H. Polzin, T. Kooyers
Peak Deutschland GmbH, Nossen, Nemčija / Peak Deutschland GmbH, Nossen, Germany

Izkušnje s termičnim strjevanjem anorganskih veziv za forme

Experiences with thermosetting Inorganic Molding Binder System

Povzetek

Ta prispevek opisuje postopek izdelave jeder iz anorganskih veziv in sušenja z vročim zrakom, ki smo ga že predstavili na predhodnih dogodkih in v katerem uporaba aktivno ogrevanega orodja za izdelavo jedra ni potrebna. [1] S pomočjo tega sistema smo imeli v zadnjem času več pozitivnih izkušenj. Predstavljene so lastnosti spojin za forme, proizvedene z vezivom, na primer dosegljive trdnosti pri različnih pogojih strjevanja ali preostale napetosti po litju ulitkov. Čeprav je bil sistem razvit posebej za livarne, ki se ukvarjajo z litjem železa ali jekla, so prikazani primeri jeder tako iz sektorja železovih litin kot sektorja neželezovih kovin. Čeprav je bilo vezivo prvotno razvito za utrjevanje formatski materialov z vročim zrakom pri približno 160 °C, se lahko sistem brez tega uporablja tudi s katerim koli jedrovnikom z ogrevanim jeklenim jedrovnikom. Predstavljeno anorgansko vezivo na osnovi vodnega stekla predstavlja alternativo postopku PUR Coldbox, ki ga je mogoče uporabljati pri litju železa in jekla. V primerjavi s podobnimi vezivi se odmeri manjša količina enokomponentnega veziva; količine veziv, uporabljene do sedaj, merijo med 1,5 % in 2,5 %, vendar jih je mogoče po potrebi tudi povečati. Enokomponentni sistem poenostavi odmerjanje veziva v napravo za proizvodnjo jeder, želene trdnosti pa se zagotovijo skozi primerljivo večje specifične trdnosti. Sušenje proizvedenih jeder poteka s toplim zrakom za prepihovanje pri temperaturi 160 °C. Orodje za izdelavo jedra se med postopkom ne greje. Pri izbiri materiala za jedrovnik je treba zagotoviti uporabo plastike z ustrezno toplotno odpornostjo. Kovinski (aluminijasti ali jekleni) jedrovniki zagotavljajo prednosti v smislu krajšega časa cikla. V primeru uporabe izredno suhega zraka lahko utrjevanje poteka pri nižjih temperaturah. Vezivo se lahko seveda uporablja tako v postopkih Warmbox kot Hotbox. Dejstvo, da se nastanek razpok v jedriozni pojavi samo v izjemnih primerih pri jedrih z anorganskimi vezivi, je zagotovo dobrodošla prednost v komori za prepihovanje. Preostala trdnost ter obnašanje pri odstranjevanju jedra sta zelo podobna kot pri postopku PUR Coldbox. Poleg veziv, zasnovanih za železne in jeklene ulitke, so na voljo tudi različice za aluminijaste ali bakrene ulitke.

Abstract

We report on a hot-air curing inorganic core-making process already presented at previous events, which works without an actively heated core-making tool. [1] A number of positive experiences have been made with this system recently. The properties of molding compounds produced with the binder system are presented, for example, the achievable strengths under different solidification conditions or the residual tension after pouring of the castings. Although the system was developed in particular for customer foundries operating in the iron or steel casting sector, core examples from both the iron and non-ferrous casting

sectors are shown. Although the binder system was originally developed for curing the molding material with hot air at about 160°C, the system can also be used without further ado with any heated steel core boxes that may be present.

The presented inorganic binder system based on water glass represents an alternative to the PUR cold box process that can be used in iron and steel casting. The liquid one-component binder is metered at a lower rate than comparable binder systems; binder quantities used to date are between 1.5 and 2.5 %, but can also be increased if required. The single-component system facilitates binder metering on the core shooter, and the desired strengths are ensured via comparably higher specific strengths. The curing of the manufactured cores takes place via 160°C warm gassing air. The core making tool is not heated in the process. When selecting the core box material, care should be taken to use appropriately thermally resistant plastics. Core boxes made of metal (aluminum or steel) offer advantages in terms of shorter cycle times. When using particularly dry air, curing can be realized at lower temperatures. The binder system can, of course, also be used in the warm or hot box process. The fact that sheet veining only occurs in exceptional cases with the inorganically bonded cores is certainly a welcome advantage in the blowroom. The residual tension or decoring behavior is very similar to that of the PUR cold box process. In addition to the binders designed for iron and steel castings, variants for aluminum or copper castings are also available.

