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APPLICATION OF NON-SILICA SANDS FOR HIGH QUALITY CASTINGS

The goal of this article is to application of non-silica sands based on aluminninosilicates as an alternative of traditionally used chromite sand for alloyed steel and iron castings. Basic parameters as bulk density, pH value of water suspension, refractoriness, grain shape of the testing sands were evaluated. Also mechanical properties of furan no-bake moulding mixtures with testing sand were determined. Finally, the influence of non-silica sand on casting quality was evaluated via semi-scale under normal casting production for sand characterization Optimization of production process and production costs were described.

Keywords: non-silica sands, chromite sand, furan no-bake

1. Introduction

One of the most widespread material as a refractory compound of moulding mixture is silica sand, not only in Central Europe Region. Generally, application of silica sands is suitable for common casting production, but on the other hand for special application (for example casting with high thermal module, heavy weight casting etc.) this sand is limited due to not satisfactory refractoriness, high thermal expansion etc. and various casting defects could be occurred [1-6]. From this point of view various non-silica sands are applied, chromite sand especially.

Even if chromite is the most used non-silica sand, mainly due to high heat resistance and chilling effect, there are also observed a lot of limited factor of chromite sand application. There is very important influence of chemical and/or mineralogical composition of chromite sand on its quality and casting quality respectively. The chromite quality (composition) is strongly influenced with the location of the mining [7]. Generally, the most suitable chromite for foundry applications comes from Republic of South Africa (RSA). Based on mineralogical composition content of pyroxene is the most important ($Mg_2Si_2O_6$). The reason is the pyroxene heat resistance is only 1300°C.

Also the pyroxene content influence the catalyst consumption for binder systems cured with acid catalyst (like furan no-bake), CaO content has also the same effect. Amount of this oxide could be indirectly estimated based on pH value. This value ranged from 7 up to 9 (10), but optimal value is close to 7. The other very important parameter is SiO_2 content. It is necessary to keep the amount of SiO_2 content below 1-1,5 % due the fact, the silicon oxide reacts with basic alloys and thus the compounds with low heat resistance are formed:

$$2Fe + O_2 + SiO_2 \rightarrow Fe_2SiO_4 \quad \text{(fayalite – 1200°C)} \quad (1)$$

$$2FeO + Mg_2Si_2O_6 \rightarrow (Mg,Fe)_2Si_2O_8 \text{ (pyroxene – 1300°C)} \quad (2)$$

Generally, quartz (Si) like the other impurities, for example iron (Fe), decrease the heat resistance of the sand. The pure Fe is formed during high thermal stress (over 600°C), when the structure of chromite sand is changed and follow reaction of iron is occurred:

$$FeCr_2O_4 \text{ (chromite)} \rightarrow Fe(FeCr)_2O_4 \text{ (chrompicotite)} \quad (3)$$

$$FeO \rightarrow Fe_2O_3 \rightarrow Fe_3O_4 \text{ (magnetite)} \quad (4)$$

$$Fe_3O_4 \rightarrow 3Fe_{metal} \quad (5)$$

Various oxidative degrees of Iron is changed up to pure iron, which is released on the grain surface (see Fig. 1).

It is also take placed under reduction atmosphere. Thus the character of the sand is changed and this effect could be a source of various casting defects as burrs, burnt-on sand etc. [8-10].

During last couple years the other non – silica sands have been started to apply for high quality casting production and also as an alternative for chromite sand. This group mainly

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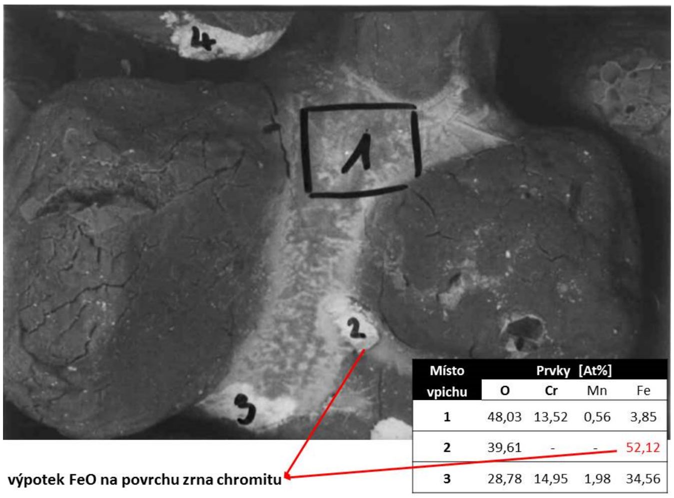

