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Thermal Reclamation of Foundry Sands Using Repurposed Sand Dryer Equipment

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Abstract

One of the biggest problems for sand casting foundries must be the waste produced from disposable molds. Stricter environmental regulations make it harder to dispose of waste sand, so a truly competitive foundry does no longer only make great products, but also concentrates on a sustainable casting process. While methods for repurposing waste foundry sand are still limited, the internal circulation of such sands proves significant possibilities. This paper will focus on thermal reclamation of foundry sands in a special rotating drum furnace in a central facility to serve several foundries. Thermal reclamation is a process for handling foundry sands in elevated temperatures to combust unwanted substances from reusable base sand. The introduction focuses on background of the Finnish foundry business, the most common sand systems in Finland and their reclaim properties. The experimental part features presentation of the new reclamation plant process and the conducted test runs. The samples collected from each test run have been laboratory tested to assure proper sand quality. The results of this work showed that the reclamation of alkaline phenolic no-bake sands was excellent. Reclamation of green sands did not provide satisfactory results as expected and the reclamation of furan no-bake sands provided mixed results, as the raw material was imperfect to begin with. The most important result of this work is still the successful initiation of a centralized thermal reclamation plant, with the ability to reclaim sands of several foundries. With this all of industrial symbiosis, circular economy and sustainability advanced in Finland, and the future development of this plant provides even further opportunities and a possibility to spread the ideas on a global scale.

Keywords: Environment Protection, Innovative Foundry Technologies, Spent Foundry Sands, Thermal Reclamation, Industrial Symbiosis

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1. Introduction

In Finland, foundries are experiencing rising pressure to properly recycle surplus foundry sands, as environmental legislations get tighter and sands become more difficult to landfill. While most Finnish foundries have different methods of mechanical reclamation, thermal reclamation is still much underutilized, as only one foundry currently reclaims their used molding sand this way. This changed in the spring of 2017, when a foundry raw material supplier acquired an out-of-operation industrial plant with the idea of converting its sand drying facility into a thermal reclamation plant. While thermal reclamation itself as a process is much researched [1,2,3], the idea of industrial symbiosis in centrally reclaiming several foundries surplus sand is considered as the novelty of this research. This aspect is even strengthened with the fact that the reclamation plant is a repurposed old facility, therefore giving even more weight on circular economy in this research. This paper shortly describes the theory of three foundry sand binder systems, the reclamation equipment, test runs of reclaiming sand in the new plant and results of analyzing the reclaimed properties of the sand samples.

Thermal reclamation of green sands is not fully beneficial because the heat deactivates active bentonite. Burned bentonite also does not break from the sand grain so a mechanical treatment afterwards should be required, which this plant did not have [4].

Furan-bonded sands are one of the easiest foundry sand types to reclaim as it consist of only organic substances that combust efficiently in even lower temperatures. The reclaimed sands are usually controlled by their acid demand value, which was unfortunately not measured in this research [5].

The alkaline phenolic no-bake system (APNB) has an interesting feature that holds back efficient thermal reclamation. Combustion of binders leaves remains of alkaline salts in the sand that can be a problem both for the reclamation process and for the rebonding characteristics. This problem is faced by mixing a special liquid into the sand before charging it to the furnace, which reacts with the salts in high temperatures [6].

2. Methodology

2.1. Used sands

Six Finnish foundries took part in the project by providing some of their used sands for the reclamation tests. One foundry has a furan no-bake system (Foundry 1), one has a green sand system (Foundry 2) and the rest have an ester-cured alkaline phenolic system (Foundries 3-6). The sands were treated in as received condition. For most foundries, this meant mechanically reclaimed sand from circulation. However, foundries 3 and 5 sent surplus sand, which was in an intermediate storage. This did not affect the reclamation process significantly, as the raw material was also mechanically reclaimed and removed from circulation, but because of storage in open air, it had to be dried beforehand.

2.2. Equipment

The plant equipment consists of a charge silo with a conveyor system. The raw material is fed through these into a rotating drum type reclamation unit with a gas burner. After burning, the sand is cooled. The material is then fed to a storage silo system with dust separation units. This process is detailed in Figure 1.

