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Influence of Silica Sand on Surface Casting Quality

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Abstract

The current casting production of castings brings increased demands for surface and internal quality of the castings. Important factors, that influence the quality of casted components, are the materials used for the manufacture of moulds and cores. For the preparation and production of moulds and cores, in order to achieve a low level of casting defects, then it used a high quality input materials, including various types of sands, modified binders, additives, etc. However, even the most expensive raw materials are not a guarantee to achieve the quality of production.

It is always necessary to choose the appropriate combination of input material together with an appropriate proposal for the way of the production, the metallurgical treatment of cast alloy, etc. The aim of this paper is to establish the basic principles for the selection of the base core mixtures components – sands to eliminate defects from the tension, specifically veining. Various silica sand, which are commonly used in foundries of Middle Europe region, were selected and tested.

Keywords: Innovative foundry technologies and materials, Castings defects, Silica sand, Veining, COLD-BOX amine

1. Introduction

Silica sand still are among the most widely used type of sands for the cores/molds manufacture. Even if higher demands on the quality of silica sand are required, these group of sands have their limitations. One of the main reasons is the expansion of silica due to rapid thermal expansion of the sand during the process of casting [1, 2, 3]. The uneven distribution of temperature in different parts of the sand of different distances from the heat source (molten metal), occurs and thus uneven thermal expansion and associated stress are created. When the forces on the surface of the mold/core are high this state resulting in core/mold cracking. Then the molten metal enters these cracks, creating various casting defects, mainly veining [4, 5]. There are a lot of ways how to eliminate veining formation, which mainly includes

application of non-silica sands, various kind of special additives and etc. These steps usually has negative effects on molding mixture costs and/or technological parameters of molding/core mixture (for example flow ability etc.).

But the phenomena of the veining formation could be solved only with the keeping the basic rules of the application of silica sands. The goal of this study is to determination of the influence of selected silica sand commonly used in foundries of medium Europe region on veining formation, new testing method for veining formation was developed and basic parameters including:

- Sand chemical purity (content of SiO₂),
- size and shape of the sand grain
- degree of mixture compactibility
- addition of binder in core mixture

were determined in order to describe the basic rules how to avoid the surface casting defects in common foundry praxis.

2. Materials and methods

In order to determination of the influence of moulding/core composition on veining occurrence a new testing method was suggested and various silica sands commonly used in foundries of middle Europe were selected.

New testing method for veining formation evaluation was designed according to [1, 7, 8]. The main criterion was to obtain maximal thermal stress of testing cores (cylinders $\phi 50$ mm, height 50 mm) and to assure veining formation. Final thermal core stress was calculated as mould +cores – metal ratio 1.39. Based on calculation the main dimensions of testing casting, cores and moulds were evaluated (Fig. 1):

- Testing casting: radius $r = 0.1811$ m; height $h = 0.040$ m; weight $w = 26.2594$ kg (without gating system)
- Testing core: radius $r = 0.025$ m; height $h = 0.040$ m; weight $w = 0.4901$ kg
- Testing square mould: side $a = 0.4121$ m; flask height $h = 0.160$ m; weight $w = 35.9683$ kg

Thermal stress evaluated as mould-metal ratio was 1.3697 (1:9), ratio of mould + cores – metal was 1.39. As a testing metal grey iron LLG20 was selected and the constant pouring temperature 1400 °C and velocity of pouring 18 s were kept for whole experiments.



Fig. 1. Design of testing mould

Various silica sand with different chemical composition (purity) grain shape (determined as “shape coefficient” W_k) and AFS Number (medium grain size d_{50}) were selected. The first group of tested sands includes very chemically pure sands with high amount of SiO_2 (over 99 %) Grudzeń Las marked as GL with different grade, and Střeč sand marked as ST. The second group, as a lower chemically pure sand, includes Bukowno sand (marked as BK). Basic testing sand parameters are summarized in Table 1.

Cold-Box Amine method (PUCB) based on phenolic polyurethane resin Ecocure MPDB1/2 with DMIPA as a catalyst were used for preparation of testing samples (cylinder cores $\phi 50$ mm, height 50 mm) with testing sands. The sample were manufactured on core shooter VGi5 with shooting pressure 300 kPa.

Mixtures were prepared with silica sand GL and soda-activated bentonite SABENIL 65 with homogenization 5min with appropriate amount of water which assured the constant compactibility 45 ± 3 % using MK 00 sand mill.

The quality of casting surface from the testing cores was determined as a total surface of defects [cm^2] and as a ratio of casting defects and whole surface of pre-casted “hole” in percentage.

Table 1.

Basic parameters of testing sands

Sand	d_{50} [mm]	AFS No.	% SiO_2	W_k^*	Refractoriness
GL27	0.26	51.80	99.5	1.10	Min. 1550 °C
GL35	0.43	33.30	99.5	1.10	Min. 1550 °C
ST27	0.28	49.20	99.2	1.20	Min. 1500 °C
BK27	0.26	52.60	98.0	1.10	Min. 1450 °C

*Note: $W_k = 1$ means sphere shape of the grain

3. Results and Discussion

The experiments were divided into subsequent steps to describe whole potential dependences between the kind of testing sand and veining formation. Whole obtained results are summarized in Table 2.