Místo vpichu	Prvky [At%]			
	O	Cr	Mn	Fe
1	48,03	13,52	0,56	3,85
2	39,61	-	-	52,12
3	28,78	14,95	1,98	34,56

Fig. 1. Detail of chromite grain after thermal stress with the rich iron region

includes sands based on aluminosilicates, where the mullite is basic mineral. Their main advantage are low thermal expansion (lower and/or similar to chromite sand); suitable heat resistance to production high quality casting (over 1750°C); value of bulk density is very close to silica sand (from 1.35 g/cm^3 up to 1.69 g/cm^3 in comparison with 1.7 g/cm^3 of silica sand) and two times lower in comparison with chromite and zircon sand. It leads to very significant costs reduction.

In the case when various sand are applied for core/mold production, there is also further positive effect. Chromite sand could be deposited in some technical facilities (cooler classifier, transport routes) due to higher bulk density. Thus presence of chromite in "system sand" (major applied sand) could causes some casting defects due to reaction between the individual sands (for example silica and chromite) and/or due to reaction with the melt (for example secondary re-oxidation). On the other hand the aluminosilicates are not deposited in system sand because they are generally exhausted during the transport of "system sand" to reclamation process.

There is a possibility to freely prepare blended sand consist of silica and alumina sands for automated core production to reduce core production costs. Also the pH value is closed to neutral level.

There is one disadvantage of aluminosilicate sand application. Generally, these sands have lower chilling effect in comparison with chromite sand because the aluminosilicates demonstrate lower value of thermal conductivity, but higher thermal capacity. So these sand operate as insulant. On the other hand it can be helpful for thin-wall casting production like impellers (mainly thin blades). Furthermore there is possibility to obtain the sand chilling effect by using any additives, with similar way how does it describe in Fig. 2 [11]. The other way is combination of sand with desirable coating with chilling effect (for example based on tellurium).

The goal of this article is to application of non-silica sands based on alumininosilicates as an alternative of traditionally used chromite sand for alloyed steel and iron castings

2. Materials and methods

Two various non – silica sand, commonly applied Chromite sand and mullite based sand LK – SAND®, were chosen. Following general parameters (Table 1) commonly used for characterization of sands were determined: a) bulk density, b) pH value of water suspension (1:10 solid-liquid ratio), c) chemical composition of major elements, d) refractoriness were determined. This summary was added with the parameters of commonly used silica sand.

Bulk density were determined according to internal standard of company SAND TEAM, spol. s r.o.. Chemical composition of the studied samples were determined using energy dispersive fluorescence spectrometer (XRFS) SPECTRO XEPOS (SPECTRO Analytical Instruments GmbH) equipped with 50 W Pd X-ray tube. The samples for analysis were prepared in the form of pressed tablets (wax was used as a binder) for this measure-