1 Uvod

Na sejmu GIFA 2003 so različni proizvajalci veziv prvič predstavili napredek na področju novih termoreaktivnih anorganskih veziv, napredek pa še vedno poteka. Podlaga za te razvoje je bilo splošno znano dejstvo, da je mogoče s segrevanjem izdelati forme z vezivom iz vodnega stekla znatno večje trdnosti kot npr. tradicionalnim prepihovanjem z ogljikovim dioksidom. Te visoke trdnosti predstavljajo ključno zahtevo za anorganska veziva, saj eden glavnih vzgibov za ta razvoj prihaja iz avtomobilske industrije oz. obsežne proizvodnje včasih izredno kompleksnih in filigranskih jeder za sestavne dele vozil. Glede na trenutno stanje tehnologije se vezivo na osnovi silikatov običajno zmeša z osnovnim materialom za formo. Nato se dovede v formo za izdelavo jedrovnika, segreto na 160–200 °C, v katerem nastane stabilna skorja. Kombiniranjem tega procesa z prepihovanjem z vročim zrakom je mogoče

1 Introduction

Starting with GIFA 2003, work on the development of new thermosetting inorganic binder systems was presented by various binder manufacturers and is still ongoing today. The basis for these developments was the well-known fact that tempered molds can bring water glass-bonded molding materials to significantly higher strengths than, for example, with classical carbon dioxide gassing. These high strengths were a fundamental requirement for inorganic binder systems, since one of the main impulses for this development came from the automotive industry and thus from the large-scale production of sometimes highly complex and filigree cores for vehicle components. The current state of the art is still that a silicate-based binder system is usually mixed with the mold base material and shot into a core-making mold tempered to 160 - 200°C, in which a stable shell is formed.

čas cikla spraviti do ustrezne ravni. Glavna pomanjkljivost teh postopkov je, da jih je mogoče zaradi visokih stroškov izdelave orodij in energije uporabljati samo v obsežni proizvodnji jeder (običajno pri izdelavi ulitkov za avtomobilsko industrijo). Poleg tega so postopki zaradi niza nezadostnih tehnoloških lastnosti (npr. preostala trdnost/vedenje ob razpadu) omejeni na proizvodnjo ulitkov iz aluminija. Pregled teh procesov, ki je v veliki meri še vedno aktualen, je podan na sl. [2].

Razvoj predstavljenega veziva naj bi livarnam železovih litin, ki so v številnih primerih *butične* proizvodnje, kjer se nabor izdelkov pogosto spreminja, omogočil uporabo jeder z anorganskimi vezivi. Tukaj je pomemben vidik odprava dragega segrevanega jeklenega orodja za izdelavo jedrovnika, ki je upravičeno izključno v obsežni proizvodnji. Uporabljeno je vezivo na osnovi alkalnega silikata ali vodnega stekla, modificiranega s celo vrsto oksidov in ki ne vsebuje organskih komponent [3]. Strjevanje materiala forme se doseže izključno z naplinjanjem z zrakom temperature pribl. 160 °C. Vezivo je enokomponentno. Enokomponentno vezivo je mogoče brez aditivov odmerjati v količini manj kot 2,5 %, pogosto celo manj kot 2 %.

2 Praktične izkušnje

2.1 Primerjava trdnosti formarskih materialov

Na sl. 1 in 2 je primerjava upogibne trdnosti veziv s tremi komercialno dostopnimi anorganskimi vezivi (imenovana B1 do B3). Prva opazna razlika je količina uporabljenega veziva, saj je treba pri teh vezivih uporabiti dejansko vezivno sredstvo kot tudi vsaj en aditiv. Primerjani so sistemi Warmbox. Procesni parametri

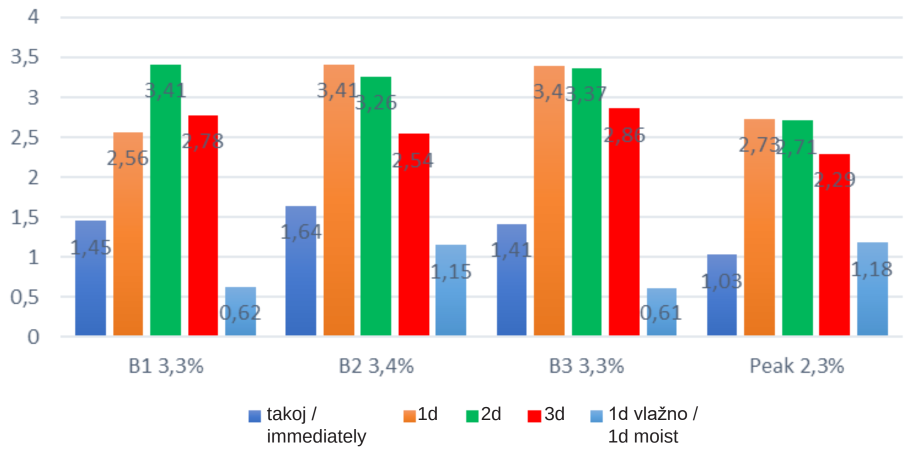
By combining this process with hot air fumigation, cycle times can be brought into reasonable ranges. The main disadvantage of these processes is that they can only be used in high-volume core production (usually automotive casting) due to the high tooling and energy costs. In addition, due to various insufficient technological properties (e.g. residual tension / collabsibility behavior), the application is limited to the production of aluminum castings. An overview of these processes, which is still largely valid, is given in [2].

