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INFLUENCE THE COMPOSITION OF THE CORE MIXTURE TO THE OCCURRENCE OF VEININGS ON CASTINGS OF CORES PRODUCED BY COLD-BOX-AMINE TECHNOLOGY

The main problem in the cores production by cold-box method is the occurence of surface defects due to the tension generated by thermal expansion of the silica sand. One of the possibilities of eliminination is exchange of silica sand from another location. Another interesting factor is the type of used binder and its amount. However, even these measures don't guarantee sufficient quality. Foundries most often solve this problem by adding expensive additives to the core mixture. Foundries may have a dilemma in choosing the right additive. The aim of this paper was to investigate the effect of silica sand from two different locations, the effect of dosing the amount of binder and the addition of several types of commonly available additives on the quality of casting cavities. For this purpose, a total of 11 differently composed core sand mixtures were prepared, but only one of these mixtures was successful.

Keywords: core mixture; quality of casting; veinings; cold-box; silica sand

1. Introduction

The cold-box process, introduced in 1968 still sets the standard for all aspects of high productivity core and mold making, quality and cost. The term cold box is generally associated with the hardening of uncured phenolicurethane resin coated sand by contacting the foundry sand mixture with a catalyst comprising an amine gas [1-3].

The main problem in the production of the core by this method is the occurence of surface defects due to tension generated by thermal expansion of the silica sand. The silica sand is the most commonly used type of sand intended for the cores and molds production. Although there are often increased demands on the quality of silica sands, this group of sands has its limits. One of the main disadvantages is the non-continuous thermal dilatation of silica sand during the casting process [4-7].

Due to the uneven distribution of temperature in different parts of the mold at different distances from the heat source, an irregular thermal expansion and subsequent tension occurs. When the acted forces on the surface of the mold or core are higher, the result is the cracking of the molds or cores. Then the liquid metal enters these cracks and various defects occur on the casting, especially the veinings [4,8]. These defects often occur in inaccessible places, such as castings cavities, so called-thermal nodes. This problem solution is to solve the problem of thermal expansion of silica sand. Advices such as replacing silica sand with sand from another location, or optimizing resin dosing and adding additives to the core mixture are often given in the literature. The addition of additives changes the thermal coefficient of expansion of the sand core and thus eliminates the amount of veinings [9,10].

The issue of cold-box core production is currently dedicated by the authors [11], who focus on the effect of different amounts of additives on the occurence of defects, depending on the binder amount. Other authors [12] evaluate the effect of thermal deformation on cores produced by cold- and hot-box methods. The authors [13] study the correlation between thermal expansion and sand mixtures deformation.

The aim of this paper is to investigate the dependence of selected high-quality silica sands from two different locations, the optimal amount of resin and commonly available additives to eliminate surface casting defects. In order to determine the effect of these paramaters, a total of 198 test bars were made to determine the compaction degree of the core mixture and 37 test castings were cast to ensure sufficient relevance of the results.

2. Materials and methods

2.1. Used materials

In order to determine the effect of different core mixtures on the occurence of surface casting defects, 2 types of test castings (Fig. 1 and Fig. 2) were designed, the basic common characteristic of which were different large internal rounded hard-to-reach cavities. High-quality silica sands and several types of commonly available additives for the cores production were selected and tested.

Fig. 1. Tested castings No. 1

Fig. 2. Tested castings No. 2

In the foundry where the experiments were carried out, two types of high quality quartz sand are used. The tested silica sands with a high SiO_2 content of more than 99.25%, with an oval grain shape and pH values around 5.5 were marked as BG from Biala Gora localities and marked as GL from the Grudzen

Las locality. The genesis of the deposit, the shape of the grain and the chemical purity are basically the same, sand factories are only a few kilometers apart. The foundry where the experiments were carried out started using a new supplier.

The basic parameters of tested silica sands are summarized in TABLE 1 [14,15].

