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Review article

# WASTE FOUNDRY SAND REGENERATION

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**ABSTRACT –** The casting industry uses large quantities of quartz sand, which is a cheap and accessible raw material that must be prepared for use in foundries. After the casting process, foundries generate huge amounts of waste foundry sand (WFS) as industrial waste. The regeneration and reuse of waste foundry sand is a practice and a necessity in many foundries for technological, environmental, and economic reasons. In this review paper, in addition to the characteristics of quartz sand for the casting industry and the characteristics of WFS, typical processes of regeneration in industrial practice, as well as the possibilities of using such recycled WFS in other industries, are presented.

**Keywords**: Quartz sand, Waste foundry sand, Regeneration, Technological process.

## INTRODUCTION

The casting industry uses large quantities of quartz sand, which is a cheap and accessible raw material, for molds and cores in the melting processes of various metals.

Quartz sand for the casting industry must satisfy certain requirements in relation to its characteristics, and it must also be prepared in advance.

The preparation of quartz sand for use depends on the type of quartz sand. For natural sands, screens, magnetic separators, and the wetting are most often used for this purpose. Then, in a mixer, quartz sand is mixed with other components (most often bentonite, coal dust, and water). The amount of sand depends on the weight, size and type of casting. Also, the mold-making procedures are different and depend on the type of quartz sand and binder, i.e., the material added to the mixture [1].

With the addition of water, the mixture acquires the required properties, the most important of which are permeability, strength, fireproof at a temperature of 1300-1600°C, and moldability. These properties allow shaping and retention of the obtained shape [2].

After the casting process, the sand mold can still be used several times to make more molds [3]. WFS is produced in foundries as an industrial waste. WFS treatment represents a big problem, because it needs to be deposited. Treatment of WFS is a practice and necessity in many foundries for technological, environmental, and economic reasons. In practice, we find for this treatment various terminology: recycling, reclamation, and reuse. In Serbia, regeneration is the most used terminology.

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About 1 ton of foundry sand is required for each ton of iron or steel casting produced [4]. According to some data, the volume of spent foundry sand generated by ferrous foundries in Europe can be estimated at around 4.5-6 Mt/yr. Only 25-30% of that waste sand is recovered in few applications, mainly in the cement industry, agricultural soils, and landfill covering [5]. Besides this, the pit cost of sand has risen 50-60%, freight costs have gone up 125%, and waste sand disposal costs have doubled or tripled [4].

This review paper presents the characteristics of quartz sands for use in the casting industry and, also, WFS. In particular, the typical industrial processes of WFS regeneration and its reuse, as well as the possibilities of applying sand after these processes, are shown.

## QUARTZ SAND IN THE CASTING INDUSTRY

The quartz sand used by the casting industry must satisfy special quality requirements.

Foundry sand consists primarily of clean, uniformly sized, high-quality silica sand that is bonded to form molds for ferrous (iron and steel) and nonferrous (copper, aluminum, brass) metal castings [4].

According to the Serbian standard, quartz sand for the casting industry must have an appropriate chemical composition, which refers to the content of $SiO_2$, the content of harmful components (for excellent quality, max. 1% $Fe_2O_3$+$Na_2O$+$K_2O$+CaO+MgO and min. 98% $SiO_2$), and LOI. Quartz sand should have the appropriate permeability for gases, pH, moisture, sintering temperature, as well as the appropriate particle size and particle size distribution. The requirements for particle size are generally 0.1-0.5 mm [2,6]. All requirements depend on the user, i.e., for what types of molds and cores quartz sand is used, so they can be specific.

The classification of foundry sands depends upon the type of binder in metal casting. On the basis of two types of binder, foundry sands are categorized as~~:~~ clay-bonded sands and chemically bonded sands. Clay-bonded sand (green sand) is composed of naturally occurring materials which are blended together: high quality silica sand (85-95%), bentonite clay (4-10%) as binder and carbonaceous additive (2-10%) to improve surface finish, and water (2-5%). Chemically bonded sand consists of silica (93-99%) and chemical binder (1-3%), like~~:~~ phenolic-urethanes, epoxy-resins, furfyl alcohol, and sodium silicate [7].

