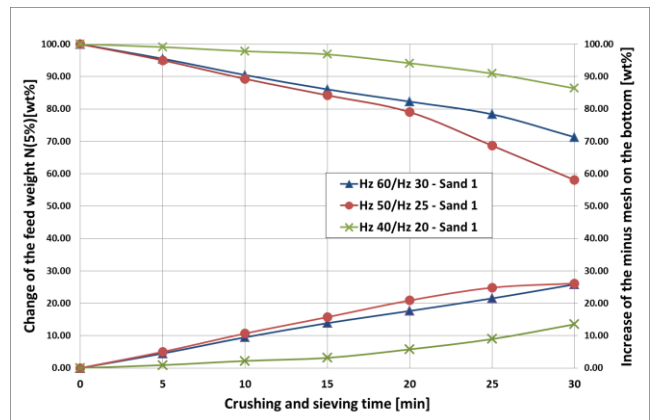


Fig. 6. Influence of crushing and sieving time of shaped element of Sand 1 (heating temperature - 100°C) on changes of feed amount on upper sieve and on minus mesh increase on bottom, at various frequencies of supplying vibratory motors

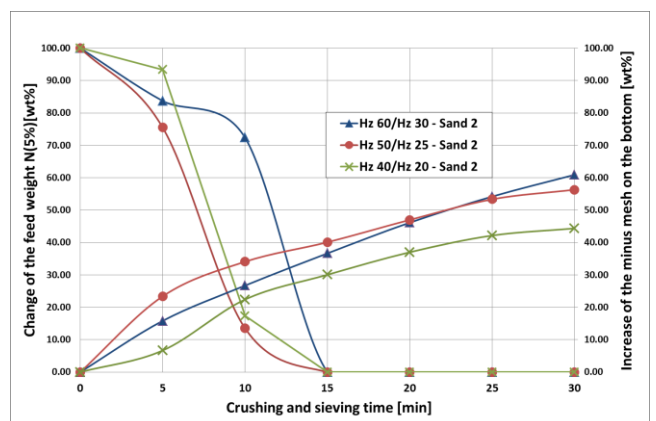


Fig. 7. Influence of crushing and sieving time of shaped element of Sand 2 (heating temperature - 200°C) on changes of feed amount on upper sieve and on minus mesh increase on bottom, at various frequencies of supplying vibratory motors

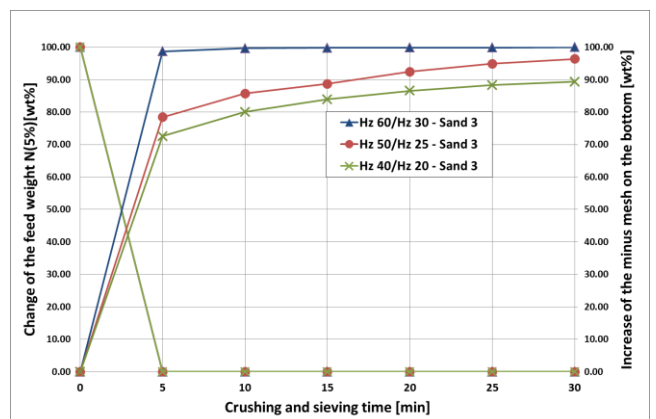


Fig. 8. Influence of crushing and sieving time of shaped element of Sand 3 (heating temperature - 300°C) on changes of feed amount on upper sieve and on minus mesh increase on bottom, at various frequencies of supplying vibratory motors

Sand 2 (Fig. 7) subjected to heat treatment at a temperature of 200°C indicates a much higher character of changes of the tested quantities than Sand 1. The significant degradation degree of the bending strength causes that all of the feed is sieved from the upper sieve after 15 minutes (regardless of the frequency of the vibrations). Also, the minus mesh increase is much larger, achieving 40-60% at frequencies of the vibratory motor supply being 40 to 60 Hz.

The heating process of the shaped elements causes changes in the binder contents, as it evaporates and undergoes partial thermal destruction. The ignition loss values of the minus mesh (presented in Table 1) reveal that heating the shaped elements at a temperature of 300°C decreases the ignition losses by half as compared to the reference sand (MR).