TABLE 1

Basic parameters of tested silica sands BG a GL

Sand	SiO_2 [%]	Fe_2O_3 [%]	Flushable fraction [%]	Refractoriness [°C]	d_{50} [mm]
BG	>99.50	0.04	max. 0.20	>1600	0.25
GL	>99.25	0.07	max. 0.15	>1500	0.26

The binder consists of component I and component II. Component I consists of a liquid yellow synthetic resin with a density of 1.07-1.08 g·cm^{-3} called Gasharz 6747. Component II consists of a liquid solution of a modified brown isocyanate with a density of 1.21-1.23 g·cm^{-3} in a separate solvent [13]. The binder consisting of components I and II was added to the core mixture in a ratio 50:50 in an amount 0.7-1.2% designated A-E.

5 types of commonly available additives were selected and tested and thus 6 core mixture were produced (1 mixture without additive):

- Core mixture without additive, marked as F;
- Anti-Finning agent NO2 form Sand Team spol. s.r.o., marked as G;
- Feranex 8718 from Hüttenes Albertus CZ s.r.o., marked as H;
- Veinseal I-35 from Hüttenes Albertus CZ s.r.o., marked as I;
- No Coating X05 Extra of F.lli Mazzon s.p.a., marked as J;
- Sand additive 031 from Sand Team spol. s.r.o, marked as K.

The differences between the used additives are not known, all the used additives are designed to remove veinings. There are many different additives available on the market, the composition of which is unknown, and therefore the aim of the conducted experiments was to find out, which of the available additives have the best effect on the elimination of veinings and, based on this, to find out the composition of this additive.

2.2. Core production and casting

The cores of the tested castings were produced by the cold-box method by shooting the core mixture in a shooting machine with shooting pressure of 2.5-3 bars. The catalyst was DMPA (dimetylisopropylamine). The time of gassing the cores with DMPA was 8 seconds. All necessary materials were pumped

TABLE 2

Final chemical analysis of cast iron

Element	C	Si	Mn	P	S	Cr	Cu	Sn	Mg	Sc
Content [%]	3.70-3.85	2.20-2.40	0.40-0.65	max. 0.05	max. 0.015	max. 0.10	max. 0.30	max. 0.01	0.03-0.05	1.04-1.07

directly from the filling tanks of automated core machines. The produced cores were then placed in a molds composed of a uniform bentonite mixture and the test castings were subsequently cast from cast iron with the designation EN-GJS 500 – 7 – cold. with the prescribed chemical composition given in TABLE 2.

2.3. Determination of veinings amount

Amount of the surface defects S was determined as the ratio of the total defect surface area of casting cavity S_d [cm^2] to the total surface area of the test casting cavity S_c [cm^2] in percent $S = S_d/S_c$.

2.4. Measurement of flexural strenght and hardness

The flexural strenght was determined using a device for determining the effect of bending loads on standardized test bars after 1, 4 and 24 hours, which were produced by shooting the core mixture in a Laempe shooting machine in a special core box designed for the production of these test bars.

The hardness was measured by the depth of impression directly on the surface of the manufactured core.

2.5. Determining the chemical composition

The structure of the core before and after casting was observed by electron microscopy PentaFET Precision and subsequantly SEM analysis was performed.

3. Results and discussion

The experiments were divided into 3 different groups depending on selected and tested factors:

3.1. Quality of silica sand

The experiments were performed on samples of high quality silica sand BG and GL. Both produced cores were shot under the same conditions and in the both cores mixtures the same amount of binder (0.9%) was added.

The obtained results show that even the use of high quality silica sands doesnt guarantee a quality surface of castings. The main reason is, of course, the uncontinuous thermal expansion of silica sand and the subsequently cores expansion. At the same time, pure high-quality silica sands have a low content of low-melting impurities, which play a very important role in the production of cold-box cores, as they give the core compound higher flexural strength (existence of high temperature points and plasticity of the core surface) [4].