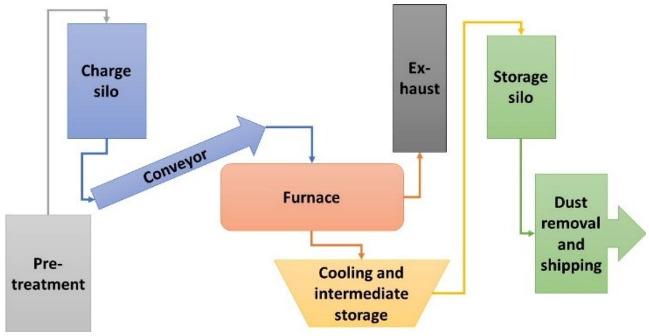

Fig. 1. Plant process chart

2.3. Test runs

Test runs with the machinery proved that automated temperature control enabled constant reclamation temperatures. The collection of two samples could be done in a single test run, as seen in figure 2. Samples for 550 and 650 degrees were made during these constant temperature periods of around half an hour, while the total time of test run was a bit over 2 hours. Frequent testing also demonstrated the capacity and capability of the rotating dryer as well as the parts of the process that required for example more insulation and heat shielding.

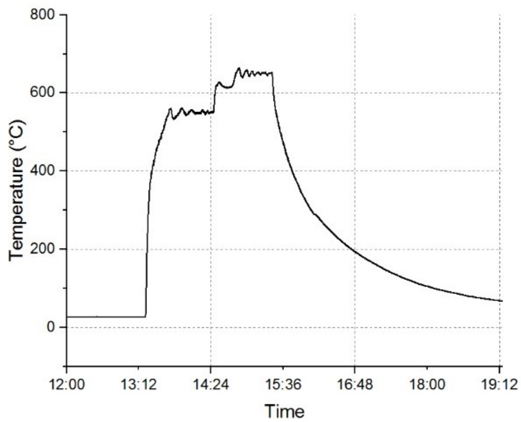

Fig. 2. Time and temperature data from one test run

2.4. Laboratory tests

All the samples were analyzed for loss on ignition (LOI) and grain size distribution, as well as the alkaline phenolic sands were tested for their pH and electrical conductivity based on the salt remains theory in reference [6]. Methods used were based on standardized procedures from AFS Mold & Core Test Handbook [7]. In addition, micrographs were taken from the as received sands compared to the reclaimed ones.

In the beginning of the research project it was decided that the quality assurance limits for the reclaimed sands should be aimed at less than 0,3% LOI and less than 0,3% fines fraction. This was based on literature for reclaimed sands [8] and opinions from the participating foundries. The pH and EC tests were added based on [6] and they had no set quality limit, except referencing to virgin sand and validating the theory in [6]. This meant that pH should rise and EC should drop.

3. Results

First, an example of the comparative micrographs are presented in figures 3 and 4. These represent the as received and reclaimed sands of one foundry. Micrographs for all foundries' sands, while not present here, are still briefly discussed in the next chapter.

Fig. 3. Micrograph of foundry 4 sand as received

Fig. 4. Micrograph of foundry 4 sand reclaimed in 550 °C

The loss on ignition results for as received sands compared to three different reclamation temperatures when applicable is in figure 5. The average grain sizes of as received, reclaimed and new sands are also presented in table 1. Dust percentages and some comparative grain size distribution curves are in table 2 and figures 6 & 7, respectively. Lastly, the pH and electrical conductivity results for alkaline phenolic sands in as received (AR) and reclaimed (RE) conditions are in table 3.

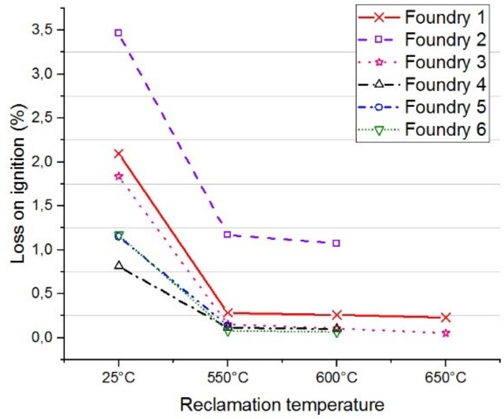

Fig. 5. LOI results for all samples

Table 1.
Average grain sizes for all samples

	Reclaimed	As received	New
Foundry 1	0,353	0,373	0,31
Foundry 2	0,319	0,297	-
Foundry 3	0,363	0,36	0,32
Foundry 4	0,247	0,278	0,27
Foundry 5	0,326	0,369	-
Foundry 6	0,355	0,36	0,31

