

Livarski Pesek kot ključni dejavnik pri zagotavljanju končne kakovosti ulitka

Foundry Sand as the Main Factor in the Final Quality of The Casting

Povzetek

Ta prispevek se osredotoča na analizo vpliva granulometrične sestave različnih mešanic za jedra, sestavljenih iz izbranih vrst livarskih peskov, z namenom odpravljanja napak, zlasti žil, na težko dostopnih mestih ulitkov iz litega železa. Spojine za brizganje jedra sestavljajo celotno prostornino jedra in so pripravljene iz novih, visokokakovostnih surovin. V smislu kakovosti so zahteve zanje višje (imeti morajo večjo odpornost proti vdoru kovin, dobro razgradnjo po ulivanju, daljši rok uporabnosti). Te boljše lastnosti je mogoče zagotoviti s kombinacijo kremenčevih livarskih peskov in livarskih peskov brez kremenca, vendar je treba poznati kamenino in določiti ustrezno količino. V okviru te raziskave je bilo spremljanih pet različnih mešanic za jedra, iz katerih je bilo po postopku cold box izdelanih 15 jeder, pod enakimi pogoji pa je bilo ulitih 10 ulitkov. Vsako zrno je bilo analizirano s sitom, iz katerega so bile pridobljene osnovne lastnosti, kot so vrednost povprečnega zrna d_{50} , stopnja pravilnosti zrn, število zrn, merilo pravilnosti razporeditve zrn, teoretična specifična površina, delež grobih, srednje finih, finih, zelo finih zrn in delež prahu. Nato so bili uliti preskusni ulitki, ki so bili vizualno ocenjeni, ob tem pa je bila spremljana tudi odvisnost med dobljenimi značilnostmi opornikov in kakovostjo površine ulitkov.

Ključne besede: pesek, ulitek, sitna analiza, žile

Abstract

This contribution is focused on the analysis of the influence of the granulometric composition of various core mixtures composed of selected types of foundry sands with the aim of eliminating defects, especially veinings, in hard-to-reach places of cast iron castings. Core molding compounds make up the entire volume of the core and are prepared from new, high-quality raw materials. In terms of quality, higher demands are placed on them (they should have higher resistance to metal penetration, good disintegration after casting, longer shelf life). These better properties can be ensured by a combination of quartz and non-quartz foundry sands, but it is important to know the stone and set the appropriate amount. As part of this research, a total of 5 different core mixtures were monitored, from which a total of 15 cores were produced using the cold-box method and 10 castings were cast under the same conditions. Each grain was subjected to sieve analysis, from which the basic characteristics such as the value of the average grain d_{50} , the degree of regularity of the grain, the number of the grain, the criterion of the regularity of the arrangement of the grains, the theoretical specific surface area, the proportion of coarse, medium, fine, very fine and dust proportions were obtained. Subsequently, test castings were cast, which were visually evaluated, and the dependence between the obtained characteristics of the bracing and the resulting surface quality of the castings was monitored.

Keywords: sand, casting, sieve analysis, veinings

1 Uvod

Glavni prostorninski in masni delež v peščeni mešanici predstavlja pesek. Pesek lahko opredelimo kot zrnati ognjevzdržni material z velikostjo delcev nad 0,02 mm. Predstavlja osnovo form in jeder, zato med njegove najpomembnejše lastnosti, vključno z aktivnostjo površine zrn, spadata tudi oglatost in granulometrija delcev. Zadnji dve lastnosti vplivata na gostoto, poroznost in s tem tudi na zračnost in prepustnost mešanice, toplotno raztezanje in nastanek napetosti zaradi omejenega toplotnega raztezanja, toplotno prevodnost mešanice, ki do določene mere določajo trdnost form in jeder [1][2][3][4][5].

Vrednost 0,02 mm je kritična velikost peščenih delcev. Delci, manjši od te vrednosti, se uvrstijo v tako imenovani delež odpranih snovi [6].