3.2 Amount of binder

In this part of work, 5 sand core mixtures with different binder contents were compared. The test cores were made of core mixtures composed of GL silica sand, to which 0.7-1.2% binder was added and all were shot under the same conditions. The results are summarized in TABLE 3.

The test casting cavities marked as A had the smallest veinings (Fig. 3). The veinings were flat and in some places there were only hints of them. The veinings exceeded to the height 1-2 mm. At the same time, we can notice that the value of flexural strenght was also the second lowest in all test experiments (the lower values was measured on test bars made of core mixture G with additive). As the amount of binder increased, the flexural strength doesn′t increase only, but also the height of the veinings, which in the case of the core mixture E reached a height of 4-6 mm.

Fig. 3. Test casting A

TABLE 3

Core mixtures with different resin content recipes and measurement results

Label	Sand	Binder [%]	Additive	Flexural strength [MPa]	Amount of surface defects [%]	Veinings size [mm]	Figure
A	GL	0.7	—	198	1.91	1-2	3
B	GL	0.8	—	234	2.07	3-4	4
C	GL	0.9	—	232	2.39	3-5	5
D	GL	1.0	—	300	2.23	4-6	6
E	GL	1.2	—	281	2.47	4-6	7

These results can be explained by the fact that with lower binder content in the core mixture, the strength of the mixture also decreases. This statement is also confirmed by the measurement with a device for hardness measurement, where with a higher content of binder in the core mixture, the height of the notch was lower. With less binder, the core becomes more flexible and softer. Conversely, as the amount of binder increases, the strength of the cores increases. Due to the greater compaction of the core, there was no space in the core allowing emerging stress to be absorbed, which was reflected in the core cracking to a greater depth. Therefore the height of the veinings was higher (Figs. 3-7) [13].

3.3. Addition of additives

Additives in core mixtures serve to prevent some surface defects, especially veinings [3,16,17]. In this part of the work, 5 types of commonly available additives were selected and compared. The tested core mixtures were made under the same conditions, changing only the type of additive added to the mixture. The amount of additive added was constant (1%). The compositions of the individual core mixtures and the results of the measurements are summarized in TABLE 4.

The results showed that the amount of veinings in each test casting no. 2, where an additive was added to the core mixture, eliminated less than 1% of the total cavity surface. The additions of almost all additives were able to remove veinings in the larger cavity of the test casting (Fig. 8-10, Fig. 12-13) except for the addition of the I-35 additive (mixture I) (Fig. 11). Only one type of NO2 additive (mixture G) removed veinings in the smaller cavity of the test casting (Fig. 9). We can notice, that it was this core mixture that had the lowest measured value of flexural strength.

Due to the addition of additives to the core mixture, the tension between the silica sand grains is eliminated. The addition of additives to the mixture makes the sand softer and more flexible and consequently able to absorb higher stresses [9,10]. Additives prevent the growth of volume in the subsurface layers and thus reduce the stress causing the formation of veinings on the surface of the mold or core [17]. However, to ensure elimination of casting defects, it is still important to know not

Fig. 4. Test casting B

Fig. 5. Test casting C

Fig. 6. Test casting D

Fig. 7. Test casting E

Recipes of core mixtures with additives and measurement results

Label	Sand	Binder [%]	Additive	Amount of additive [%]	Flexural strength [MPa]	Number of defects in the larger cavity [%]	Number of defects in the smaller cavity [%]	Figure
F	BG	0.9	—	—	257	1.68	2.91	8
G	BG	0.9	NO2	1	188	0	0	9
H	BG	0.9	8718	1	275	0	0.91	10
I	BG	0.9	I-35	1	223	0.44	0.94	11
J	BG	0.9	X05	1	215	0	0.89	12
K	BG	0.9	031	1	238	0	0.62	13

Fig. 8. Test casting F

Fig. 9. Test casting G

Fig. 10. Test casting H

Fig. 11. Test casting I

Fig. 12. Test casting J

Fig. 13. Test casting K

only the type of additive added but also the effective amount in the core mixture.