Table 2.
Dust percentages for all samples

	Reclaimed	As received	New
Foundry 1	0,03	0,03	0,06
Foundry 2	0,07	0,34	-
Foundry 3	0,04	0,04	0,01
Foundry 4	0,15	0,01	0,01
Foundry 5	0,18	0,03	-
Foundry 6	0,08	0,04	0,08

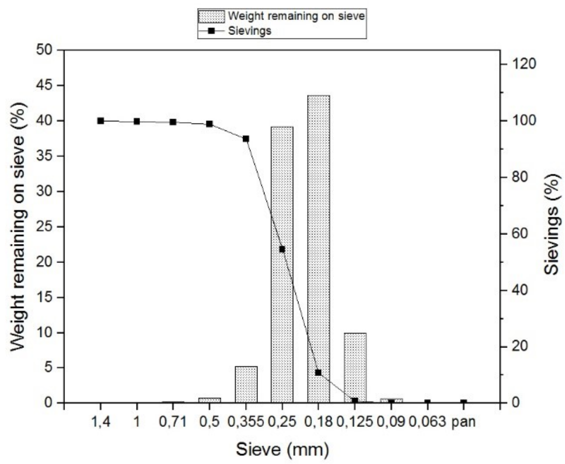

Fig. 6. Grain size distribution for foundry 4 sand as received

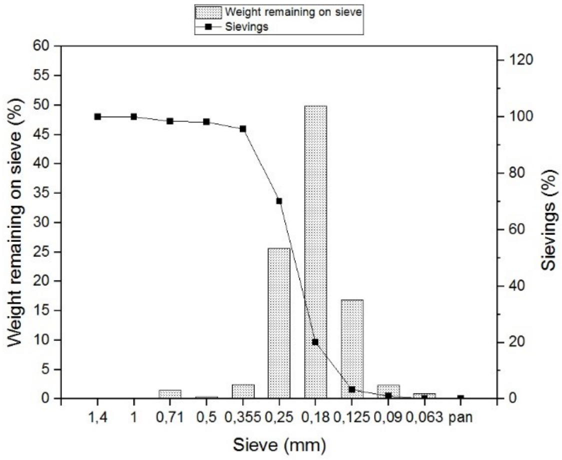

Fig. 7. Grain size distribution for foundry 4 sand reclaimed in 550 °C

Table 3.
pH and electrical conductivities for APNB sands

	pH (AR)	pH (RE)	EC (μS) (AR)	EC (μS) (RE)
Foundry 3	10,97	11,11	1575	522
Foundry 4	10,08	10,65	564	283
Foundry 5	10,4	9,85	158	64
Foundry 6	8,08	10,74	945	250

4. Discussion

The micrographs and general visual inspection showed that the alkaline phenolic sands had an appearance very similar to virgin quartz sand. Green sand did not have such good appearance and the furan-bonded sand provided mixed results, as the surplus sand had a high percentage of chromite sand that affected visual inspection and loss on ignition tests. Loss on ignitions were lower than the pursued 0,3% for all samples except the green sand, which was expected. Furan-bonded sand had a LOI slightly higher than APNB sands because of the chromite sand that oxidizes during the LOI test.

Grain size distribution did not change dramatically in any case, but most samples showed that the impure sand grains settle on the higher sieves, while the reclaimed sands have those grains cleaned so they can settle on their actual lower sieves. This is effectively presented in figures 6 and 7, where in figure 6 the as received sand has a 0,25 mm fraction of close to 40% and in the reclaimed sand in figure 7 this has dropped to around 25%. The dust percentages show that the as received green sand still has valuable fine fractions like seacoal and bentonite present, which has combusted in the thermal reclamation process, thus significantly lowering the dust percentage.

The results for APNB sands were in greater focus as this showed most promising results and opportunities to serve several foundries. The dust percentage slightly rose for some samples, which can be explained by a few factors. It can be an effect of the liquid additive used in reclamation or the side effects of thermal reclamation that can break weakened sand grains and release dust that was bound by the resin over the grains. The pH and EC tests mostly validated the theory, that the liquid additive forms more complex saline compounds that raise the pH and simultaneously lower the EC, as these compounds no longer dilute in water used in the EC test procedure.

The plant equipment fit the thermal reclamation needs well. Initial testing and co-operation with foundries and suppliers has shown interest to continue on developing the facility. While the laboratory tested samples showed good results, the most important result of this work was the successful initiation of a central reclamation facility in the Finnish foundry business. This does not only advance sustainability and circular economy, but also the idea of industrial symbiosis, where companies exchange material streams for efficient waste management and use of natural resources.

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