Osnovne lastnosti livarskih peskov so zlasti velikost zrn, značilnosti površine zrn in njihova kemijska čistost. Zelo pomembna značilnost je pravilnost peska. Z večanjem vsebnosti nepravilnih zrn se povečuje stisljivost, prepustnost pa se zmanjšuje. Oblika, površina zrn in kemijska čistost bolj vplivajo na trdnost ali tehnološke lastnosti peščene mešanice [7][8].

Zrnavost označuje granulometrično strukturo zrna, tj. velikost delcev, ki sestavljajo zrno. Ta lastnost vpliva predvsem na kakovost površine ulitka. Bolj ko so zrna ostroroba, boljša je kakovost površine ulitka in manjša je hrapavost površine. Vendar se prepustnost zmanjšuje sorazmerno z drobnostjo školjkastih zrn [9][10].

Z večanjem oglatosti zrn se povečuje poraba veziva, saj je učinkovita površina (površina, ki jo navlaži vezivo) oglatih zrn večja od površine okroglih zrn. Na robovih zrn se ovoji veziva pretgajo, zaradi česar se mehanske lastnosti zmesi zmanjšajo. Povečanje vrednosti mehanskih lastnosti

1 Introduction

The main volume and mass fraction in the molding mixture is the sand. We can define sand as a granular refractory material with a particle size above 0.02 mm. It forms the material skeleton of molds and cores, and therefore its most important properties, including grain surface activity, also include the angularity and granulometry of the particles. These last two characteristics influence bulk density, porosity and thus also on the breathability and permeability of the mixture, thermal expansion, and the generation of stresses from inhibited thermal expansion, thermal conductivity of the mixture, which to a certain extent determine the strength of molds and cores [1][2][3][4][5].

The value of 0.02 mm is the critical size of the sand particles. Particles smaller than this value are classified into the so-called leachable fraction [6].

The basic properties of foundry sands are, in particular, grain size, characteristics of the grain surface and its chemical purity. A very important feature is the regularity of the sand. With the increase in the content of irregular grains, the compactibility increases and the permeability decreases. The shape, surface of the grain and chemical purity rather affect the strength or technological properties of molding mixtures [7][8].

Granularity indicates the granulometric structure of the grain, i.e. the size of the particles that make up the grain. This property mainly affects the quality of the surface of the casting. The finer the sharpening, the higher the quality of the casting surface and the lower the surface roughness value. However, the permeability decreases proportionally with the fineness of the oyster grains [9][10].

As the angularity of the grains increases, the binder consumption

lahko ponovno dosežemo z dodajanjem več veziva, vendar to lahko povzroči več napak na ulitku. Zaradi tega oglatih abrazivov ni mogoče učinkovito kombinirati z organskimi vezivi. Po Jelínku se oglatost povečuje s finostjo peska [11, 12, 13]. Najbolj optimalne so okroglozrnate vrste peska, ki zagotavljajo najbolj optimalen sistem veziva [14].

2 Materiali in metode

Peski: kremenčev pesek z nahajališča Biela Góra, LK-PESEK, Cerabeads, Kerphalite KF, kromitni pesek. Cerabeads je idealen pesek za najzahtevnejše ulitke iz avstenitnih krom-nikljevih jekel ter drugih visoko legiranih jekel in železovih litin [15].

Veziva:

Komponenta I – GASHARZ 6747 – rumena sintetična smola v obliki tekočine z gostoto $1,07\text{--}1,08\text{ g/cm}^3$ po postopku cold-box. Odlikujejo ga visoka temperaturna stabilnost, dolgotrajna obdelovalnost peščene zmesi in nizka stopnja lepljivosti. Obdelano je z aktivatorjem v razmerju 1:1.

Komponenta II – aktivator 8196 je raztopina modificiranega izocianata v ustreznem topilu z gostoto $1,210\text{--}1,230\text{ g/cm}^3$.