The development of the binder system presented is intended to give iron foundries, which in many cases are customer foundries with frequently changing product ranges, an opportunity to use inorganically bonded cores. An important aspect of this is the elimination of an expensive heated core-making tool made of steel, which can only be justified in large-scale production. The binder system used is an alkali silicate or water glass based binder, which has been modified with a whole range of oxides and does not contain any organic components [3]. The solidification of the molding material is achieved exclusively by gassing with air at a temperature of approx. 160°C. The binder is a one-component binder. The binder is a one-component binder, which can be dosed without additional additives in ranges of less than 2.5 %, in many cases less than 2 %.

2 Practical Experiences

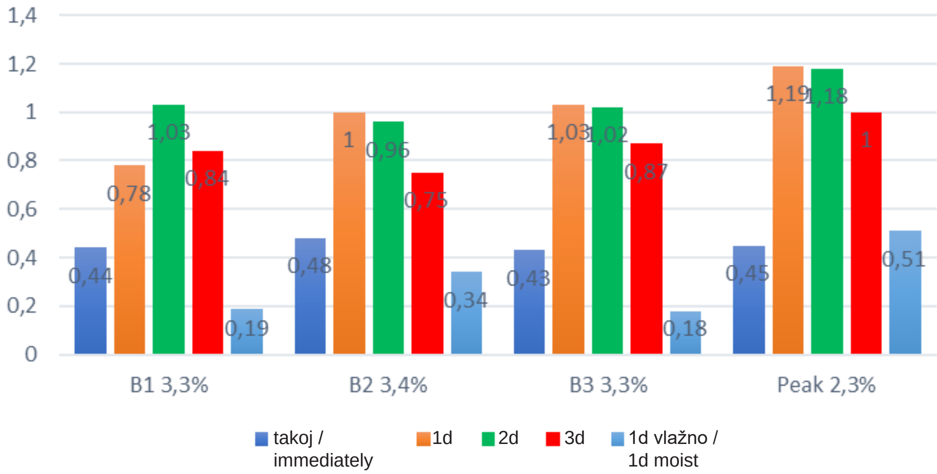
2.1 Molding Material Strengths in Comparison

In figs. 1 and 2, the bending strengths of the binder system are compared with those of three other commercially available inorganic binders (designated B1 to B3). A first



Slika 1. Upogibna trdnost veziva CC-VC v primerjavi z drugimi anorganskimi sistemi, temperatura sušenja 150 °C, kremenčev pesek H32

Figure 1. Bending strengths of binder system CC-VC compared with other inorganic systems, curing temperature 150 °C, silica sand H32

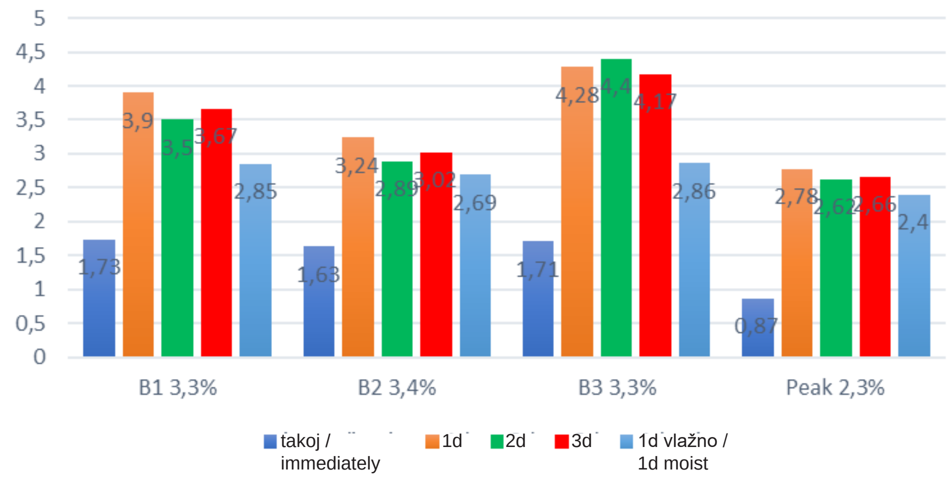


Slika 2. Specifična upogibna trdnost veziva CC-VC v primerjavi z drugimi anorganskimi sistemi, temperatura sušenja 150 °C, kremenčev pesek H32

Figure 2. Specific bending strengths of binder system CC-VC compared with other inorganic systems, curing temperature 150 °C, silica sand H32