Since only one of the tested additives was successful (Anti-Finning agent NO2), the next step was to observe this test core mixture under an electron microscope (Fig. 14a, Fig. 14b) and determine the chemical composition (Fig. 15).

From the results of the SEM analysis it is clear that the successful additive is probably based on Fe, becasuse the other elements come from the used sand and organic binder.

4. Conclusions

In the production of cores by the cold-box-amine method, it is very important to define the possibilities of preventing the occurrence of defects on castings, to produce strong and stable cores, and thus to reduce the occurrence of defects to the lowest possible level. Therefore, foundries must constantly experiment and find the most effective components for a particular type of casting. Even the use of the best components may not ensure
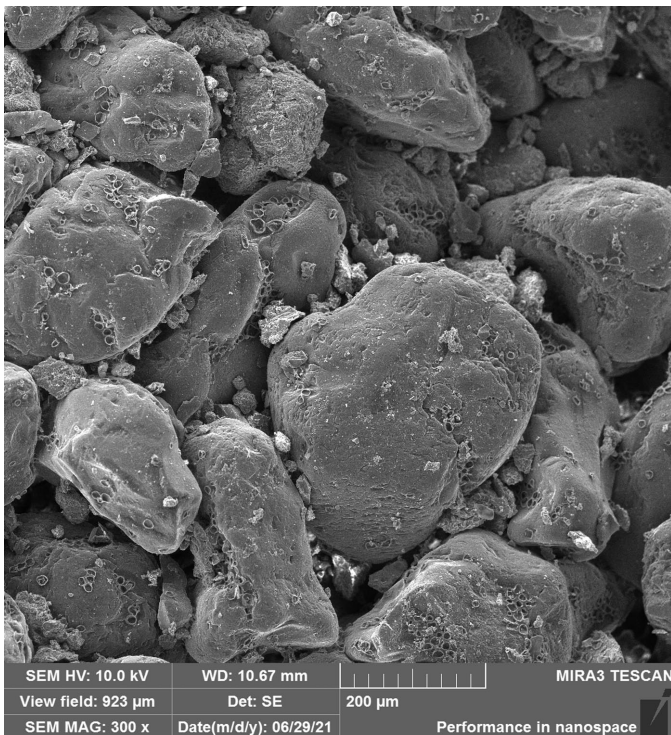

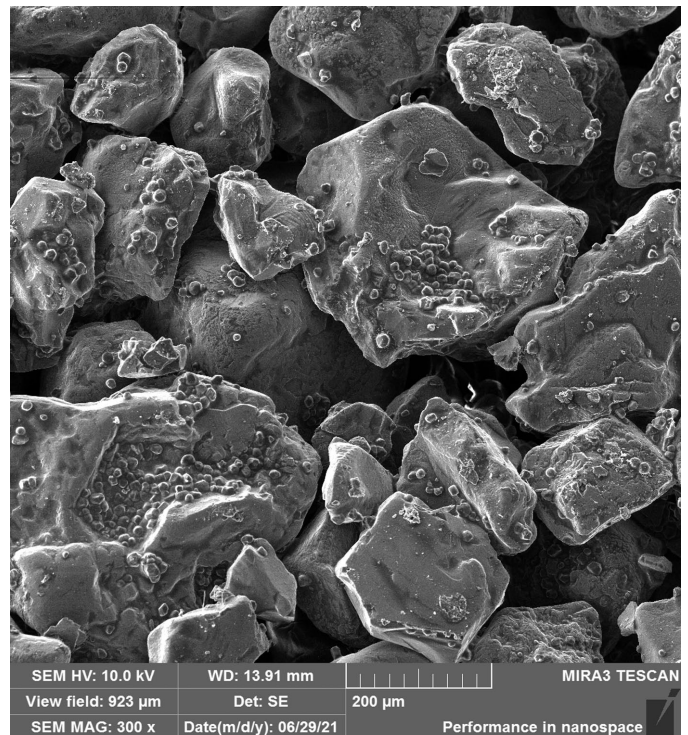Fig. 14a. Sample of sand core mixture G before casting, maginification 300×