Določanje deleža odpranih snovi

Odtehtajte 50 g posušenega in ohlajenega peska v čašo s prostornino 300 ml in dodajte 250 ml destilirane vode. Vsebina posode vre 3 do 4 minute, nato pa se 10 minut meša s propellerskim mešalnikom. Dodajanje natrijevega hidroksida preprečuje nastajanje grudic delcev žilindre. Mešalnik speremo in čašo napolnimo z močnim curkom vode, tako da je njena gladina 10 cm nad spodnjim robom sesalne odprtine šobe. Po 10 minutah – po usedanju se voda z delci, manjšimi od 0,02 mm, posesa s črpalko, visokim 0,1 mm, do oznake na črpalki. Ko se zmes

increases, because the effective surface (the surface that is wetted by the binder) of angular grains is larger than the surface of round grains. At the edges of the grains, the binder envelopes are broken, which leads to a decrease in the mechanical properties of the mixtures. An increase in the values of mechanical properties can be achieved again by adding more binder, but this can cause several casting defects. For these reasons, angular abrasives cannot be effectively combined with organic binders. According to Jelínek, angularity increases with fineness of the sand [11, 12, 13]. The most optimal are round-grained types of sand, which ensure the most optimal binder system [14].

2 Materials and methods

Sands: quartz sand from the Biela Góra locality, LK - SAND, Cerabeads, Kerphalite KF, chromite sand. Cerabeads is an ideal sand for the most demanding castings from austenitic chromium nickel steels and other highly alloyed steels and cast irons [15].

Binders:

Component I - GASHARZ 6747 – yellow synthetic resin in the form of a liquid with a density of $1.07 - 1.08\text{ g/cm}^3$ cold-box process. It is characterized by high temperature stability, long workability of the sand mixture and low stickiness. It is processed with an activator in a ratio of 1:1.

Component II - Activator 8196 is a solution of modified isocyanate in a suitable solvent with a density of $1.210 - 1.230\text{ g/cm}^3$.

Determination of flushable particles

Weigh 50 g of dried and cooled sand into a beaker with a volume of 300 ml, add 250 ml of distilled water. The contents of the beaker are boiled for 3 to 4 minutes and then mixed with a propeller stirrer for 10 minutes. The addition of sodium hydroxide

usede, se voda ponovno izsesa in postopek se ponovi, dokler voda nad usedlino ni čista. Preostanek čiste vode odlijemo in pesek v čaši posušimo pri temperaturi 100 °C. Na koncu se trdna snov stehta in izračuna količina odpranih snovi [16].

Sejalna analiza

Bistvo testa je določiti granulometrično sestavo zrn s sejanjem na kompletu sit, določiti srednjo velikost zrn d_{50} in stopnjo pravilnosti glede na krivuljo skupne velikosti zrn. Po določitvi odpranih snovi se vzorec posušenih izboklin prelije na predhodno preverjen komplet sit, zapre s pokrovom in za 15 minut se vključi sejalno napravo [16].

Določanje upogibne trdnosti

Ta preskus trdnosti se določi z uporabo upogibne obremenitve na normaliziran vzorec, utrjen na predpisan način, in se določi z upogibno obremenitvijo, pri kateri se preizkušane uniči. Upogibna trdnost je bila izmerjena takoj po utrjevanju upogibnega vzorca in po 24 urah [16].

Proizvodnja jedra

Jedra preskusnih ulitkov so bila izdelana po metodi cold-box-amine, tako da je bila peščena mešanica za jedra vpihana v napravo za izdelavo jeder LAEMPE LL20 pri tlaku 3 bare. Katalizator je DMPA, imenovan katalizator 704. Vsi potrebni materiali so se črpali neposredno iz vsipnih rezervoarjev avtomatskih strojev za izdelavo jeder.