Table 1.

Ranges of ignition losses of minus mesh [wt.%]

Sand MR	1.29÷1.34
Sand 1	1.23÷1.25
Sand 2	1.14÷1.15
Sand 3	0.68÷0.69

Sand 3 (Fig. 8) heated at a temperature of 300°C indicates the high degradation degree of the binder and the lack of strength, which causes that 70% of the feed is sieved already after 5 minutes of device operation; after 30 minutes, nearly 90% is sieved at the lowest supplying frequency of the vibratory motors (40 Hz)

It was shown in [2] that, for assessing the given sand ability for the primary reclamation, the overall diagram of minus mesh increase on the bottom based on the performed investigations of crushing and sieving can be applied. The relative crushing index was proposed in the following form:

$$W_{\text{krusz}} = \frac{P_{DM(i)}}{P_{DMR}}$$

where:

$P_{DM(i)}$  – minus mesh on the bottom increase for tested used sand, %

$P_{DMR}$  – minus mesh on the bottom increase for reference sand, %

The graphical presentation example of the calculated relative crushing indexes  $W_{\text{crush}}$  for the model sands subjected to heating for 4 hours at temperatures of 100°, 200°, and 300°C [2] is given in Figure 9. The frequency of the supplying vibratory motors equal 50Hz.

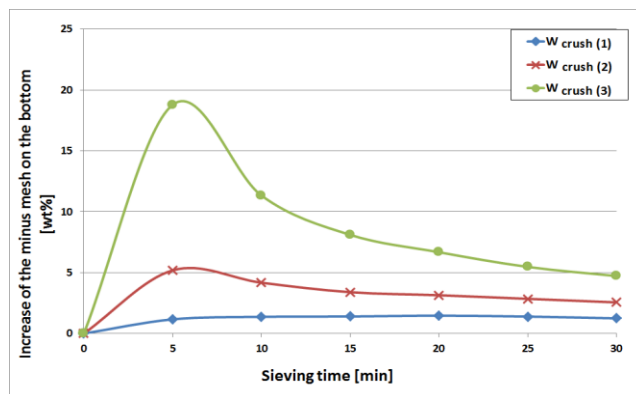


Fig. 9. Graphical presentation of calculated crushing indices for model sands subjected to heating for 4 hours at temperatures of 100°, 200°, and 300°C [2]. Frequency of supplying vibratory motors equal 50Hz

Analysis of the data allows us to notice that the initial 10 minutes of sieving time determines the assessment of the index value. The highest intensity of the crushing of the tested used sands as related to the crushing of the reference sand is observed after 5 minutes of process duration. The highest value of the relative crushing index is observed for Sand 3, which was heated at a temperature of 300°C. Between the onset and 5 minutes, the crushing of this sand is almost 20 times more intensive than the crushing of the reference sand. Sands 1 and 2 are not as susceptible to crushing as Sand 3. This results from the heating temperature. As can be noticed in the data presented in Figure 5, the bending strength of the sand samples after heating to a temperature of 300°C and holding it at this temperature for 4 hours is close to zero. When the sand is heated to temperatures of 100°C (Sand 1) and 200°C (Sand 2), the bending strength of the sands is higher after 4 hours of treatment (Sand 1 – 4.47 MPa; Sand 2 – 2.22 MPa).

## 4. Conclusions

The investigations performed on the model vibratory stand allows us to state that:

- the highest influence on the primary reclamation process has the sand overheating degree. Already at a temperature of 200°C, the bending strength value of the sand samples is decreased by half, while the total loss of this value occurs after long-term heating (4h) at a temperature of 300°C.
- The process of primary reclamation runs the most intense during first 5 minutes of the process. This assumption can be expressed based on the value of the relative crushing index, which is described in the paper.
- Influences of the process parameters such as the supply frequency of the rotodynamic motors and crushing time are also important for the effectiveness of the lump fragmentation. When the frequency is higher, the effectiveness of the primary reclamation process is greater.
- The laboratory stage designed and presented in the paper for primary reclamation allows us to test and compare the



different molding sands used in terms of their susceptibility to the primary regeneration process.

