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ALTERNATIVE UTILIZATION OF THE CORE SAND FOR A GREEN-SAND SYSTEM

ALTERNATIVNA UPORABA PESKA ZA JEDRA V SISTEMU PRIPRAVE LIVARSKEGA PESKA

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The foundry industry, like the other human activities, is associated with the production of various wastes. These secondary products of manufacturing are mainly composed of the moulding mixture, dust waste, fire-refractory materials and other wastes. A utilization of the waste moulding mixture, especially the core sand based on organic resins, as a replacement for new sand, can be a way of decreasing the portion of moulding-mixture waste, thus also decreasing its negative impact on the environment. Nowadays, the most preferred technology for manufacturing moulds is the green-sand system with clay (bentonite) as the binder.

The aim of this study is to determine the influence of a core-sand addition on the mechanical, physical, chemical and technological properties of the green-sand system.

Keywords: innovative foundry technologies and materials, green-sand system, organic binders, environment protection, active bentonite, waste management

Livarska industrija je kot vse človeške aktivnosti povezana z nastankom različnih odpadkov. Odpadki, ki nastajajo pri proizvodnji, so večinoma sestavljeni iz mešanice form, prahov, ognjevzdržnih materialov in drugih odpadkov. Uporaba odpadnih mešanic iz form, kot nadomestilo za nov pesek, posebno mešanic za jedra, ki temeljijo na organskih vezivih, je lahko pot za zmanjšanje količine odpadnega peska, s čimer se lahko zmanjša negativni vpliv na okolje. Dandanes je najbolj priljubljena tehnologija za izdelavo form sistem z novim peskom in glino (bentonit) za vezivo.

Namen te študije je ugotoviti vpliv dodatka peska jeder na mehanske, fizikalno-kemijske in tehnološke lastnosti peščene mešanice.

Ključne besede: inovativne livarske tehnologije in materiali, sistem priprave peska, organska veziva, varovanje okolja, aktivni bentonit, ravnanje z odpadki

1 INTRODUCTION

Industrial activity is associated with the waste production. A large part of these wastes is characterized as hazardous materials. The basic question of how we can use these wastes or how we can dispose of these wastes is the primary problem for today's society. The main reason for its disposal is the protection of human health. We have to establish environmentally friendly technology, but here the economic aspect also plays an important role. An elimination, or at least a minimization, of the amount of waste and/or recycling of the incurred wastes and/or a utilization of these wastes as raw materials in other technologies are possible ways of the solution.[1]

The foundry industry generates about 0.6 t of waste per 1 t of castings.[2] Moulding mixtures represent the largest proportion of the wastes. Most of the attention is paid to the recycling of the sands. The regeneration and/or reusing of the mixtures have had a considerable progress in recent years. The mixtures should be used as a secondary material or be deposited. In this case the cost of a casting production is determined by the cost for depositing the used sand mixtures, not by the cost of the raw materials.[3]

The most used technology for the mould production is the green-sand system (with bentonite as the binder)[4] due to its low cost, easy recyclability and its environmentally friendly binder character. The cores, based on different types of organic resins, allow a faster curing and a production of thin-wall castings. The cores, cured with chemical and thermal processes, exhibit a high primary strength at low binder content and a good storability. Furthermore, a low adhesive strength of the binder to the sand grains allows a simple regeneration. A low temperature of the binder thermal destruction ensures an excellent collapsibility. However, a faster collapsibility of the cores is the main problem, because the core sand becomes a part of the green sand and then the properties of the moulding mixture can be affected and the casting defects such as scabs, defects of the gases and pinholes can occur.[3,5] During a casting process the moulding and core mixtures are subjected to higher temperatures. The bentonite binding capacity is influenced by the physical and chemical changes that occur due to the heat exposition of the moulds. At elevated temperatures the bentonite behavior is not only affected due to a degradation of its plastic properties, caused by dehydroxylation, but also due to the sorption of the liquid and gaseous products of carbonaceous additives and synthetic resin pyrolysis. The mixture is refreshed in order to keep the basic sand properties.

