

Influence green sand system by core sand additions

N. Špirutová *, J. Beňo, V. Bednářová, J. Kříž, M. Kandrnál

Department of Metallurgy and Foundry Engineering, FMME, VŠB-Technical University of Ostrava
17. listopadu 15/2172, 708 33 Ostrava Poruba, Czech Republic

*Corresponding author. E-mail address: nikol.spirutova@centrum.cz

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Abstract

Today, about two thirds of iron alloys casting (especially for graphitizing alloys of iron) are produced into green sand systems with usually organically bonded cores. Separation of core sands from the green sand mixture is very difficult, after pouring. The core sand concentration increase due to circulation of green sand mixture in a closed circulation system. Furthermore in some foundries, core sands have been adding to green sand systems as a replacement for new sands. The goal of this contribution is: "How the green sand systems are influenced by core sands?"

This effect is considered by determination of selected technological properties and degree of green sand system re-bonding. From the studies, which have been published yet, there is not consistent opinion on influence of core sand dilution on green sand system properties. In order to simulation of the effect of core sands on the technological properties of green sands, there were applied the most common used technologies of cores production, which are based on bonding with phenolic resin. Core sand concentration added to green sand system, was up to 50 %. Influence of core sand dilution on basic properties of green sand systems was determined by evaluation of basic industrial properties: moisture, green compression strength and splitting strength, wet tensile strength, mixture stability against staling and physical-chemistry properties (pH, conductivity, and loss of ignition). Ratio of active bentonite by Methylene blue test was also determined.

Keywords: Environment protection; Innovative foundry technologies and materials; Green sand system; Organic binders; Active bentonite

1. Introduction

Industrial activity is connected to waste production. A large part of these wastes is characterized as hazardous materials. The basic question "How can we use these wastes or how can we disposed this wastes?" is the primary problem for today's society. The main reason is protection of human health, establishment of environmental friendly technology, but also the economic aspect plays important role. The main aim of European Union is wastes reduction to the 50 % during the period of 2010 - 2050. Elimination or at least minimization the amount of waste and/or recycle of incurred wastes and/or utilization of these wastes as

raw materials in the other technologies are possible ways of solution [1].

Foundry production is also associated to production of various secondary products (emissions, contaminated water, or solid waste). Foundry industry generates about 0.6 tons of waste per 1 ton of castings, even though the raw metal material for casting production is recycled. Foundry wastes are essentially composed of used sand mixture (about 71 %), small amount of dust (approx. 12 %), heat resistant materials (8 %) and other wastes (9 %) [2]. Molding mixtures (sand mixture) represent the largest proportion of wastes. The most attention is paid to recycling of sands. The regeneration and/or re-using of mixtures have been considerable progress in the last years. In the North European

countries, foundries regenerate and recycle about 80–98 % of all the used sand mixtures; however they producing about 400,000 tons of excess mixtures per year. The mixtures should be a secondary used or deposited. Thus it results that the costs on casting production is determined by cost for depositing of used sand mixtures, not by the cost of raw materials [3].

The most used technology for the molds production is a green sand system (used for 70 % graphitizing iron and steel casting). Relatively low cost, easily recyclable, and fact that the binder is environmentally friendly are the mean reasons that this mixture is so widespread. The cores are produced by using new technologies based on different types of organic resins because it allows faster curing and casting thinner wall components. The cores, cured with chemical and thermal processes, distinguish a high primary strength at low binder content and good storability. Furthermore these cores have a low adhesive strength to the sands grains, which allows simple regeneration. Low temperature of thermal destruction ensures excellent collapsibility. On the other side faster collapsibility is a main problem, because the cores sand become a part of the green sand, even more than 15 % by weight of the mixture, influences its properties and affects the formation of casting defects such as scabs, defects of the gases, pinholes [3] [4]. The cores and bentonite mixtures are subjected to the higher temperatures. Bentonite binding capacity is influenced by physical-chemical changes that occur due to the heat exposition of molds. At elevated temperatures bentonite behaviour is not only affected due to degradation of its plastic properties, caused by dehydroxylation, but also due to sorption of liquid and gaseous products of carbonaceous additives and synthetic resins pyrolysis. The mixture is refreshed in order to keeping basic sand properties.