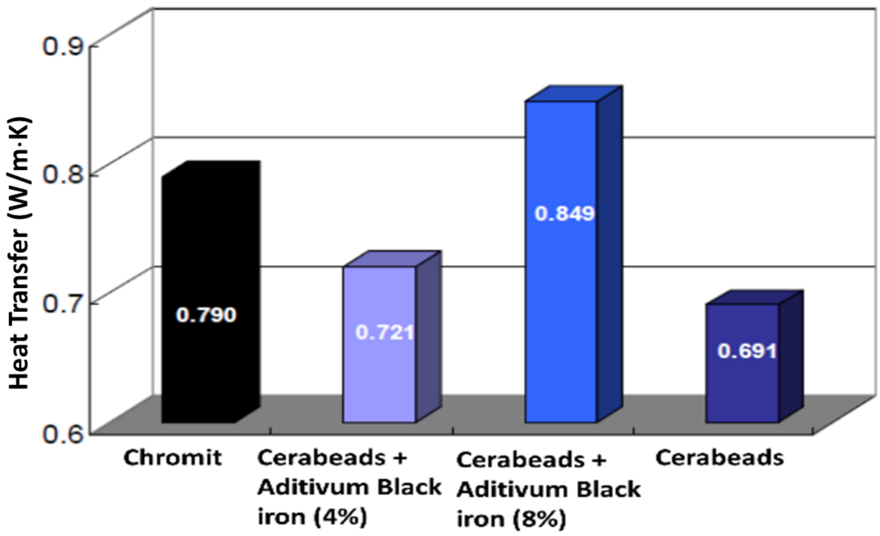

Fig. 2. Comparison of chilling effect of selected sands [11]

ment. Kind of main mineral and the way of production was obtained from technical data sheets of individual sands. The refractoriness were determined according to Czech standards ČSN EN 993-12:1998, Part 12 and according to ČSN EN 993-13:1996, Part 13.

The grain shape of a sand is also very important parameter. It has very significant influence on mechanical properties of moulding mixtures, durability etc. The grain shape of studied samples was determined using electron microscope JEOL JSM-6490LV. The grain shape were evaluated keeping constant magnification 500×.

In order to obtain complex physical – chemically properties of the studied sands, thermal expansion was also determined. Thermal expansion of studies samples were evaluated indirectly as a coefficient of thermal expansion based on the results of dilatometry analysis of individuals sand samples. Dilatometry analysis were conducted using NETZSCH DIL402C, samples were analysed in air atmosphere with the heating rate of 10°C/min from 20°C to 1000°C.

The samples of Furan No – Bake were prepared by 60 s of each component homogenization of the mixture of the studied sands with commonly used furan binder addition Kaltharz U204 TN 011 and catalyst mixture of Aktivator 500T1 and 100T3. The samples were rammed handy, and the transverse strengths were measured using testing machine LRU – 2e type.

Finally, the influence of non – silica sand on casting quality was evaluated via semi-scale under normal casting production.

3. Results and discussion

3.1. Characterization of studied sands

Several properties is typical for whole non-silica sands based on aluminosilicates. These properties give them a very interesting potential to widespread into common core/mould production. Basic physical-chemistry properties are summarized in Table 1. This table is replenish with data of silica and zircon sand to obtain full review. From this review it is evident, these sands could replace commonly used non-silica sands.

TABLE 1

Comparison of physical – chemically properties of selected sands

		LK-SAND®	Zircon	Chromite	Silica sand
Bulk density [g/cm^3]		1.35	2.95	2.81	1.58
pH value		5.8-6.5	5.7	7.9	6.6
Main mineral		Mullite	Zircon	Chromite	Quartz
Chem. composition*	Al_2O_3 [%]	42	—	—	—-
	SiO_2]%]	52.1-55.6	32	—	95-99
	ZrO_2 [%]	—	66	—	—
	Cr_2O_3]%]	—	—	45	—
	Fe_2O_3 [%]	—	—	25	—
Refractoriness [°C]		1750	>1800	1880	<1600
Way of production		Sintering	Natural	Natural	Natural

* only major elements are mentioned

From the review it is evident, the main difference is, that the chromite sand is natural sand in comparison with LK-SAND®. Also the difference of pH value was found. The pH value of chromite could be changed, normally from 7 up to 9(10), due to fact, that chromite is natural sand. Thus the pH content, calcium oxide (CaO) content respectively, differs based on the Chromite sand source. Based on its pH value, the LK-SAND® could be applied with whole commonly used binder systems and for casting production based on various alloys (mainly for grey and nodular cast irons and/or steel alloys). Thanks to the fact the silica is chemically bonded this sand is eco-friendly and it has no negative influence on working environment too. The LK-SAND® should be used individually or as a blended mixture with silica sand in moulding/core mixture due to similar value of bulk density and pH (mixture cost reduction). Even if the initial cost of aluminosilicate sand could be comparable and/or higher in comparison with chromite, it is necessary to mention significant differences of bulk density. It is evident that from 1 t of LK-SAND® it is possible to prepare 0.77 m^3 of moulding mixture in comparison with 0.34 m^3 of chromite. Due to this fact it is possible to prepare a bigger amount of cores/moulds (Fig. 3), but the weight of cores will be 2 times lower. This is also helpful for manipulation with the cores and friendly for core shop employees.