## Acknowledgements

This work was supported by AGH project no. 18.18.170.318, task 2.

## References

- [1] Central Statistical Office (2015). Waste (excluding municipal waste) according to the Waste January 20, 2018 from: [http://swaid.stat.gov.pl/StanOchronaSrodowiska\\_dashboards/Raporty\\_predefiniowane/RAP\\_DBD\\_SROD\\_6.aspx](http://swaid.stat.gov.pl/StanOchronaSrodowiska_dashboards/Raporty_predefiniowane/RAP_DBD_SROD_6.aspx). (in Polish).
- [2] Skrzyński, M. (2017). Analysis of the initial and proper phase of the working cycle of the Regmas universal regenerator. Dissertation. Faculty of Foundry Engineering AGH. (in Polish).
- [3] Integrated Pollution and Control. Reference Document on the Best Available Techniques in the Smitheries and Foundries Industry. European Commission, July 2004.
- [4] Leidel, D.S. (1994). The influence of sand and binders on reclaimability. *Foundry Trade Journal*. 3497(168), 384-387.
- [5] Tordoff, W.L., Miller, J., Trembly, J. & Stempo, M. (1998). Could cryogenics crystallize as an option for sand reclamation? *Modern Casting*. Aug., 35-37.
- [6] Johnson, J.A., Lister, D.R. (2002). 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., (pp. 53-72).
- [7] Ramrattan, S.N. and others (1997). Thermal Distortion in Process Control of Chemically-Bonded Sands. *AFS Transactions*. 152, 152-165.
- [8] Ignaszak, Z. & Prunier, J.B. (2013). Synergy of practical knowledge of molding sands reclamation in heavy casting foundry of iron alloys. *Archives of Foundry Engineering*. 13(3), 30-36.
- [9] Ignaszak, Z. & Prunier, J-B. (2006). The practice of optimizing the quality of the masses of sand reclaimed furan in ferrous foundries. *Foundry Review*. 7-8, 310-314.
- [10] Used Foundry Sand – classification and disposal. EPA (Environmental Protection Act) Guidelines. Re-issued September 2003.
- [11] Günay, Y., Sirin, B. (2002). Practical Experiences and Saving Achieved with Mechanical Sand Reclamation, Proceedings of the 65th World Foundry Congress. Gyeongju, Korea, (pp. 823-828).
- [12] Łucarz, M. (2015). Thermal reclamation of the used moulding sands. *Metallurgija*. 54(1), 109-112.
- [13] Szlumczyk, H., Janerka, K., Homa, D. & Myszor, A. (2007). Pneumatic moulding sand reclamation in the linear regenerator system. *Archives of Foundry Engineering*. 7(2), 53-56.
- [14] Kamińska, J., Kmita, A., Kolczyk, J., Żymankowska-Kumon, S. (2012). Reclamation of spend moulding sands with the carbophen 8178 resin. *Metallurgy and Foundry Engineering*. 14(2), 163-170.
- [15] Holtzer, M., Drożyński, D., Bobrowski, A., Mazur, M. & Isendorf, B. (2010). Evaluation of the effect of regenerate on the properties of masses with furan resin. *Przegląd Odlewnictwa*. 11(2), 61-64. (in Polish).
- [16] Grabowska, B., Łucarz, M. & Kaczmarska, K. (2014). Thermal Reclamation Process of the Spent Moulding Sand with the Polymer BioCo2Binder. *Archives of Metallurgy and Materials*. 14(3), 90-94.
- [17] Łucarz, M. (2012). Ecological installation of the thermal reclamation of used foundry sands. *Archives of Foundry Engineering*. 12(spec.1), 125-130. (in Polish).
- [18] Łucarz, M. (2010). Investigation of combined thermal and mechanical regeneration of used mass from hot-box technology. *Archives of Foundry Engineering*. 10(spec.2), 93-98. (in Polish).
- [19] Daňko, R. (2007). Development of energetic model for dry mechanical reclamation process of used foundry sands. *International Journal of Cast Metals Research. British Cast Iron Research Association*. 20(4), 228-232.