Particulate cores are added to green sand as a replacement for new sand, during re-preparing mixtures. This way of waste core recycling can be a solution of hazardous waste utilization and then the foundry produces no waste from molding sand and cores. However, green sand properties may be changed. From theoretical study of literature sources there is no uniform opinion on the used cores impact on the green sand system technology and re-bonding properties [4] [5] [6] [7] [8] [9]. Therefore, the objectives of this study are experimentally determination of the cores effect on the green sand system technological and re-bonding properties, and unite different opinions on these problems. With emphasis on:

- Determination of green sand system (GSS) properties
- Impact of the cores on the technological properties of GGS
- Degree of bentonite passivation

2. Materials and methods

2.1. Green sand system (GSS)

For this investigation only “pure” GSS without any additives was used. Composition of GSS was silica sand from the site Šajdkovy Humence ŠH 35 (medium grain size $d_{50} = 0.37$ mm, the degree of homogeneity $S = 0.66$).

The first GGS standard of comparison is composed of 100 parts by weight sands ŠH 35 and 8 parts by weight quality activated bentonite Sabenil 65 (medium grain size $d_{50} = 49\ 938$ μm , specific surface area 35.57 m^2g^{-1}).

The second comparative GGS standard is a mixture of the composition 100 parts by weight sands ŠH 35 and 8 parts by weight quality activated bentonite Keribent R. Keribent is a mixture of bentonite with different properties, specifically aimed to increasing the degree of flexibility

2.2. Core sand system

For the cores preparation Grudzeň Las sand were used (medium grain size $d_{50} = 0.29$ mm and the degree of homogeneity $S = 0.75$). To simulate the effect on the technological properties of GGS were used the most common technology for production cores, based on phenolic resins:

1. Method ASHLAND COLD – BOX (CB) based phenolic polyurethane resins Askocure EP3929 300 (0.8%) and polyisocyanate component Askocure 600 FW 3 (0.8%) with catalyst 704.
2. Method HOT – BOX (HB) is based on phenolic resins Thermophen 1002 with hardener Härter HP.
3. Croning method was used phenolic resin Plastisable 42 B 630 X.
4. Method Resol cores used Novanol phenolic resin 180, which is intended for the produce hardened core of CO_2 gas.

Addition of core concentration, ranged from 10 to 50 %, were studied, and compared to GGS standard (I. STANDARD with bentonite Sabenil 65; II. STANDARD with Keribent R). Content of active bentonite (8 parts by weight), compactibility and preparation (mixing) time of GGS was kept at constant values, because the compactibility (moisture) and mixing time significantly affect the mechanical properties of the GGS.

Moisture of bentonite molding mixture was controlled according to compactibility ($45 \pm 3\%$), moisture was evaluated under temperature of 105 $^{\circ}\text{C}$ up to constant weight according to the CSN 44 1377. The mixture was prepared on a MK 00 sand mills with mixing time of 15 min. after addition of forming water. Conductivity and pH were determined in water suspension (1:10 ratio) employing of WTW InoLab pH/Cond Level 1. Mechanical strength of GGS samples were measured on standard cylinders $\text{Ø} 50 \times 50$ mm (green compression strength, splitting strength on equipment of the firm WADAP the LRU-1 type, wet tensile strength on equipment of the firm +GF+, the SPNF type). Wear (loss in weight after 1 min/Bodine Electronic Company NS1-12RH) was also determined. Loss of ignition of samples was obtained after sample heat exposure under 900 $^{\circ}\text{C}$ for 2 hours.

Influence of the core bentonite bonding capacity in GGS was investigated in two temperature regimes.

The first temperature regime included a study of the physical-chemical and mechanical properties of GGS with increasing proportion of core sands (0 - 50%) at laboratory temperature (25 $^{\circ}\text{C}$).

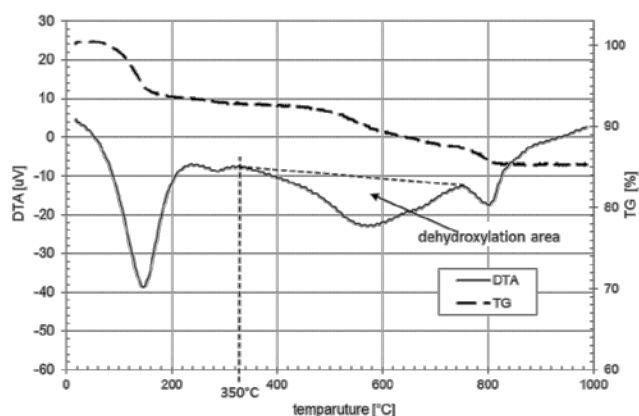


Fig. 1. DTA/TG analysis of bentonite Sabenil 65

For the second part of the experiment was chosen working temperature of 350 °C. This temperature was resulted from

Table 1.