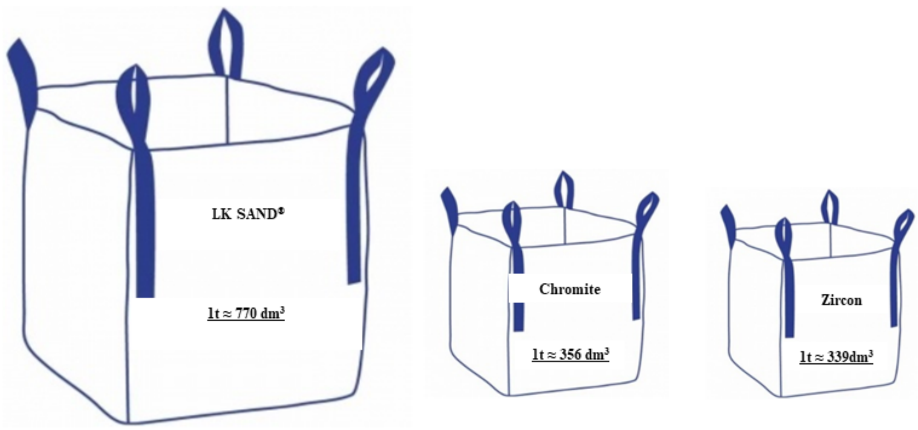

Fig. 3. Influence of sand bulk density on applicable sand amount

Further the heat resistance of the LK-SAND® is close to chromite sand. There is no negative effect of iron presence due to its low content, which was evaluated for LK-SAND®. In addition, there is observed good heat resistance for long time thermal exposition in comparison with chromite sand (helpfully for application of thin-wall cores). This behaviour is described in Fig. 4, and accords to typical behaviour of aluminosilicates generally. This effect was also described in [12].

Synthetic sand LK-SAND® presents coarse sand (Fig. 5 and Fig. 6; SEM analysis of LK SAND® and Chromite) with suitable properties for foundry production. The sand get rid of dust particles. Also it has high durability, what is helpful during the manipulation with the sand and/or during transport throw the foundry or reclaim process. Thus the dust content is not increased and medium grain size is not significantly changed.

The values of thermal expansion of LK-SAND® is lower in comparison with silica sand as a chromite sand (there is typical shrinkage 0.5% at 1400°C).

Lower values of thermal expansion of non silica sands is the next reason, why these sand had been applied for casting production. Very intensive thermal expansion of silica sand cause a lot of casting defects, mainly surface defects as veining, hot cracks, penetration etc. [13]. Comparison of thermal expansion were made indirectly as determination of coefficient of thermal expansion α in temperature range 20-1100C (Fig. 7).

This summary was added with the silica sand with different chemical purity to obtain complete concept. Generally, it is evident non – silica sands demonstrate linear thermal expansion without any maximum on the curve, that it is typical for silica sand due to change of crystal lattice from Alpha- to Beta-quartz,