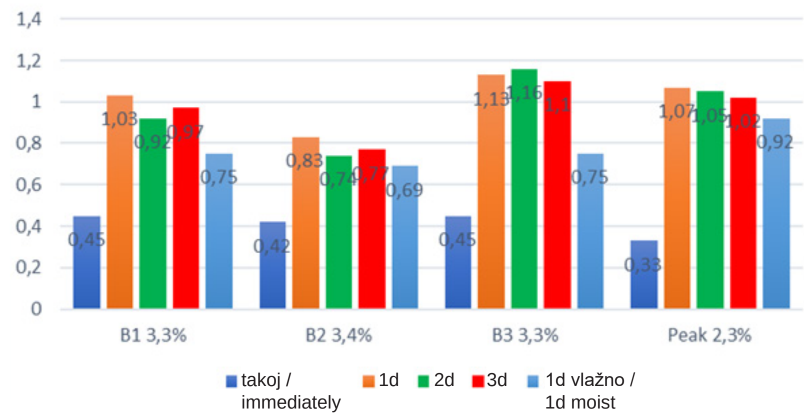
sistema Peak CC-VC so bili: Temperatura sušenja z zrakom 150 °C, čas sušenja 45 s, temperatura peska 23 °C, relativna vlažnost 45 %. Trdnosti smo določili nemudoma po postopku in po 1 do 3 dneh. Preskusni

difference becomes apparent in the binder contents used, since for these binders the binder itself and at least one additive have to be considered as total binder content. Furthermore, the systems compared are



Slika 3. Upogibna trdnost veziva CC-VC v primerjavi z drugimi anorganskimi sistemi, temperatura sušenja 200 °C, kremenčev pesek H32

Figure 3. Bending strengths of binder system CC-VC in comparison with other inorganic systems, curing temperature 200°C, silica sand H32



Slika 4. Specifična upogibna trdnost veziva CC-VC v primerjavi z drugimi anorganskimi sistemi, temperatura sušenja 200 °C, kremenčev pesek H32

Figure 4. Specific bending strength of binder system CC-VC compared with other inorganic systems, curing temperature 200°C, silica sand H32

pogoji za vrednosti »vlažno 1d« so bili 25 °C in 75-odstotna relativna vlažnost. Pri vezivih B1 do B3 se temperatura nanaša na temperaturo jedrovnika. Dosežene trdnosti povejo celotno zgodbo. Z vsemi vezivi se trdnost poveča v prvih dneh v normalnih

warm-box systems. The process parameters of the Peak system CC-VC were here: 150 °C curing air temperature, curing time 45s, sand temperature 23 °C, relative humidity 45 %. The strengths were determined immediately and after 1 to 3 days. The test pogojih shranjevanja, povečanje pa je mogoče pripisati progresivnemu sušenju. Dva primerjalna sistema sta se močneje odzvala na shranjevanje v vlažnem okolju. Trdnosti veziva Peak so nižje od drugih sistemov, kar je seveda posledica nižje vsebnosti veziva. Te vrednosti je mogoče po potrebi povečati z dodatkom večje količine veziva, vendar tukaj prikazane trdnosti zadostujejo za številne aplikacije. Potencial sistemov je jasno prikazan na sl. 2, ker so bile po enem dnevu opredeljene bistveno višje specifične trdnosti.

Predpostavlja se, da se trdnosti povečajo, kadar se uporabijo višje temperature. Na sl. 3 in sl. 4 je to povečanje prikazano za temperaturo 200 °C (znova jedrovnik in temperatura naplinjanja). Pravzaprav pa pride do povečanja trdnosti samo pri vezivih B1 in B3; pri sistemu Peak ostane trdnost skoraj nespremenjena. To je zanimiv vidik optimalne temperature naplinjanja v smislu stroškov in varovanja okolja. Vendar pa je pri shranjevanju jeder v vlažnem okolju prednost višjih temperatur strjevanja še očitnejša. Z vidika specifične trdnosti je vezivo B3 povezano z ugodnejšimi vrednostmi.