The physical, chemical, and mechanical characteristics of WFS depend on the type of quartz sand and on the casting process for different industries, i.e., molds and cores making.

Grain size distribution of WFS is uniform (grain size is between 0.15-0.6 mm, mostly 85-95% b.w). WSF has low absorption capacity and is non-plastic. Also, this sand has good durability properties, while chemical compositions depend on the types of metal and binder, and combustible used. Sand is rich in silica content [7]. One potential limitation to their beneficial use is concern that WFS will leach high levels of trace metals [8]. But, in most cases are shown that WFS is not hazardous both as regards the limits imposed by TCLP and by European legislation [9].

Regenerated quartz foundry sand, in addition to reuse in foundries, can also be used in the following areas and industries: embankments, barrier layers construction, flowable fills, road-way construction, agriculture (soil reinforcement/amendments), hot mix asphalt, Portland cement manufacturing, mortars, traction material on snow and ice, vitrification of hazardous materials, smelting, rock wool and fiberglass manufacturing [7]. Some data shows that WFS to 20-30% can be used as fine aggregate in concrete production [10].

**REGENERATION OF WFS**

The problem of WFS foundries is solved by the regeneration and its reuse.

The regeneration of WFS from the molds and cores can be done by mechanical and thermal process. The mechanical process can be wet or dry.

The wet regeneration process is very efficient and expensive and includes a crushing and hydroclassification system for washing and classifying of washed sand and drying. The dry regeneration process has the greatest application, and includes: shaking out of the mold, separation of metal impurities using a magnetic screen, crushing, first cooling, stocking, pneumatic transport through a filter where dust is separated from clean sand, re-cooling of clean sand in a special cooler and, finally, pneumatic transport to the silos above the continuous mixer [1].

Hot regeneration is carried out in furnaces at very high temperatures~~,~~ when the goal is to burn all the binders (furan, bentonite, etc.) and separate them from the sand, i.e., to obtain quartz sand with clean surfaces that can be used again [1]. Depending on the application of the available techniques, sand regeneration amounts to 90-94% and even 98% [11].

Some examples of WFS regeneration processes in practice are described at the next text.

In Teksid foundry plant in Italy, mechanical and thermal processes are combined with the aim of reclaiming green molding sands for core manufacture with theoretical silica sand recovery equal to the 80% b.w. After separating the magnetic component (90% b.w. metallic iron of size class +0.6 mm) on screen and control separation of the magnetic component in magnetic belt separator (size class of -0.6 mm), low intensity pneumatic mechanical scrubbing treatment is followed. After that, thermal treatment at the temperature of 800-900°C and, finally high intensity pneumatic mechanical scrubbing treatment is performed. In cyclones and bag filters, by dedusting are obtained two kinds of residues: first, inert fine particles with a minimum content of active clay and second, not inert fine particles, which contain active clay [12].

The company KHD Humboldt Wedag from Germany has developed the following FWS regeneration procedure: after separating unwanted metal components in a magnetic separator, sand is sent to a fluidization furnace for thermal decomposition and then to a special cooler and heat exchanger. In the heat exchanger, heat is exchanged from sand with water. The cooled sand is then sent to the air jet mill, where the sand surface is abrasively cleaned of impurities in a stream of compressed air. These impurities, i.e., dust, sent to the air classifier, where the light and fine product is separated as dust, while the sand as a coarse and heavy product is separated as a definitive product after being treated in a magnetic separator [13].

A combined (mechanical and thermal) process of WFS regeneration was applied in the foundry in Kikinda in Serbia [14]. The technological scheme of that process is shown in Figure 1.