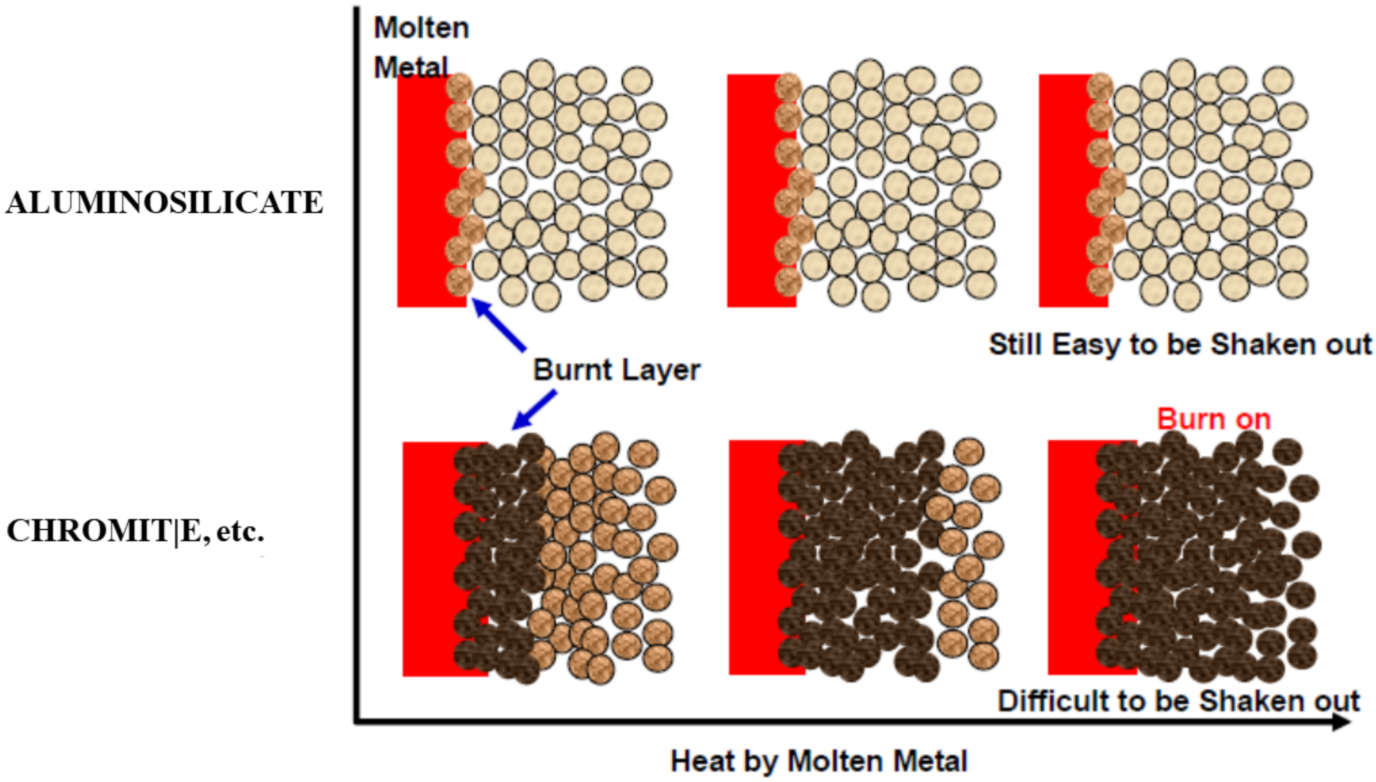

Fig. 4. Comparison of heat resistance of studied sands [12]