2.2 Vpliv temperature prepihovanja

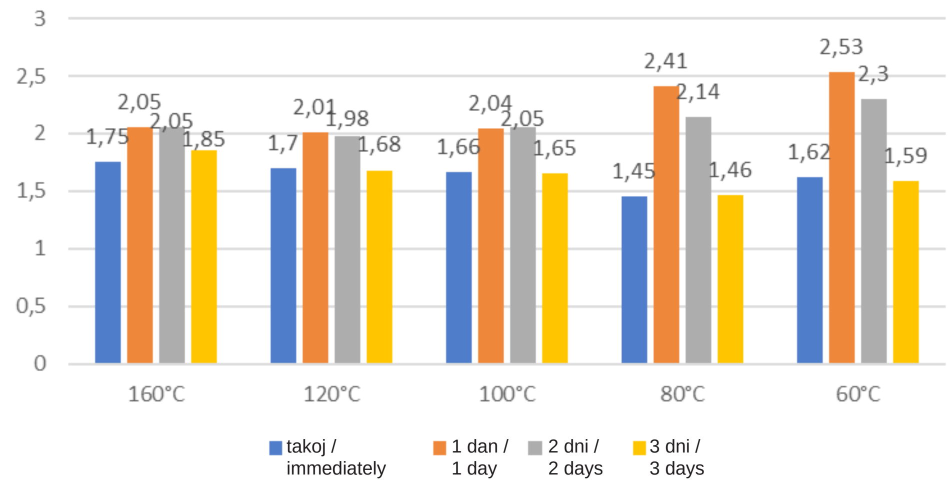
Ker je temperatura sušenja stroškovni dejavnik, smo izvedli preiskave, v katerih smo spreminjali zračno temperaturo med naplinjanjem ali sušenjem. Na slikah 5 do 7 so prikazani rezultati preskusov treh veziv. Vezivo, označeno z VC, je prvotni sistem, VC-HR in VC-CB pa sta vezivi, zasnovani za posebne uporabe. V tem nizu preskusov smo uporabili naslednje preskusne parametre: temperatura naplinjanja 160 °C do 60 °C v pet korakih, čas naplinjanja 60 s, temperatura peska 25 °C, kremenčev pesek QQ 26, relativna vlažnost 45 %. Na slikah

conditions for the “1d moist” values were 25 °C and 75 % relative humidity. For binders B1 to B3, the temperature refers to the core box temperature. The achieved strengths speak for themselves, all binders experience strength increases during the first days of storage under normal conditions, which can be attributed to progressive drying. Two of the comparative systems react more sensitively to storage in a humid environment. The strengths of the Peak binder system are lower than those of the other systems, which is of course due to the lower binder content. These values could be increased by higher binder additions if necessary, but the strengths shown here are sufficient for many applications. The potential of the system is clearly shown in fig. 2, where significantly higher specific strengths were determined after one day.

In principle, it is assumed that the strengths also increase when higher temperatures are used. In figs. 3 and 4, this is shown for a temperature of 200 °C (again, core box and gassing temperature). In fact, an increase in strength only occurs for the B1 and B3 binders; for Peak’s system, the strengths remain about the same. This is interesting with regard to the optimum gassing temperature in terms of cost and environmental protection. However, when cores are stored in a humid environment, the advantage of a higher hardening temperature comes into its own. In terms of specific strengths, binder B3 has the better values here.

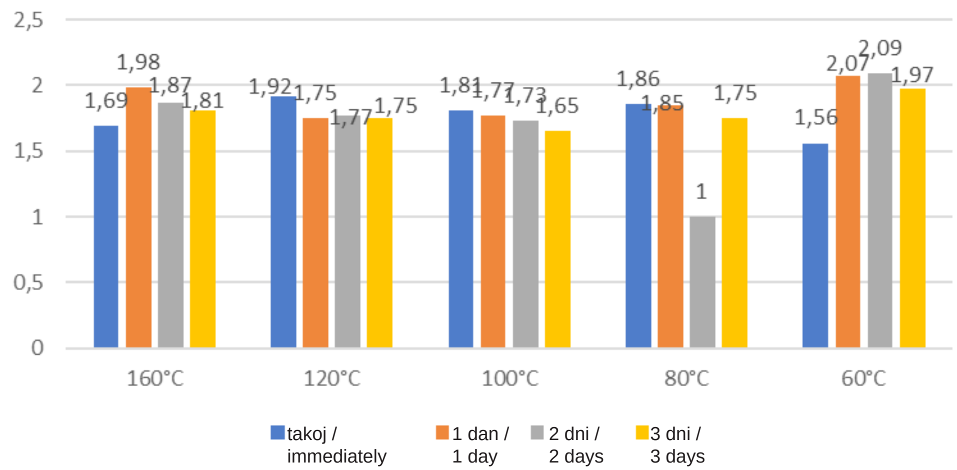
2.2 Influence of the Gassing Temperature

Since the temperature of the curing air is a cost factor, investigations were carried out to vary the air temperature for gassing or curing. Figures 5 to 7 show the results of



Slika 5. Upogibna trdnost veziva CC-VC pri različnih temperaturah utrjevanja, vsebnost veziva 1,75 %, kremenčev pesek QQs 26

Figure 5. Bending strength of CC-VC binder at different curing temperatures, binder content 1.75%, silica sand QQs 26