Technological properties of GGS with bentonite Sabenil 65 (STANDART I.) or Keribent R (STANDART II.)

	compactibility [%]	wet tensile strength [kPa]	green compression strength [kPa]	splitting strength [kPa]	wear [%]
STANDARD I.	44	3,04	139	35,2	2,85
STANDARD II.	45,5	4,95	151,84	48,34	5,69

	moisture [%]	pH [-]	conductivity [μS.cm-1]	active bentonite [%]	loss of ignition [g]
STANDARD I.	2,15	10,46	504	8	0,97
STANDARD II.	2,26	10,1	239	7,65	0,52

Table 2.

Technological properties of GGS (STANDART I.) with increasing CB and HB cores concentration

		GSS		10%		20%		30%		40%		50%	
		CB	HB	CB	HB	CB	HB	CB	HB	CB	HB		
wet tensile strength	[kPa]	3,04	3,34	2,92	3,30	3,16	3,3	3,22	3,4	2,84	3,24	3,08	
green compression strength	[kPa]	139	133	120	157	161	150	161	155	158	158	156	
splitting strength	[kPa]	35,2	39	31,4	37,6	32,8	37,6	25,6	40,8	28,6	36,6	28,6	
wear	[%]	2,85	2,86	3,06	2,61	3,07	2,24	2,38	3,79	3,87	5,05	2,84	
pH	[-]	10,5	10,46	10,45	10,48	10,4	10,21	10,4	10,41	10,54	10,4	10,55	
conductivity	[μS.cm-1]	504	489	484	507	490	469	485	434	476	454	465	
active bentonite	[%]	8	-	-	-	-	-	-	-	-	7,7	8,8	
loss of ignition	[%]	0,97	-	-	-	-	-	-	-	-	1,39	1,52	

thermal DTA/TG analysis, conducted on laboratory samples at 15 °C/min under oxidizing atmosphere using NETZSCH GmbH equipment, of used bentonite samples (Fig.1). Under this temperature (350 °C) bentonite dehydroxylation, losing of binding properties and destruction of the crystalline structure, does not occurred and "burn-out" bentonite does not formed [10].

3. Experimental results and discussion

Evaluation of GGS technological properties was a first part of the experiments. The table 1 shows the averages of measured values of both GGS with bentonite Sabenil 65 (STANDARD I.) and GGS with bentonite Keribent R (STANDARD II.).

Further testing was conducted under laboratory temperature. Core sands were added in to the GGS gradually (from 10 up to 50 %). Major changes of GGS properties have been achieved, as demonstrated on the following table 2.

The addition of particulate CB and HB cores in the range from 10 to 50 % did not exhibit any significant influence on the mechanical properties of GGS.

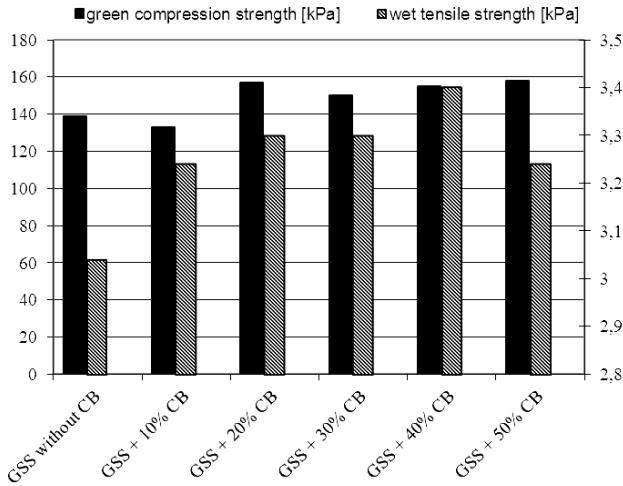


Fig. 2. Green compression strength [kPa] and Wet tensile strength [kPa] for GGS (STANDART I.) with CB