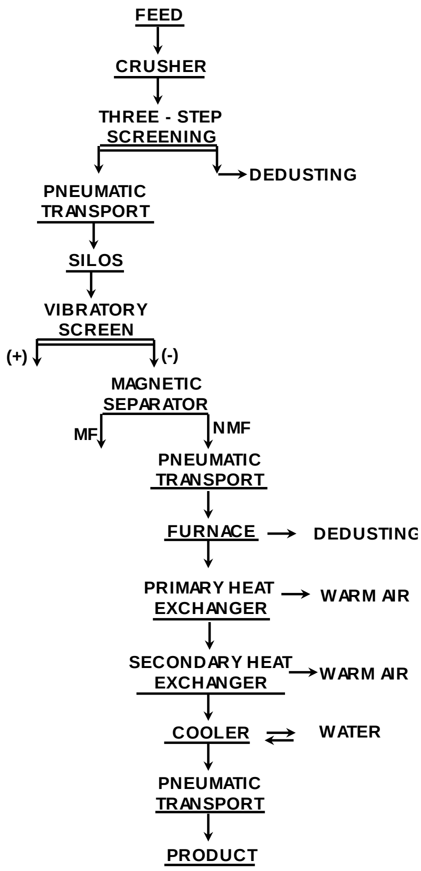


**Figure 1** Technological scheme of WFS regeneration

Mechanical treatment involves first crushing the casting molds in a crusher, which are then entered to a part of the plant, where a three-stage screening is performed. The first attrition screen has two screening surfaces - the first for coarse screening and the second for fine screening. On this screen, which is set in motion with a vibrator, by the movement of the material, in addition to screening, its disintegration is carried out at the same time. The screened sand from the attrition screen is directed to the third, tertiary screen, under which there are tubes for dispersing air. On this screen, screening, i.e., classification in a fluidized bed, is performed. Sand is obtained as undersize and, than, pneumatically transported to the silos. This part of the plant for screening, i.e., classification, is closed, and dedusting is ensured in it.

From the silos, the sand is further directed to screening on a vibratory screen, to separate large particles. The undersize enters a drum magnetic separator for separating undesirable metal impurities, which can be used as secondary raw material. After separating the magnetic components, the sand is collected in a box and then pneumatically transported to the furnace for the thermal regeneration of the sand. The system ensures continuous dosing of sand into the furnace. Thermal regeneration of sand (to burn organic components and free the sand from phenolic resins) is carried out in the furnace at a temperature of 800±50°C in a fluidized bed. From the furnace, the regenerated quartz sand, which is free from the remains of phenolic resins, is sent first to the primary, then to the secondary heat exchanger, and finally to the cooler. The warm air from the primary heat exchanger is used in the fluidization furnace. The cooled sand from the cooler is pneumatically transported to the silos of the regenerated sand. Sand which separated as the smallest dust in the gas intake and dedusting system, i.e., separation of dust, is used as a secondary raw material (for the production of cement in cement factories or the production of concrete).

CALCIFIRE FWS reclamation technology makes it possible to obtain quartz sand that is chemically of the same or even better quality than the quartz sands used for this purpose. This process is also suitable for reclaiming clay-bonded sands (green sands). In addition to mechanical treatment, crushing, and treatment in a magnetic separator, the sand is sent to the furnace where the binder is burned. The CALCIFIRE system involves direct combustion of binder material in the furnace in the fluidization bed, which eliminates heat exchange problems during combustion, while similar systems introduce sand into the furnace from the top and ensure full wall-to-wall fluidization. Air or natural gas, whose operating costs are low, are introduced automatically through special distribution tubes. Heat-resistant steel and ceramic fiber insulation eliminate the need for costly ram-up-type refractory linings, ceramic membranes, or temperature-resistant moving mechanical parts. Without a lining to preheat, the system reaches operating temperature in minutes, not hours. The flow of sand through the furnace is easily regulated. The sand can be reused in molds and cores, making it competitive with new sands in most areas. In order to burn sand and achieve gas emissions at or below the level prescribed by EPA standards, it is necessary to reach a temperature of 700-760°C, while the CALCIFIRE system achieves a temperature of 930°C [15].

## CONCLUSION

WFS represents industrial waste that is generated in enormous quantities in the world. For technological, ecological, and economic reasons, foundries recycle and re-treat this waste, i.e., regeneration by mechanical and thermal processes, in order to reuse it for their own needs. Due to its properties (chemical, physical, and mechanical), this sand is also used in many other industries, especially in the construction industry.

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