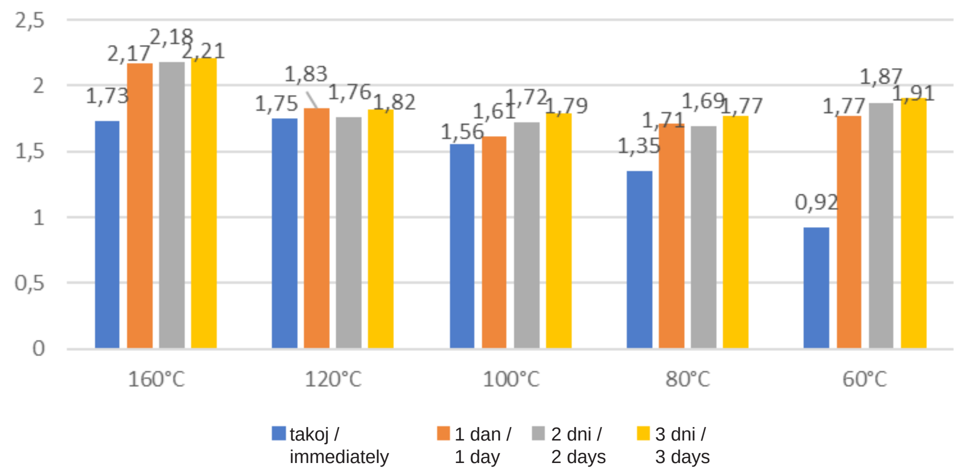


Slika 6. Upogibna trdnost veziva CC-VC-HR pri različnih temperaturah utrjevanja, vsebnost veziva 1,75 %, kremenčev pesek QQs 26

Figure 6. Bending strength of CC-VC-HR binder at different curing temperatures, binder content 1.75%, silica sand QQs 26

5 do 7 je opaziti, da se uporabni rezultati (z nekaj izjemami) pridobijo pri temperaturi naplinjanja 60 °C. Tukaj je zanimiva tudi izredno nizka vsebnost veziva, in sicer 1,75 %. Razlog za to opaženo vedenje

these tests for three binder systems. The binder labeled VC is the initial system, while VC-HR and VC-CB are binders designed for special applications. The following test parameters were used in this series of tests:



Slika 7. Upogibna trdnost veziva CC-VC-CB pri različnih temperaturah utrjevanja, vsebnost veziva 1,75 %, kremenčev pesek QQs 26

Figure 7. Bending strength of binder CC-VC-CB at different curing temperatures, binder content 1.75%, silica sand QQs 26

je uporaba izredno suhega zraka za naplinjanje preskusnih vzorcev. Tako je omogočeno zadovoljivo odvajanje vode in vodnih hlapov iz jedra med sušenjem tudi pri nizkih temperaturah. Ta razmerja bomo podrobneje proučili v bližnji prihodnosti.

2.3 Vedenje pri odstranjevanju jedra in preostala trdnost

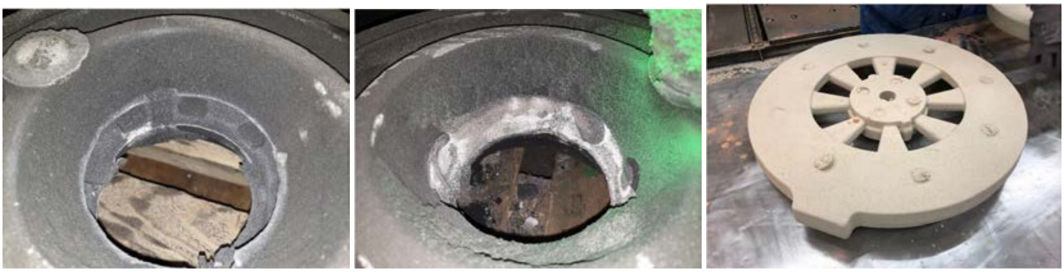
Ena od »klasičnih pomanjkljivosti« veziv iz vodnega stekla, znanih iz literature, je visoka preostala trdnost jeder ali form po litju, ki je povezana z velikimi napori pri odstranjevanju jeder. Nenazadnje je ta pomanjkljivost odločilno vplivala na močan upad deležev postopka od približno sedemdesetih let prejšnjega stoletja. Cilj razvoja sodobnih anorganskih veziv se mora med drugih osredotočati tudi na izboljšanje vedenja pri odstranjevanju jeder. Ker je bilo predstavljeno vezivo razvito zlasti za uporabo pri litju železa in jekla, je bilo treba temu vidiku posvetiti prav posebno

Gassing temperature 160°C to 60°C in five steps, gassing time 60s, sand temperature 25°C, silica sand QQs 26, relative humidity 45 %. From Figs. 5 to 7 it can be seen that useful results are obtained up to a gassing temperature of 60°C with some exceptions. Interesting at this point is also the very low binder content of 1.75 %. The reason for this observed behavior is the use of very dry air for the gassing of the test specimens. This apparently allows satisfactory water or water vapor removal from the core during curing even at lower temperatures. These relationships will be examined more intensively in the near future.