3 Rezultati in razprava

Najnižjo vrednost d_{50} je imel Kerphalite KF, sledil mu je Cerabeads, približno enako vrednost sta imela kremenčev pesek in LK-pesek, najvišjo vrednost pa kromitni pesek. Vrednost srednje velikosti zrn d_{50} (srednje zrno) je osnova za oceno zrnatosti peska, odčitano iz diagrama zrnatosti za vrednost 50 % peska, ki se ujame na sita. Hkrati je odločilen dejavnik za doseganje zahtevane

prevents the clumping of the slag particles. The stirrer is rinsed and the beaker is filled with a strong stream of water so that the level is 10 cm above the lower edge of the suction opening of the nozzle. After 10 minutes - after settling, water with particles smaller than 0.02 mm is sucked off using a suction cup with a height of 0.1 mm, up to the scale on the suction cup. After settling, the water is sucked out again and the process is repeated until the water above the settlement is clean. The rest of the clean water is poured out and the sand in the beaker is dried at a temperature of 100 °C. Finally, the solid is weighed and the number of flushable substances is calculated [16].

Sieve analysis

The essence of the test is to determine the granulometric composition of the grain by sowing on a set of sieves, to determine the size of the medium grain d_{50} and the degree of regularity according to the total grain size curve. After the determination of leachable substances, the sample of the dried outcrop is poured onto a pre-checked set of sieves, closed with a lid and the seeding machine is switched on for 15 minutes [16].

Determination of bending strength

This strength test is determined by the application of a bending load to a normalized sample hardened in the prescribed manner and is determined by the bending stress at which the test specimen is destroyed. The bending strength was measured immediately after hardening of the bending sample and after 24 hours [16].

Core production

The cores of the test castings were produced by the cold-box-amine method by blowing the core mixture in a LAEMPE LL20 core machine at a shot pressure of 3 bars. The catalyst is DMPA called Catalyst 704. All the necessary materials were drawn

kakovosti površine ulitka. Gre za kompromis med zahtevano finostjo površine ulitka in potrebno prepustnostjo za pline peščene mešanice [17].

Razmerje med vrednostmi d_{75}/d_{25} označuje vrednost enakomernosti zrn. Z večanjem nepravilnosti velikosti zrn se povečuje stisljivost in zmanjšuje prepustnost peščene mešanice, hkrati pa se povečuje trdnost, vendar je take forme težje odstraniti od modela. Ko se stopnja pravilnosti zrn približuje vrednosti 1, je ostrost bolj enakomerna in obratno [17]. Za najbolj enakomeren pesek se lahko šteje pesek Cerabeads, ki mu sledijo pesek Kerphalite, kromitni pesek, kremenčev pesek in LK-pesek.

Osnovne značilnosti testiranih peskov, pridobljene po določitvi izluženih snovi na podlagi sejalne analize, so prikazane v preglednici 1.

Na sliki 1 so prikazane krivulje skupne velikosti zrn posameznih peskov. Krivulje skupne velikosti zrn peska Cerabeads in Kerphalite imajo podoben potek, vendar se hkrati razlikujejo od krivulj skupne velikosti zrn kremenovega peska, LK-peska in kromitnega peska zaradi večjih deležev drobnih, zelo drobnih in prašnih delcev.

Največ grobih zrn je bilo v kremenovem in kromitnem pesku, medtem ko sta imela

directly from the filling reservoirs of the automated machines producing the cores.

3 Results and Discussion

Kerphalite KF had the lowest d_{50} value, followed by Cerabeads, quartz sand and LK-Sand had about the same value, and chromite sand had the highest value. The value of the average grain size d_{50} (medium grain) is the basis for assessing the grain size of the sand, it is read from the grain size diagram for the value of 50% of the sand caught on the sieves. At the same time, it is a decisive factor for achieving the required surface casting quality. It is a compromise between the required smoothness of the casting and the necessary breathability of the molding mixture [17].

The ratio of d_{75}/d_{25} values indicates the value of grain uniformity. As the irregularity of the grain size increases, the compressibility increases and the permeability of the molding mixtures decreases, at the same time the strength of the molding mixture increases, but such molds are harder to punch out. When the degree of grain regularity approaches the value 1, the sharpness is more uniform and vice versa [17]. Cerabeads sand can be considered the most uniform sand, followed