An addition of the treated cores to the green sand as a replacement for a new sand can be a way of a waste-core recycling, a form of hazardous waste utilization, and then the foundry produces no waste from the moulding sand and cores. However, the green-sand properties may be changed. In the theoretical studies in the literature there is no uniform opinion on the used cores' impact on the green-sand-system technology and re-bonding properties.[5–8] Therefore, this study aims to experimentally determine the effect of a core addition on the green-sand technological system and re-bonding properties and it considers different opinions on these problems. The problem was solved by determining:

- the properties of the green-sand system (GGS) standard,
- the influence of the cores on the GGS properties,
- the degree of the bentonite passivation.

2 MATERIALS AND METHODS

In order to simulate the core-sand influence on the GGS properties, four kinds of the most common technology for the core production were used:

1. ASHLAND COLD – BOX (CB) based on phenolic polyurethane resins Asckocure EP3929 300 and polyisocyanate component Askocure 600 FW 3 with catalyst 704.
2. HOT – BOX (HB) based on phenolic resins Thermophen 1002 with hardener Härter HP.
3. Croning method (CR) using phenolic resin Plastisable 42B 630X.
4. The method of Resol cores (RE) using Novanol phenolic resin 180 hardened by CO_2 gas.

Additions of a core concentration, ranging from 10 % to 50 %, were studied and compared to the GGS standard prepared from the Czech-foundry soda-activated bentonites without any additives.

The samples of the green-sand systems (the standard ones or the samples with cores) were prepared with a 6 min homogenization of the mixture of the studied bentonite with the silica sand in the constant weight ratio of 8 : 100 and an appropriate amount of water, which provided for a constant compactibility of (45 ± 3) % using a MK 00 sand mill. The prepared mixtures were shaped into the standard cylinders (diameter of 50 mm, the height of 50 mm) to obtain the samples for determining the technological parameters.

Technological parameters of active bentonite (8 parts by weight), compactibility (moisture of the mixture) and preparation (mixing) time were kept at the constant values, as they can significantly affect the mechanical properties of GGS.

The following general parameters (**Table 1**), commonly used for characterizing GGS, were determined:

a) moisture under a temperature of 105 °C up to the constant weight,
b) pH and conductivity of water suspension (1 : 10 ratio),
c) loss of ignition of dried samples (105 °C up to the constant weight) at 900 °C/2 h.

Strength parameters of the GGS samples including the green compression strength and splitting strength were measured using a testing machine WADAP, the LRU-1 type; wet tensile strength was measured using a testing machine +GF+ (the SPNF type). Wear (the loss in weight after 1 min) was also determined using an NS1-12RH from the Bodine Electric Company.

Experiments were carried out in two temperature regimes. At first the core influence on the GGS properties was studied at laboratory temperature (25 °C) and then the moulding mixture was annealed at the temperature of 350 °C and the samples were prepared in order to simulate a realistic condition in a mould when a decomposition of the resins occurs and bentonite dehydroxylation (a loss of the binding properties and a destruction of the crystallic structure) does not start and the "burnt-out" bentonite is not formed.[9] This working temperature resulted from the thermal DTA/TG analysis of the used bentonite binder, conducted on the laboratory samples at 15 °C/min under oxidizing atmosphere using the NETZSCH GmbH equipment, according to the details from the literature.[10]

Table 1: General parameters of the GGS-standard
Tabela 1: Glavni parametri GGS-standarda

Property		STD
compactibility	(%)	44–45
wet tensile strength	(kPa)	3.04–4.95
green compression strength	(kPa)	139.0–151.8
splitting strength	(kPa)	35.20–48.34
wear	(%)	2.85–5.69
moisture	(%)	2.15–2.26
pH	(–)	10.1–10.5
conductivity	(μS cm^{-1})	239–504
active bentonite	(%)	7.65–8
loss of ignition	(%)	0.52–0.97

3 EXPERIMENTAL RESULTS AND DISCUSSION

The influence of a core, based on organic resins in the range of 10–50 % at laboratory temperature, on the technological properties of the GGS standard is shown in **Figures 1** to **4**.