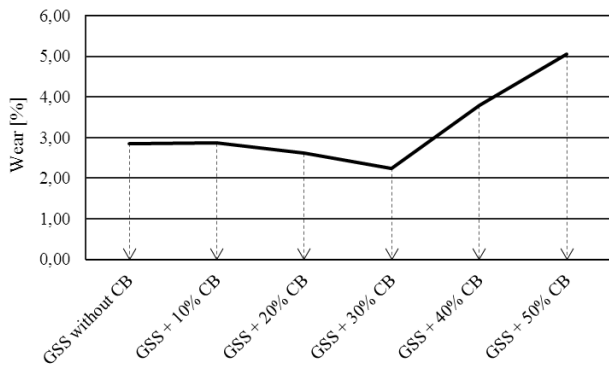


Fig. 3. Wear [%] for GGS (STANDART I.) with CB

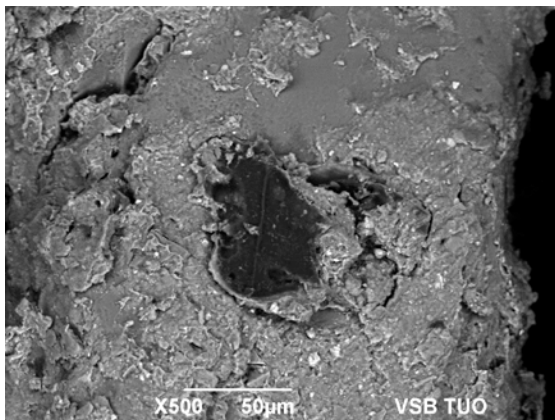


Fig. 4. Detail of grain surface with locally excluded pyrolytic carbon (GGS with 50% CB cores)

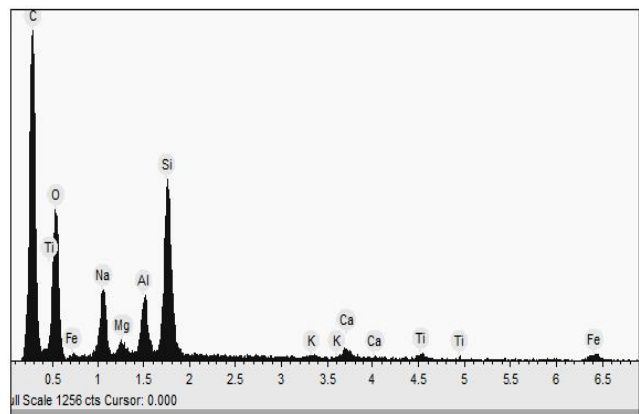


Fig. 5. Spectral analysis GGS with 50 % CB cores

Only slight increase of green compression strength was observed for GGS with addition of CB cores (about 14 %) - fig.2. Improvement of green compression strength and wet tensile strength were confirmed by some foundries. This effect was also documented in some other sources [6] [11]. Core addition exhibits negative impact on the wear, especially for system GGS – CB cores, the wear increased up to 44 % (fig. 3). The GGS with increasing content of CB cores is more tend to drying than pure GGS with the same moisture content. Therefore there is a greater risk of mold damaging during their manipulation and composition, thus the possibility of erosion by molten metal increased. Addition of Croning cores showed the values of green compression strength demonstrate growing trends in comparison with the standard. The increase is gradual and there were no significant perturbations. The splitting strength and wet tensile strength shows a gradual reduction of mechanical properties due to increasing content of the Croning cores. Increasing of the Resol cores content shows a gradual decrease in strength values. Measurement of the pH indicated that the amount of all analyzed cores has no significant effect on the pH values of the standard mixture GGS.

For the next part of the experiment the samples were subjected to heat exposure (350 °C), partially simulation of the conditions in the molds after the heat stress. At this temperature it can be assumed start of thermal decomposition of resin and the binding capacity bentonite may be influenced by the pyrolysis products (passivation of active bentonite), thus it will be reflected in changes of the mixture properties. Therefore, scanning electron microscope (JEOL JSM-6490LV) and quantitative analysis with energy dispersive analyzer Inca EDS X-ACT analysis of selected samples was employed and the theoretical assumptions were confirmed. On the surface layer of grains were detected pyrolysis products, according to the chemical composition can be assumed that they are excluded pyrolysis carbon layer (Fig. 2 and Fig. 3). After annealing on the 350 °C mixture was again remixed and moisture was adjusted to the required value of compactibility and then technological properties of the sample were established (Fig. 6. and 7.)

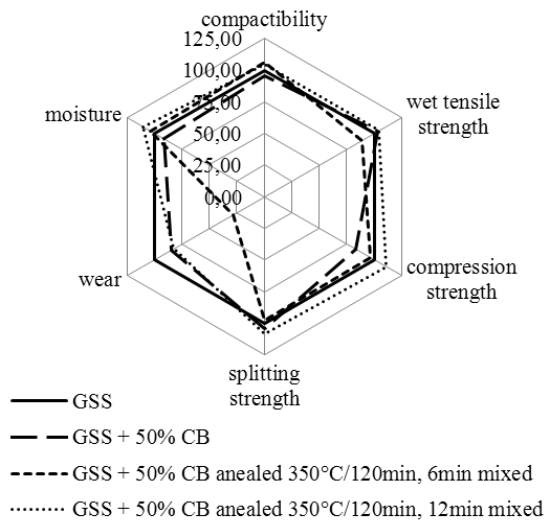


Fig. 6. Technological properties GSS with increasing concentration of CB cores after annealing