Preglednica 1. Rezultati analize testiranih peskov s sitom

Table 1. Results of tested sands sieve analysis

	Kremenčev pesek / Quartz sand	LK-pesek / LK-Sand	Cerabeads	Kerphalite KF	Kromitni pesek / Chromit sand
S_{th} [cm ² /g]	79,51	56,1	107,51	115,95	74,06
AFS	45,3	45,1	61,3	66,1	42,2
d_{50} [mm]	0,316	0,319	0,216	0,207	0,327
d_{75} [mm]	0,240	0,233	0,178	0,163	0,260
d_{25} [mm]	0,419	0,415	0,261	0,249	0,424
d_{75}/d_{25}	57,4	56,1	68,2	65,7	61,4
log w [%]	64,9	60,3	53,4	54	60,1
Delež pod mm / Fraction under [%]	0,05	0,10	0,1	0,91	0,2

LK-pesek in Cerabeads enako, vendar manjšo količino grobih zrn. Kerphalite KF ne vsebuje grobih zrn. Kremenov pesek, LK-pesek in kromitni pesek imajo približno enako in razmeroma visoko vsebnost srednje velikih zrn. V primerjavi s prej omenjenimi peski sta imela Cerabeads in Kerphalite KF trikrat manj srednje velikih zrn, vendar dvakrat več drobnih zrn in 2,5- do 3-krat več zelo drobnih zrn. Ta dva peska sta bila tudi edina, ki sta vsebovala prašne delce (Slika 2).

Po odstranitvi odpranih snovi in drobnih delcev pesek poveča trdnost mešanici z organskim vezivom, ne glede na vrsto kremenčevega peska [1], kar dokazuje tudi graf na sliki 3, kjer ima najvišje vrednosti upogibne trdnosti kromitni pesek, za katerega je značilen najmanjši delež drobnih in zelo drobnih zrn ter največja vsebnost srednjih zrn. Hkrati ima vpliv grobih delcev nad 0,4–0,5 mm negativen učinek na dobljeno trdnost [1], kar v tem

by Kerphalite sand, chromite sand, quartz sand and LK-Sand.

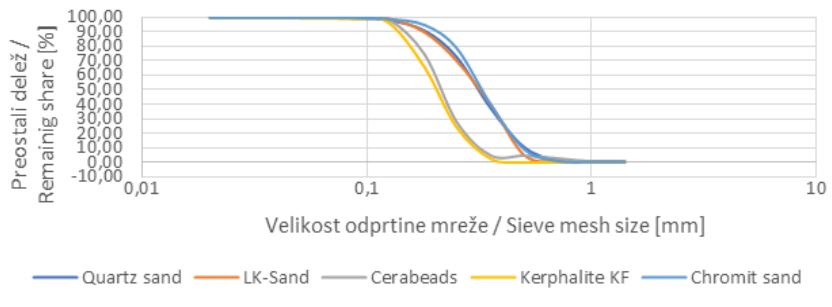
The basic characteristics of the tested sands obtained after the determination of leachable substances from sieve analysis are shown in Tab. 1.

Fig. 1 shows the total grain size curves of individual sands. The total grain size curves of the Cerabeads and Kerphalite sands have a similar course but at the same time different from the total curves of the quartz sand, LK-Sand and chromite sand due to higher proportions of fine, very fine and dust particles.

The highest amount of coarse grains was found in quartz and chromite sand, while LK-Sand and Cerabeads had the same but lower amount of coarse grains. Kerphalite KF doesn't contain any coarse grains. Quartz sand, LK-Sand, and chromite sand has approximately the same and relatively high content of medium-sized grains. Compared to the aforementioned

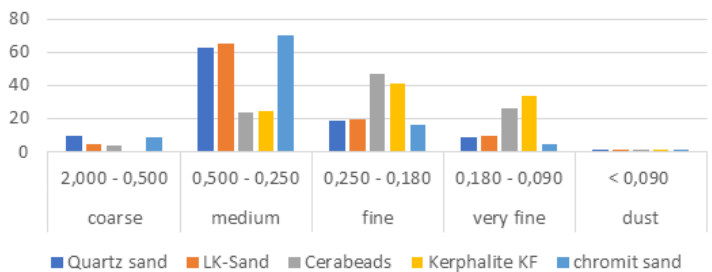
Slika 1. Krivulje kumulativne porazdelitve velikosti zrn testiranih peskov