From these figures it is evident that no significant change has been achieved for the CB and/or HB cores over the whole concentration range. Only the addition of the CB cores caused a slight increase in the green compression strength (about 14 %). This effect was also documented in some other sources.[6,8] A presence of the

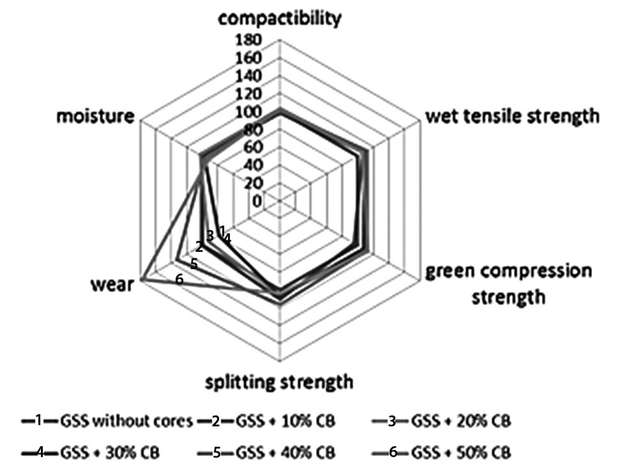

Figure 1: Properties of the moulding mixture with CB-cores (10–50 %)

Slika 1: Lastnosti formarske mešanice z dodatkom CB-jeder (10–50 %)

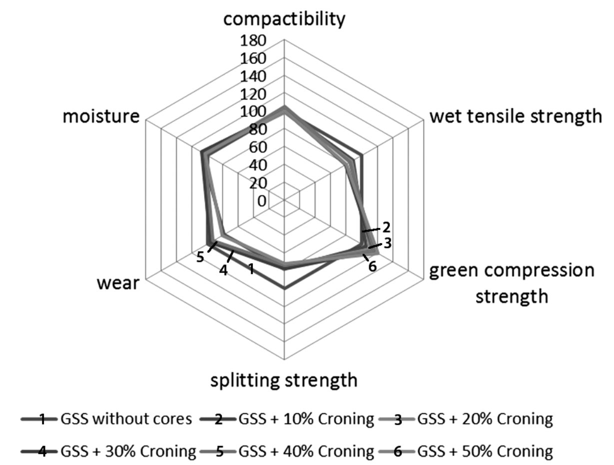

Figure 3: Properties of the moulding mixture with CR-cores (10–50 %)

Slika 3: Lastnosti formarske mešanice z dodatkom CR-jeder (10–50 %)

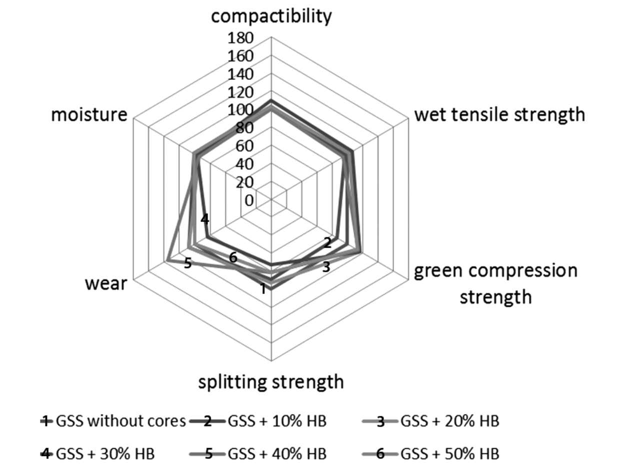

Figure 2: Properties of the moulding mixture with HB cores (10–50 %)

Slika 2: Lastnosti formarske mešanice z dodatkom HB jeder (10–50 %)

