

Prispevek h postopku izdelave jeder in form z vodnim steklom

Contribution to Waterglass Process for Cores and Moulds

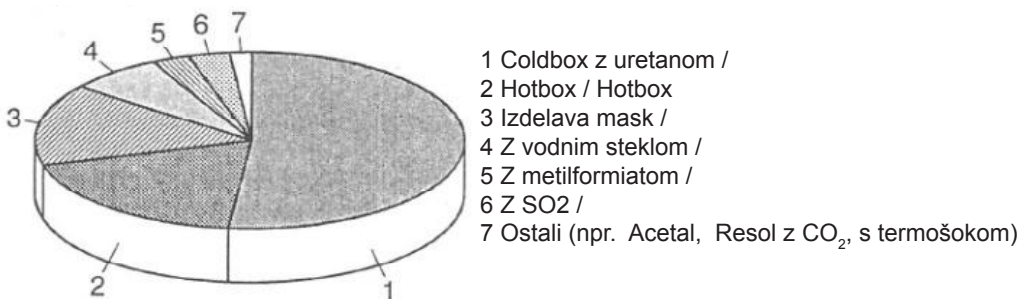
1 Uvod

Glede na sliko 1 po R. Ellinghausu [1] in H. Wolffu [2] se je vodno steklo uporabljalo kot kemično vezivo za jedra le pri okoli 7 % peščenih jeder. Pogosto se je razpravljalo o prednostih in slabostih tega postopka. Dosedanji zagovorniki CO₂ postopka so bili npr. W. Schumacher, I. Bindernagel, G. Gettwert, F. Richarz in U. Kleinheyer v Nemčiji, H. G. Levelink na Nizozemskem, F. Hofmann v Švici, H. Sagmeister v Avstriji, I. L. Svensson na Švedskem, F. W. Nield in D. Epstein v Veliki Britaniji, D. V. Atterton v ZDA, P. Doroshenko v Rusiji, in ne nazadnje L. Petržela in J. Gajdusek, P. Jelinek, C. Vančura, M. Julina in V. Slaveniček v Češki republiki. Nekaj zanimivih podrobnosti se lahko najde v literaturi [3-7].

V zadnjem času sta posebno E. Flemming and H. Polzin s Tehniške univerze

1 Basic Considerations

According to Fig.1 from W. Ellinghaus [1] and H. Wolff [2] the waterglass process in the 1990 years reached only about 7% of the chemical bonded sand materials for cores. The reasons for restrictions on the one hand and the advantages on the other were frequently discussed. Early promoters of the CO₂ process were for example W. Schumacher, I. Bindernagel, G. Gettwert, F. Richarz and U. Kleinheyer in Germany, H. G. Levelink in the Netherlands, F. Hofmann in Switzerland, H. Sagmeister in Austria, I. L. Svensson in Sweden, F. W. Nield and D. Epstein in Great Britain, D. V. Atterton in USA, P. Doroshenko in Russia, last but not least L. Petržela and J. Gajdusek, P. Jelinek, C. Vančura, M. Julina and V. Slaveniček in the Czech Republic. Some interesting details could be found in literature [3-7].



Slika 1. Izdelava jeder iz kemično vezanih formarskih materialov (serijska izdelava), Nemčija 1993 – deleži posameznih postopkov od vseh formarskih materialov

Figure 1. Production of cores with chemical bonded sands (serial production) in Germany 1993 – parts of the different procedures in percentage of the total amount of these materials [1, 2]

Bergakademie Freiberg zagovornika, ki vzpodbujata uporabo tega procesa. Sta tudi naša aktivna sodelavca v Clausthalu, za kar jima gre velika zahvala. Zahvale gredo tudi za teoretično in praktično pomoč članom mednarodne komisije CIATF-WFO 1.6 anorganska veziva, ki jo sedaj predstavljata H. Polzin iz Freiberga in H. Wolff, tajnica iz Düsseldorfa. Pred kratkim, l. 2012 [8], je H. Polzin objavil delo »Anorganska veziva ... Glavni vzrok, da se danes in v prihodnosti vzpodbuja uporaba vodnega stekla, je njegova prednost pri varovanju zdravja delavcev in sosedov, ker ni škodljivih emisij kot BTX (benzen, toluen, ksilene) in PAK. Poleg tega je postopek ekonomičen, ker so številne tehnične izboljšave zmanjšale nekdanje omejitve posebno, kar se tiče tekočnosti peščenih mešanic pri