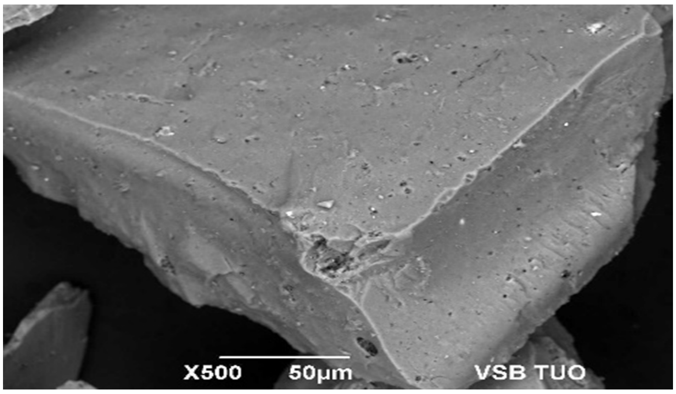

Fig. 5. Detail of LK-SAND® grain

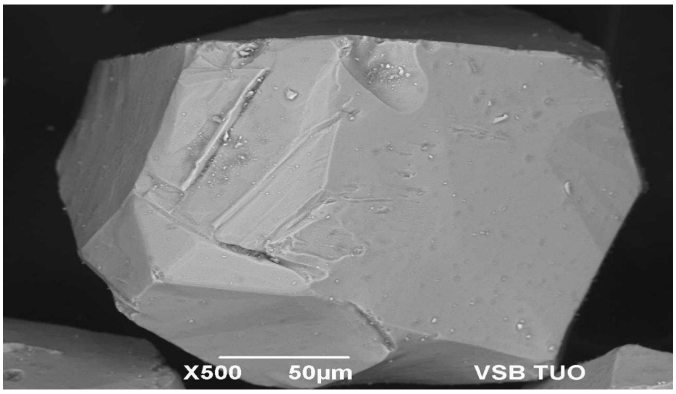

Fig. 6. Detail of chromite grain

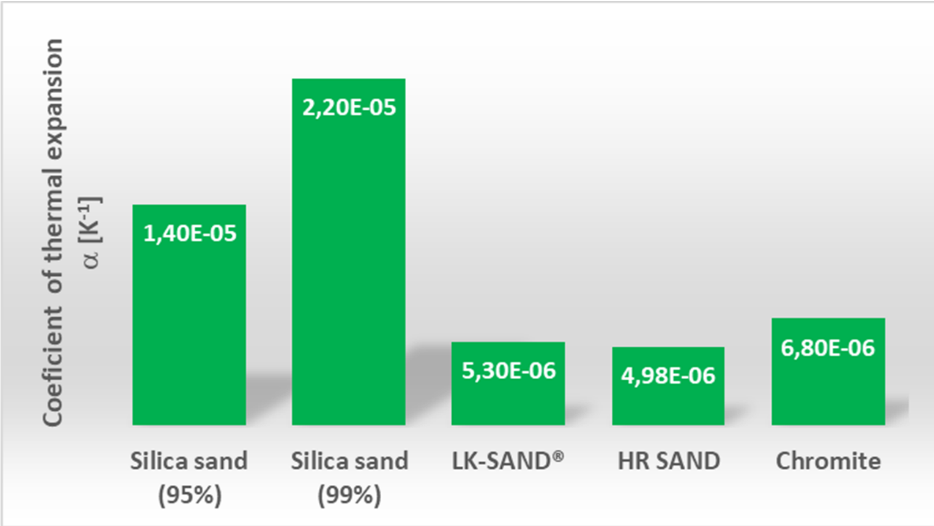

Fig. 7. Coefficient of thermal expansion of selected sands

which occurs close to 600°C) and the value of the expansion is up to 1 %. Generally it could be mentioned the LK-SAND® shows lower value of thermal expansion in comparison with chromite sand, which it could be helpful to limited the casting defects which they are caused by thermal expansion.

3.2. Casting trials

The LK-SAND®, which is rank into non – silica sand based on aluminosilicates, presents the sands with neutral and/ or slightly acid character. Due to this fact LK-SAND® could be used for whole commonly applied binder systems. Even if they could be used for mold manufacture, also as a uniform sand, but the most expanded application is core production. The semi-scale trials were conducted with furan no-bake cores. Furan binder Kaltharz U204 TN 011 and catalyst mixture of Aktivator 500T1 and 100T3 were used. Binder addition for mixtures with individuals testing sands is summarized in follow Table 2.

The difference of binder addition is caused with different bulk density (two times bigger volume of LK-SAND® in comparison with chromite, see Fig. 3), but if the binder addition is calculated as volume percentage, the binder addition correspond to each other.