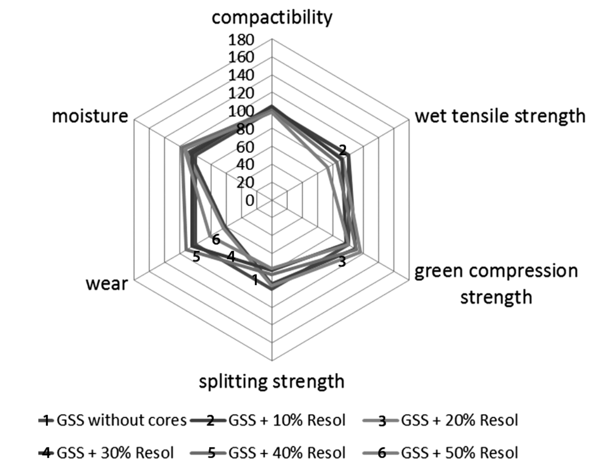

Figure 4: Properties of the moulding mixture with HB-cores (10–50 %)

Slika 4: Lastnosti formarske mešanice z dodatkom HB-jeder (10–50 %)

core in GGS causes an increase in the wear of the mixture, especially for the GGS–CB system cores, increasing up to 44 %. This can lead to a greater risk of a mould damage during its manipulation and composition, thus the possibility of an erosion of the molten metal increased as well.

The addition of the CR cores showed growing trends in the values of the green compression strength in comparison with the standard. The splitting strength and wet tensile strength show a gradual reduction in the mechanical properties due to the increasing content of the CR cores. An increase in the RE-core content shows a gradual decrease in the strength values. Both can be caused by a deactivation of the bentonite plastic properties due to various ions, salt and other formations of the organic resins and their additives (as catalysts, etc.).

Further experiments were conducted with a study of the interaction between GGS and the core sand under annealed temperature (350 °C) in order to partially simulate the conditions in the moulds after the heat stress. At this temperature it can be assumed that the start of a thermal decomposition of the resin and the binding-capacity bentonite may be influenced by the pyrolysis products (passivation of the active bentonite), which will be reflected in the changes of the mixture properties.

Therefore, with the scanning electron microscope (JEOL JSM-6490LV) and the quantitative analysis with an energy dispersive analyzer Inca EDS X-ACT, an analysis of the selected samples was employed and the theoretical assumptions were confirmed. On the surface layer of the grains pyrolysis products (PC) were detected and, according to its chemical composition, it can be assumed that this layer corresponds to the pyrolysis carbon layer. For example, an analysis of the surface layer of the grains with a mixture of GGS and CB is shown in **Figure 5**.

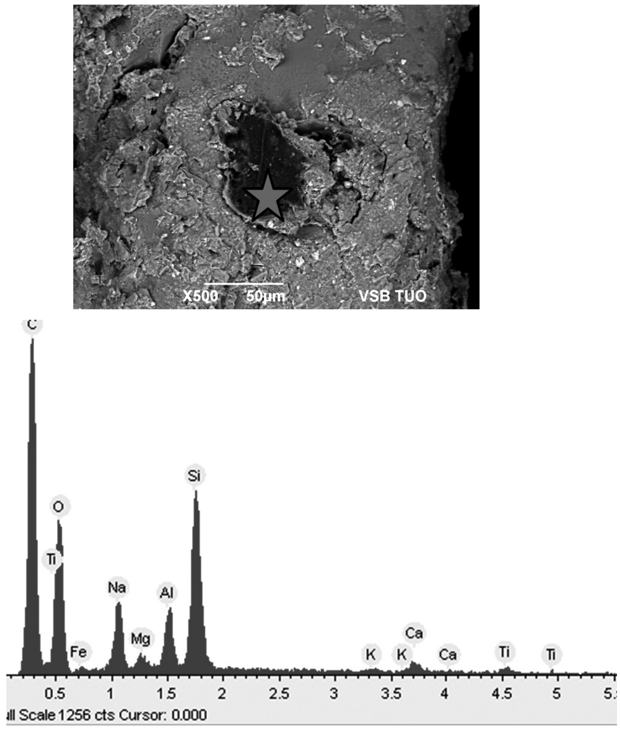

Figure 5: Detail of the grain surface with the locally excluded PC
Slika 5: Detajl površine zrna z lokalno odsotnostjo PC

These experiments were carried out only for the 50 % addition of the cores. The preparation (mixing) time of the mixture was also changed (from 6 min to 12 min) in order to study the mechanism of the bentonite passivation (a kind of sorption). The results of these experiments are shown in **Figures 6** to **9**.