Fig. 14b. Sample of sand core mixture G after casting, maginification 300×
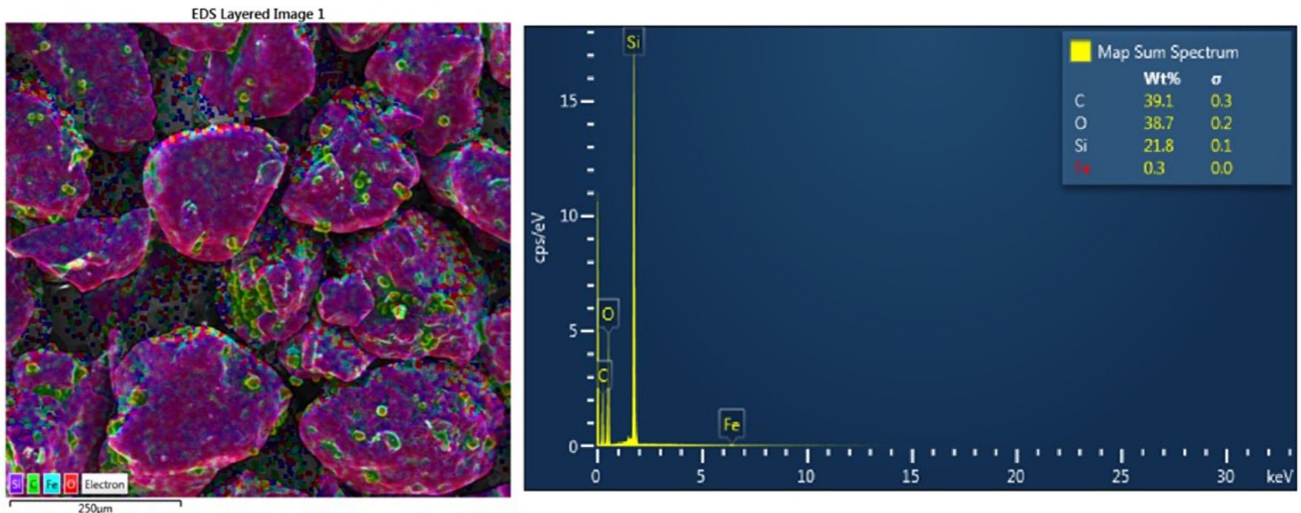
Fig. 15. Map of elements and results of SEM analysis of core sand sample mixture G

100% removal of surface defects, which has been confirmed in this research. For this reason, all the factors that cause these casting defects must be taken into account. One of the possibilities is, in addition to changing the composition of the core mixture, the addition of additives.

The following conclusions can be summarized from the performed experiments:

- The use of high quality silica sands does not guarantee the high quality of castings. The main reason is the high chemical purity and the associated expansion of silica at high temperatures.
- The amount of binder added is a very important factor. As the binder content in the core mixture increases, the strength increases, which has a negative effect on the quality of the castings due to the fact that the core mixture cannot absorb the stress created during expansion.
- The most important means of eliminating veinings seems to be the application of additives. Even the addition of an additive in an amount of 1% in the core mixture indicates that it is a suitable agent for the production of cores by the cold-box method. However, with the exception of one test additive, such an amount of additive was not sufficient for the cavities of these test castings.

The results of research experiments show that in the case of problem areas in castings, places that are highly thermally stressed and difficult for additional cleaning, such as cavities on test castings, the use of high quality and often expensive sands is not enough, as well as reduced binder but it is necessary, above all, to add additives to the core mixture and to constantly experiment with the required amounts, to study their chemical properties and their combination, which will be the goal of the following experiments. The benefits of this research is that only one additive of the currently available was successful in an amount of only 1% in the elimination of veinings.

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