2.3 De-coring Behavior and Residual Tension

One of the “classic disadvantages” of water glass binder systems known from the literature is the high residual tension of cores or molds after casting, combined with a high de-coring effort. Last but not pozornost. V ta namen so bili v livarni železovih litin opravljeni preskusi litja. Jedro, ki se uporablja za hlajeni zavorni kolut (masa približno 15 kg), je prikazano na sliki 8a. Številna takšna jedra so bila nedokončno utrjena in dokončana z lamelarnih grafitnim litim železom. Za primerjavo smo uporabili klasična jedra Coldbox PUR. Najprej je treba poudariti, da ni bilo jasnih razlik med premazanimi in nepremazanimi jedri. Vizualno opazovanje vedenja pri razpadu oz. odstranjevanju je razkrilo, da so bili pri

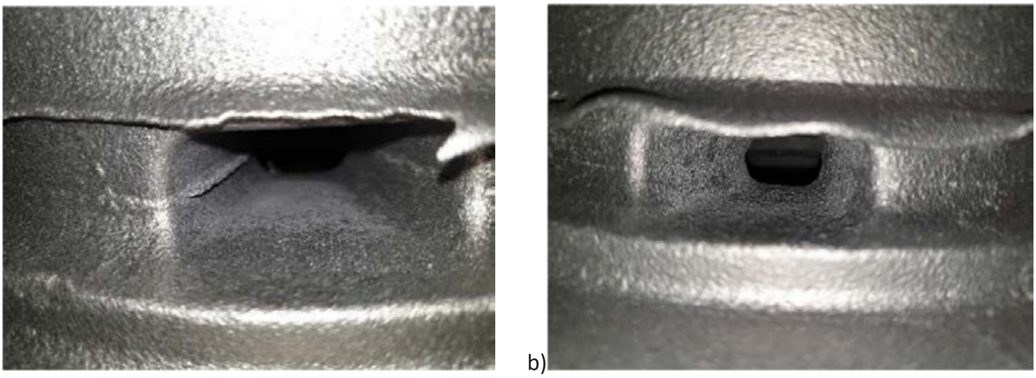
least, this disadvantage has decisively led to the strong decline of the process shares approximately from the 70s of the last century. The aim of developing modern inorganic binder systems must therefore be, in addition to other properties, to improve the de-coring behavior. Since the binder system presented was developed in particular for use in iron and steel casting, special attention had to be paid to this point. For this purpose, casting tests were carried out in an iron foundry. The core



a) b) c)

Slika 8. Jedro za zavorni kolut, približno 15 kg (a), liti zavorni kolut, anorgansko jedro, sprijemanje peska (b), liti zavorni kolut, jedro PUR Coldbox (c)

Figure 8. Core for brake disc, approx. 15 kg (a), Cast brake disc, inorganic core, sand adhesion (b), Cast brake disc, PUR Cold Box core (c)



a) b)

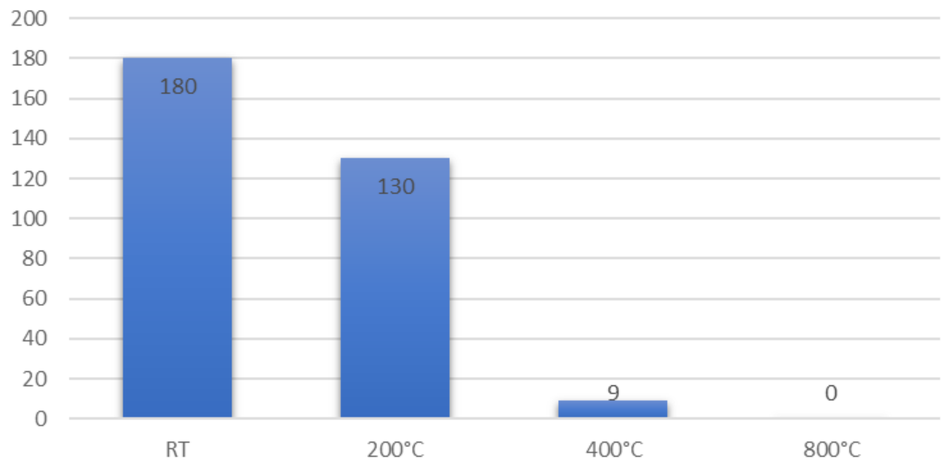
Slika 9. Ulitek s Slike 8 po peskanju, anorgansko jedro brez napak kot posledica razpok na jedru (a), jedro PUR Coldbox z razpokom kot posledica razpok na jedru (b)

Figure 9. Casting from Fig. 8 after shot blasting, inorganic core without veining (a), PUR cold box core with veining (b)

anorganskih jedrih kanali v ulitkih, izdelani s temi jedri, zapolnjeni, ki v primeru jeder Coldbox niso bili prisotni (sliki 8b in 8c). Po običajnem postopku peskanja so bili prilepki peščenega materiala popolnoma odstranjeni. Preostala jedra te serije so se v proizvodnji uporabljala brez težav in niso povezana s pritožbami. Pri ocenjevanju ulitkov se je pokazala prednost anorganskih veziv na osnovi vodnega stekla, ki je ne smemo podcenjevati: skoraj popolna odsotnost razpok na jedru. Ta napaka, ki nastane pri raztezanju materiala forme, je značilna zlasti za postopek PUR Coldbox, ki se pri vezivih na osnovi vodnega stekla zaradi prisotnosti termoplastične vezi in pri posebnih razredih ulitkov pojavlja zgolj v zelo majhnem obsegu. To je jasno prikazano na sliki 9.