As a result of the core addition (50 %) there is a marked decrease in the active bentonite, probably due to its deactivation caused by the pyrolysis products generated during the heat exposure of the cores. Therefore, this fact has an influence on the mechanical properties of

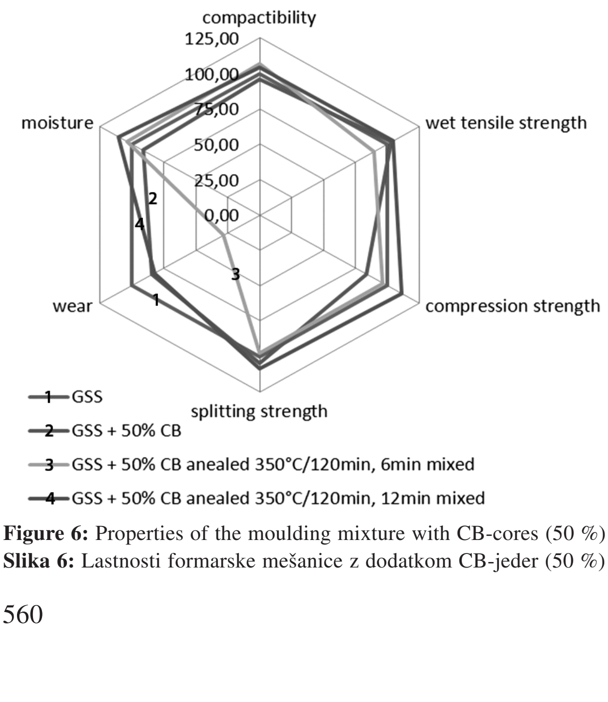

Figure 6: Properties of the moulding mixture with CB-cores (50 %)
Slika 6: Lastnosti formarske mešanice z dodatkom CB-jeder (50 %)

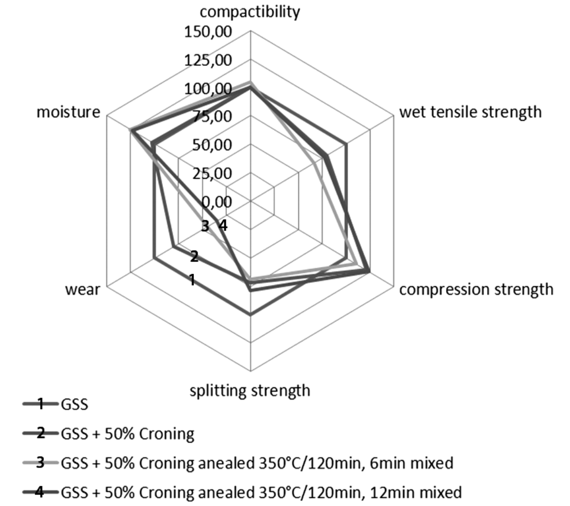

Figure 7: Properties of the moulding mixture with CR-cores (50 %)
Slika 7: Lastnosti formarske mešanice z dodatkom CR-jeder (50 %)

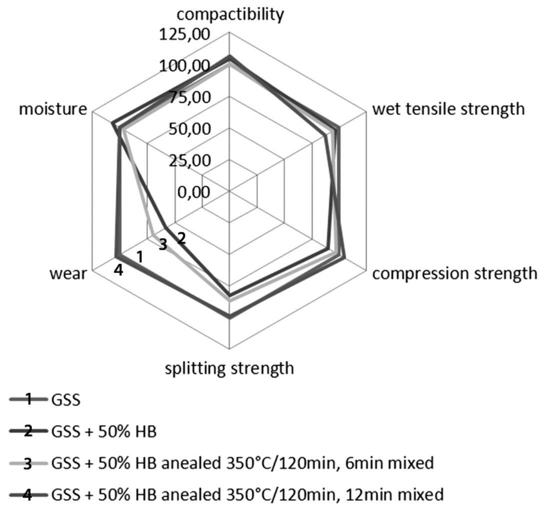

Figure 8: Properties of the moulding mixture with HB-cores (50 %)
Slika 8: Lastnosti formarske mešanice z dodatkom HB-jeder (50 %)