TABLE 2

Influence of studied sands on mechanical properties of Furan No-Bake mixtures

Sand	Binder addition [%]	Transverse Strength/24h [MPa]
Chromite	1.2	2.18
LK-SAND®	2.4	1.92

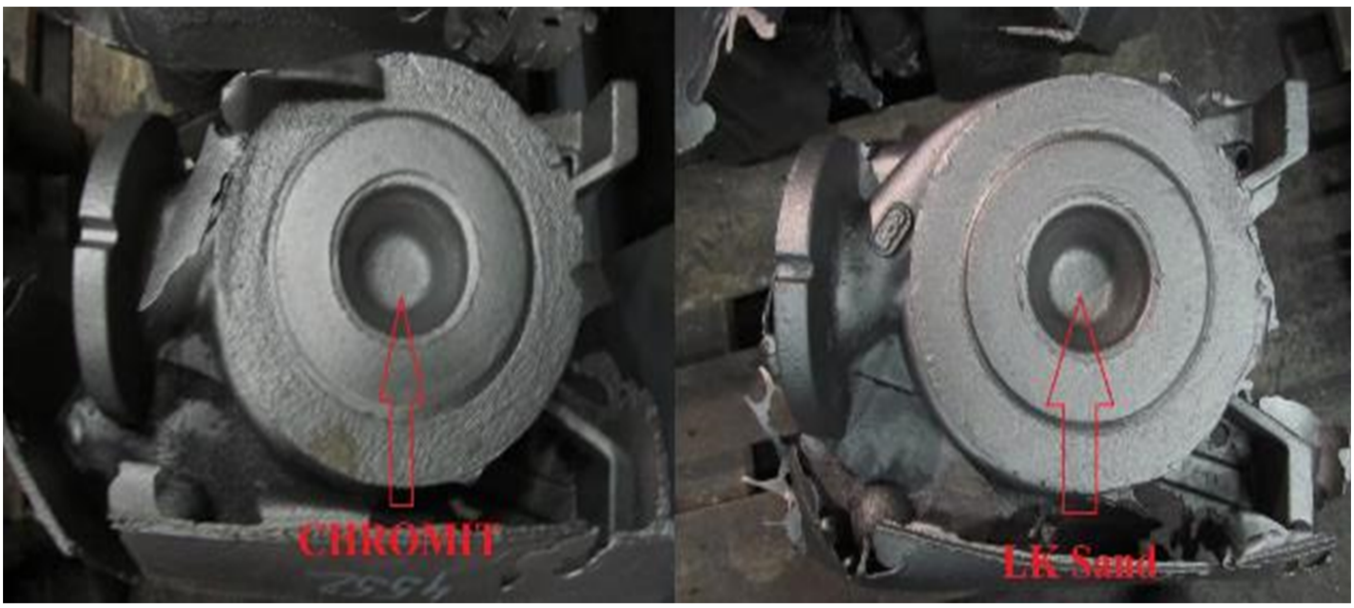

Fig. 8. Comparison of LK-SAND® and chromite for standard production

The trials were connected to production of commonly manufactured casting Spiral body manufacture from high alloyed steel (Fig. 8). The casting netto weight is 80 kg, pouring temperature was 1660°C. Both testing sands were used was used for core, which was situated directly under the two raiser. As a binder furan resin was used. Binder addition was 2 Vol % and 50% of the catalyst.

From the point of view of surface casting quality from the cores, where the studied sands were used, It is evident there was no significant difference between chromite and LK-SAND® application. It can be assumed the LK-SAND® could be applied as an alternative of commonly used Chromite sand.

4. Conclusion

Non silica sands based on aluminosilicates presents very interesting way of solution for various casting defects. Application of these sand group, namely LK-SAND® afford several advantages in comparison with standardly used non silica sands (chromite) LK-SAND® shows the similar heat resistance (elimination of burnt-on sands), lower thermal expansion (veining elimination) and there is not significant differences in mechanical strengths of the mixtures with various sands.

Generally known higher initial cost of this sand is compensated for lower bulk density in comparison with commonly used non silica sands. It means it is possible to produce bigger amount of core mixture and the core weights are lower. It is helpful mainly during manipulation with the cores and it is also pleasant for Core shop employees.

The main disadvantage of LK-SAND® (lower chilling effect, higher binder addition) could be effectively solved with various additives; application of suitable aluminosilicate and with keeping the basic rules for degassing of the cores and moulds.

Probably one of the most important property of this sand is stable initial costs. The price of LK-SAND® sand is not influenced by global effect, which has so significant effect nowadays.

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