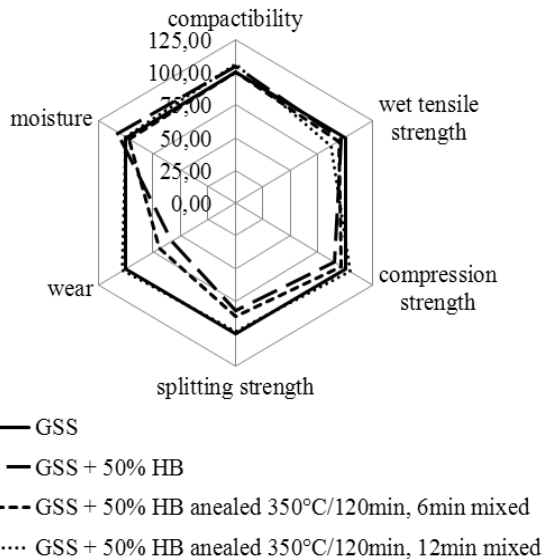


Fig. 7. Technological properties GSS with increasing concentration of HB cores after annealing

On the basis of core addition (50%) there is a marked decrease of active bentonite due to probably its deactivation by pyrolysis products generated during heat exposure of cores. Therefore this fact has an influence on the mechanical properties of mixture and strengths have been decreased on an average 20% to 40%. The deterioration of mechanical properties is higher for the CB cores.

The Bönisch reached the same conclusions in their study [12] and CB evaluated as a binder system with the greatest influence on the deactivation of bentonite in the comparison with HB or

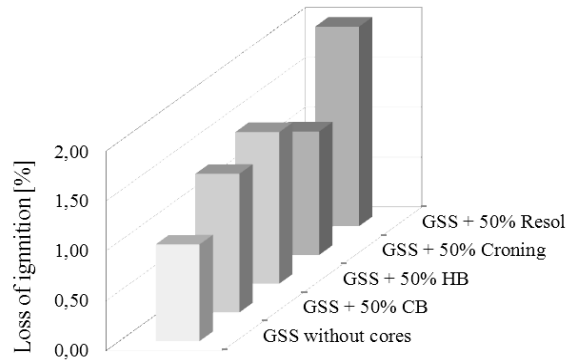


Fig. 8. Loss of ignition

Croning. However, this view is not uniquely confirmed by other authors [6]. In this research, active bentonite deactivation was confirmed by occurring films of Pyrolysis Carbon, which were found on grain surface and determined by EDX analysis. Extension of sample preparing time (from 6 to 12 minutes) caused an increase of mixture mechanical properties (strengths). It is probably inflicted by activation of passive bentonite.

Loss on ignition test was implemented to verification of the presence burnable products, which could passivate the standard after heat exposure. Measured results are shown in figure 8.

4. Conclusion

Utilization of sand waste in circulation system of foundry molding sand is one of the many ways how to reduce wastes of foundry production. There is very significant problem, how these waste could affected a technological properties of foundry molding mixture (green sand system) during its circulation.

Aim of this contribution is determination of impact of selected core systems (COLD - BOX, HOT - BOX, CRONING, CO₂ - RESOL) on bentonite molding sand properties. For the purpose of this research the "un-circulated" molding mixture was used. This investigation was divided into two groups of experiments. At first the core influences was determined under laboratory temperature and further the sands was subjected to heat exposure in order to simulate real conditions in a mold during pouring and solidification of castings.

Slight increase of some strength (e.g. green compression strength after addition of COLD - BOX cores) was obtained. On the other hand addition of CRONING and RESOL cores affected decrease of sand mechanical strengths. Core addition exhibits negative impact on the wear, especially for system GGS with COLD - BOX cores. Measurement of the pH indicated that the amount of all analyzed cores has no significant effect on the pH values of the standard mixture GGS.

After thermal exposition significant decrease of sand properties was observed. It was probably caused by forming of Pyrolysis Carbon films on grain surfaces (deactivation of bentonite), which was confirmed by EDX analysis of sand samples. Extension of sample preparing time (from 6 to 12 minutes) caused an increase of mixture mechanical properties

(strengths) due to probably activation of passive bentonite. This paper is the first of a series of articles on this topic.

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