Figure 1. Cumulative grain size distribution curves of tested sands



Slika 2. Analiza deleža frakcij testiranih peskov na silih

Figure 2. Fraction proportion analysis tested sands on sieves



primeru ne velja zaradi majhne vsebnosti grobih delcev v testiranih peskih (do 10 %). Drobne frakcije imajo veliko površino in povečajo porabo veziva, zaradi česar se zmanjšata debelina zrnatega ovoja veziva in trdnost zmesi. Tako najbolj drobni deli v ovoju veziva delujejo kot notranje vdolbine [1]. Preizkušene palice, ki so vsebovale LK-pesek, so imele najnižje vrednosti upogibne trdnosti, vendar v tem primeru to ni povezano samo z vsebnostjo drobnih delcev in prašnih frakcij, saj je imel ta pesek približno enak delež vseh frakcij kot kremenčev pesek, temveč je to povezano tudi z ostrimi robovi in nepravilno obliko zrn.

Jedra testiranih ulitkov (Slika 4) so bila izdelana iz petih različnih mešanic, sestavljenih iz različnih peskov in enake količine veziva 1,6 %. Vsi potrebni materiali so se zajemali neposredno iz vsipnih lijakov avtomatiziranih strojev za izdelavo jedra.

Na površini večje luknje preskusnega ulitka iz peščene mešanice, ki je vsebovala kremenčev pesek, so bili izrastki veliki do 1 mm. V malih votlinah je bilo skupaj 6 izrastkov velikosti do 2,5 mm (Slika 5(1)).

Na površini lukenj testnih odlitkov, katerih jedra so bila izdelana iz otočka LK-peska (Slika 5(2)), so bili drobci, hrapava površina, izrastki velikosti 3–4 mm in nič srhov povzročenih s pokanjem jeder.

Površina lukenj preskusnih ulitkov iz jeder iz peska Cerabeads (Slika 5(3)) je bila rahlo hrapava, brez srhov ali drugih napak.

Površina lukenj preskusnih ulitkov iz jeder peska Kerphalite (Slika 5(4)) je imela gladko površino z znaki nastajanja izjed, brez srhov in drugih napak.

Površina votlin testnih ulitkov iz jeder iz kromitnega peska (Slika 5(5)) je imela hrapavo površino brez srhov in drugih napak.

sands, Cerabeads and Kerphalite KF had three times less medium-sized grains but twice as many fine grains and 2.5 – 3 times more very fine grains. These two sands were also the only ones that contained dust particles (Figure 2).

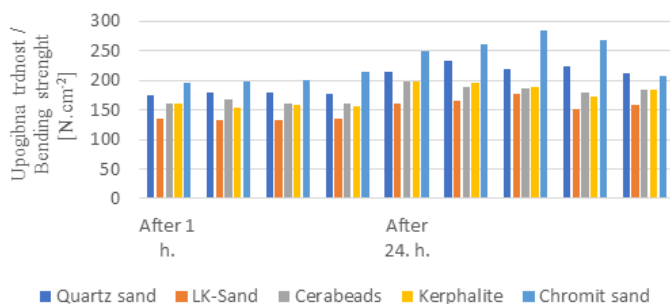
After the removal of leachable parts and fine particles, sand increases the strength of mixtures with an organic binder, regardless of the type of quartz sand [1], which is also proven by the graph in Fig. 3, where the highest values of the bending strength have the chromite sand, which is characterized by the lowest proportion of fine and very fine grains and the highest content of medium grains. At the same time, the effect of coarse particles above 0.4-0.5 mm has an adverse effect on the resulting strength [1], which is not the case in this case due to the small content of coarse particles in the tested sands (up to 10%). Fine fractions have a large surface and increase the consumption of the binder, as a result of which the thickness of the grain envelope of the binder and the strength of the mixtures are reduced. Thus, the finest parts in the envelope of the binder act as internal indentations [1]. The tested bars containing LK-Sand had the lowest bending strength values, but in this case it is not only related to the content of fine particles and dust fractions, because this sand had approximately the same proportion of all fractions as the quartz sand, but it is also related to sharp-edged and irregular grain shape.