3.1. Sand chemical purity

These experiments were carried out with the samples of BK27 and GL27 sands (Fig. 2 and 3). Both prepared samples were compacted and the constant level of binder (0.5 %) was added. The results are summarized in Table 2. From the obtained results it is evident, that the sand with lower chemical purity (BK27) significantly demonstrates lower amount of veining. For the GL27 2.20 % of testing surface was covered with veining in comparison with BK27 (0.41 %). There are few theses how to explain this phenomena. At first, silica sands with lower chemical purity shows lower absolute value of expansion generally. Further, low melted impurities gives the system higher tensile strength (existence of high temperature bonds) and plasticity of the core surface and thus the cracking of the core surface is not proceeded.

3.2. Size and shape of the sand grain

In this step of the work two sands with different grain shape were compared: GL27 (sphere, $W_k = 1.10$) and ST27 (angulary, $W_k = 1.20$). There was no influence of chemical purity. Samples prepared from testing sands had constant addition of the binder (0.5 %) and they also had been compacted. The results are summarized in Table 2.

From the obtained results it is evident, the sands with lower sphere shape of the grains (ST27) gives lower volume of veining (0.82 %, Fig. 4) in comparison with the sample GL 27, where the total amount of casting defects was 2.20 %. These effect is connected to the fact that tension on the core surface is lower for angularly sand in comparison with sphere grain (lower thermal expansion due to lower compactibility).

Table 2.

Influence of mixture composition on veining formation

Sand	State	Binder [%]	Total surface of defects [cm ²]	Amount of casting defects [%]
GL27	compacted	0.5	1.53	2.20
GL35	compacted	0.5	1.58	2.28
GL35	non – compacted	0.5	0.06	0.23
GL35	compacted	0.7	1.36	1.96
GL35	non – compacted	0.7	0.07	0.11
GL35	compacted	0.9	1.97	2.85
GL35	non – compacted	0.9	0.00	0.00
BK27	compacted	0.5	0.28	0.41
ST27	compacted	0.5	0.58	0.82



Fig. 2. BK27/0.5 %/compacted



Fig. 3. GL27/0.5 %/compacted



Fig. 4. ST27/0.5 %/compacted



Fig. 5. GL35/0.5 %/non-compacted



Fig. 6. GL35/0.7 %/non-compacted



Fig. 7. GL35/0.9 %/non-compacted



Fig. 8. GL35/0.5 %/compacted



Fig. 9. GL35/0.7 %/compacted



Fig. 10. GL35/0.9 %/compacted

Also the influence of grain size on veining formation was tested. In these experiments sands GL35 (Fig. 5) and GL27 were

compared. In spite of theoretical suggestion, higher trend for veining formation was observed for the sand GL35 (2.28 %) in

comparison with GL27 (2.20 %). It is probably caused with different distribution of individual fraction of the GL35.

This sand has more mono fraction character in comparison with GL27 and thus sands with low different grain sizes shows higher tension which leads to veining formation

3.3. Degree of mixture compactibility

Generally, degree of compactibility has significant influence on thermal expansion, respectively on tension, which is formed on the core surface and it is the source of core cracking. For these experiments the sand GL35 was selected and compacted and non-compacted samples were prepared. Also various level of binder (0.5 %; 0.7 % and 0.9 %) were added. From the obtained results (Table 2) it is evident that with increasing compactibility of the samples the amount veining increase. It is caused with thermal expansion and/or formation of higher tension respectively, which resulted to cracking of the cores. This effect could be also restricted with higher binder addition. It was found that increasing addition of binder reduce amount of veining (Fig. 6-10).

4. Conclusions

Surface casting defects caused with the tension stress that is exerted at the mould-metal interface due to thermal expansion of silica sand is very widespread casting defect mainly with organic resin as a binder. There are a lot of ways how to eliminate veining formation, which mainly includes application of non-silica sands, various kind of special additives and etc. These steps usually has negative effects on moulding mixture costs and/or technological parameters of moulding/core mixture (for example flow ability etc.).

There are several accepted methods of reducing veining in casting without application of non-silica sand, additive etc. These method includes:

- Application silica sand with lower chemical purity. These materials generally exhibits lower thermal expansion and Further, low melted impurities gives the system higher

tensile strength (existence of high temperature bonds) and plasticity of the core surface and thus the cracking of the core surface is not proceeded

- Very important factor is a shape of the grain. Angularly grains helps to reduce tension stress on the core surface and thus the veining formation.
- Also the degree of compactibility and amount of the binder play important role on veining formation. Lower degree of compactibility of core/mould has positive effect due to decreasing of surface tension stress.

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