Da bi to subjektivno pozitivno vedenje podprli s številkami, je bilo treba vedenje pri odstranjevanju jedra oceniti na podlagi preostale upogibne trdnosti. V ta namen so bile izdelane upogibne palice, ki so bile 24 ur po izdelavi 5 minut izpostavljene preskusni temperaturi in preskušane 2 uri po

used for a ventilated brake disc (mass approx. 15 kg) is shown in fig. 8a. A number of these cores were cast unfinished and finished with lamellar graphite cast iron. The standard PUR cold box cores served as a comparison. First of all, it should be noted that there were no clear differences between coated and uncoated cores. Visual observation of the disintegration or de-coring behavior revealed that in the inorganic cores, the channels of the castings were filled with mold material adhesions, which was not the case with the cold box cores (figs. 8b and 8c). After the normal sandblasting process, however, this sand adhesion was also completely removed. The other cores of this series were fed normally into production and did not give rise to any complaints. When evaluating the castings, one advantage of the inorganic binder system on water glass, which should not be underestimated, became apparent: the virtual absence of sheet veins. This molding material expansion defect, which is typical in particular for the PUR cold box process, only occurs to a very small extent



Slika 10. Preostala upogibna trdnost pri različnih temperaturah žarjenja, kremenčev pesek QQs 26 VC 2%

Figure 10. Residual bending tension at different annealing temperatures, silica sand QQs 26 VC 2%

odstranitvi iz peči. Preskusne temperature so bile 200 °C, 400 °C in 800 °C. Rezultati, prikazani na sliki 10, potrjujejo pozitivne lastnosti, ki so v to smer kazale že na podlagi preskusov litja. Preskusna temperatura 400 °C je namenjena predstavitvi tendence na področju aluminijevih ulitkov, temperatura 800 °C pa litega železa. Na tej podlagi lahko zaključimo, da je predstavljeno anorgansko vezivo značilen razpad in vedenje pri odstranjevanju jedra, ki je precej podobno vedenju pri postopku PUR Coldbox.

3 Primeri iz prakse

Jedra s predstavljenim sistemom anorganskih veziv so v številnih livarnah že

with water glass-based binder systems due to the thermoplastic bonding present there and with special casting grades. This is clearly demonstrated in Fig. 9.

In order to substantiate this subjectively positive behavior with figures, the de-coring behavior was to be evaluated on the basis of the residual bending tension. For this purpose, bending bars were produced which were exposed to the test temperature for 5 minutes 24 h after their production and tested 2 hours after removal from the oven. The test temperatures were 200°C, 400°C and 800°C. The results shown in Fig. 10 confirm the positive properties already evident from the casting tests in this direction. The test temperature of 400°C is intended to represent the tendency in the area of

Slika 11. Primeri uporabe anorgansko vezanih jeder za ulitke iz železovih litin

Figure 11. Application examples of inorganically bonded cores for iron castings

Slika 12. Primeri uporabe anorgansko vezanih jeder za neželezne ulitke

Figűre 12. Application examples of inorganically bonded cores for non-ferrous castings uspešno izdelali kot tudi uporabili. Jedra, prikazana na slikah 11a do 11c, so primeri ulitkov iz železovih litin. Razpon se razteza od zunanjih jeder za komplete jeder do že omenjenih jeder za kolutne zavore in filigranska jedra za ulitke ventilov. Področje neželeznih ulitkov, ki se jih v tem prispevku še nismo dotaknili, je slikovito ponazorjeno s primerom v sl. 12. Tudi tukaj obsega mogoč razpon enostavna jedra, npr. za sesalni kolektor, do izredno kompleksnega jedra glave valja. Prikazani primeri se uporabljajo za bakrene in aluminijeve ulitke.

aluminum casting, while the temperature of 800°C stands for iron casting. From this it can be concluded that the inorganic binder system presented exhibits decomposition and de-coring behavior quite similar to that of the PUR cold box process.

3 Examples from Practice

So far, cores with the inorganic binder system presented have been produced and successfully used in a whole series of foundries. The cores shown in figs. 11a to 11c are examples of iron castings. The range extends from outer cores for core packages to the aforementioned brake disc core and filigree cores for valve castings. The area of non-ferrous casting, which has not been the focus of this article so far, is impressively illustrated by the examples shown in fig. 12. Here, too, the feasible range extends from simple cores, e.g. for intake manifolds, to the highly complex core of a cylinder head. The examples shown are used in copper and aluminum castings.

Viri / Literature

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