The cores of the tested castings (Fig. 4) were made from 5 different core mixtures composed of different sand and the same amount of binder 1.6 %. All the necessary materials were drawn directly from the filling hoppers of the automated core-making machines.

On the surface of the larger hole of the test casting from the core mixture containing

Slika 3. Upogibna trdnost testiranih standardiziranih palic, izdelanih iz testiranih mešanic peščenega jedra

Figure 3. Bending strenght of tested standardized bars made from the tested sands core mixtures



Slika 4. Jedra, izdelana iz mešanic testiranih peskov

Figure 4. Cores made from core mixtures of testes sands



Slika 5. Reprezentativni posnetki površin testiranih ulitkov

Figure 5. Representative images of the tested casting surface

4 Zaključek

Ulitki iz peskov brez kremenca v nasprotju z ulitki iz kremenčevega peska niso vsebovali srhov zaradi nezveznega toplotnega raztezanja kremenčevega peska. Ulitek iz LK-peska brez kremenca je bil edini z vključki in izrastki, kar je povezano z najnižjimi vrednostmi upogibne trdnosti v primerjavi z drugimi peski, kar je povezano z oglasto obliko zrn tega peska. Iz rezultatov poskusov izhajajo naslednje ugotovitve:

quartz sand there were outgrowths up to 1 mm in size. There was a total of 6 outgrowths up to 2.5 mm in size in the small cavities (Fig. 5(1)).

On the surface of the holes of the test castings, the cores of which were made from the LK-Sand mixture (Fig. 5(2)) there were crumbs, a rough surface, growths of 3-4 mm in size and no veinings.

The surface of the holes of the test castings from the cores from the Cerabeads

vrednost d_{50} ne vpliva na kakovost površine ulitkov, kromitni pesek je imel višjo srednjo velikost zrn v primerjavi s kremenčevim peskom, kljub temu pa je bila površina ulitkov kakovostna; stopnja pravilnosti zrn S pomembno vpliva na površino ulitkov; delež grobih in prašnih delcev v pesku je povezan z dobljeno kakovostjo ulitkov, vendar je za vsak pesek individualen, kromitni pesek je imel približno enako razmerje posameznih deležev kot kremenčev pesek in LK-pesek, kljub temu ni bilo poleg hrapave površine vidnih drugih napak; teoretična površina zrn S_{th} ima pomemben vpliv na hrapavost ulitka, najvišjo vrednost S_{th} je imel Kerphalite KF, ki je imel tudi najbolj gladko površino.

sand (Fig. 5(3)) it was slightly roughened with no veinings or other defects.

Surface of holes of test castings from cores from Kerphalite (Fig. 5(4)) they had a smooth surface with signs of small pitting without occurrence of veinings and other defects.

Surface of cavities of test castings from cores from chromite sand (Fig. 5(5)) they had a roughened surface with no veinings or other defects.

4 Conclusion

Castings from non-quartz sands, unlike casts from quartz sand, did not contain veinings due to non-continuous thermal expansion of the quartz sand. Casting from the non-quartz sand LK-Sand was the only one with inclusions and growths, which is related to the lowest values of bending strength compared to the other sands, which is related to the angular shape of the grains of this sand. The following conclusions emerge from the results of the experiments: the d_{50} value does not affect the surface quality of the castings, the chromite sand had a higher mean grain value compared to the quartz island, and yet the casting had a high-quality surface; the degree of grain regularity S has a significant effect on the resulting surface of the castings; the proportion of coarse and dusty parts in the sand is related to the resulting quality of the castings, but it is individual for each sand, the chromite sand had approximately the same proportion of individual shares as the quartz sand and the LK-sand, despite this, there were no in addition to the roughened surface, other defects are visible; the theoretical surface of the S_{th} grains has a significant influence on the roughness of the casting, the highest S_{th} value was the Kerphalite KF, which also had the smoothest surface.

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