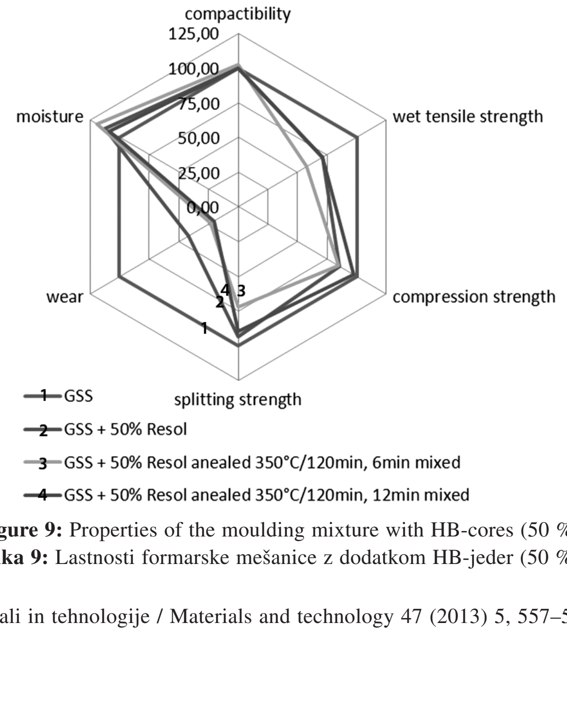

Figure 9: Properties of the moulding mixture with HB-cores (50 %)
Slika 9: Lastnosti formarske mešanice z dodatkom HB-jeder (50 %)

the mixture, and the strengths have been decreased, on average, by 20 % to 40 %. The deterioration of the mechanical properties is higher for the CB cores. Boenisch[11] reached the same conclusions and maintained that CB is a binder system with the greatest influence on the deactivation of bentonite in comparison with HB and/or CR. However, this view is not unanimously confirmed by the other authors.[6] In this research, an active bentonite deactivation was confirmed due to the developed films of pyrolytic carbon, found on the grain surface and determined with an EDX analysis.

An extension of the sample preparation time (from 6 min to 12 min) caused an increase in the mixture mechanical properties (strengths). This probably happened due to the activation of the passive bentonite. We can probably conclude that the mechanism of the bentonite passivation is a physical sorption (reversible changes).

4 CONCLUSIONS

Utilization of the sand waste in a circulation system of a foundry moulding sand is one of the many ways of reducing wastes of a foundry production. There is a very significant problem as to how this waste can affect the technological properties of a foundry moulding mixture (green-sand system) during its circulation.

The aim of this contribution is to determine the impact of the selected core systems (COLD-BOX, HOT-BOX, CRONING, CO_2 – RESOL) on the bentonite moulding-sand properties. For the purpose of this research an "uncirculated" moulding mixture was used.

At laboratory temperature, a slight increase in certain strength (e.g., the green compression strength after an addition of the CB cores) was obtained. On the other hand, an addition of the CRONING and RESOL cores caused a decrease in the sand mechanical strengths. The core addition exhibits a negative impact on the wear, especially for the GGS system with the CB cores.

After a thermal exposure a significant decrease in the sand properties was observed. It was probably caused by a formation of the pyrolytic-carbon films on the grain surfaces (a deactivation of the bentonite); this assumption was confirmed with an EDX analysis of the sand samples. An extension of the sample preparation time (from 6 min to 12 min) caused an increase in the mixture mechanical properties (strengths), probably due to an activation of the passive bentonite. This paper is the first in a series of articles on this topic.

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