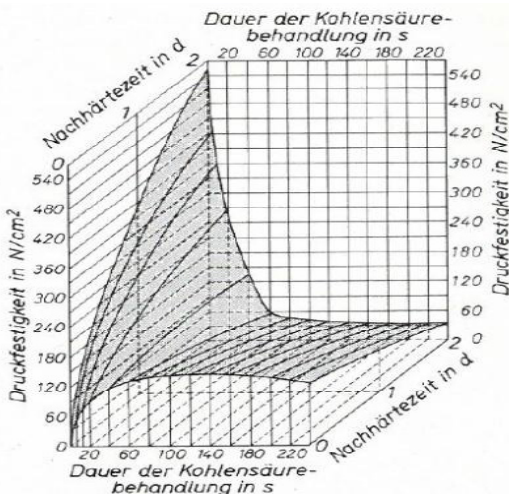
In later times especially E. Flemming and H. Polzin in Technical University Bergakademie Freiberg were encouraging promoters and active cooperation partners for us in Clausthal. This is gratefully acknowledged. Thanks for theoretical and practical assistance shall also be said to the members of the international CIATF-WFO-commission 1.6. Inorganic Binders, now represented by H. Polzin - Freiberg and secretary H. Wolff - Düsseldorf. A comprehensive study "Anorganische Binder..." was published recently by H. Polzin in 2012 [8]

The main reason to promote and to use the waterglass process yesterday, today and tomorrow is the advantage of health security for working people and for neighbours, because no critical emissions like BTX and PAH occur. Furthermore, the process is economical, because a lot of technical improvements have reduced the former restrictions, especially concerning fluidity of the sand mixture during core shooting and residual strength of cores and moulds.

One example of the numerous factors influencing the pressure strength is the diagram of H. G. Levelink [9] Fig.2, frequently mentioned and discussed, f. i. by W. Schumacher [4], I. Bindernagel [10] and R. Döpp, R. Deike and G. Gettwert [7]. It would be useful to develop similar diagrams for specific other conditions in the foundry.

Examples from G. Gettwert and co-authors for improvements of the initial compressive strength Fig.3 [11, 7], storage capability Fig. 4 [6, 7] and residual compressive strength Fig.5 [11, 7] could strongly promote the practical application of the waterglass-CO₂ process.

Own experiments of R. Deike, G. Gettwert and R. Döpp [7, 12] show that sands with Na-waterglass have higher compressive strength, but are somewhat



Slika 2. Odvisnost tlačne trdnosti od trajanja obdelave z ogljikovim dioksidom in trdenje na zraku pri dodatku 4 % vodnega stekla z modulom 2,59 po [3], glej tudi [4, 5]

Figure 2. Influence of gassing time with CO₂ and storage time in air on compressive strength of cores with 4 % waterglass, modulus 2,59, according to [3], see also [4, 5]

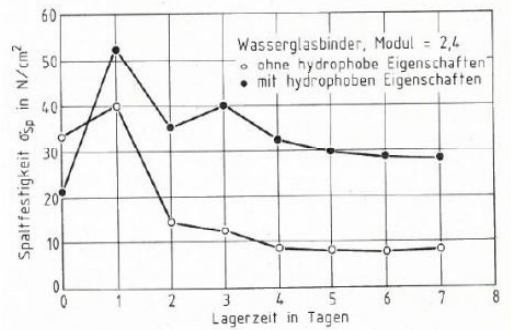
vbrizgavanju jeder in zaostale trdnosti jeder in form.

Primer številnih dejavnikov, ki vplivajo na tlačno trdnost, predstavlja diagram H. G. Levelinka [9] na sliki 2, ki ga pogosto omenjajo in o njem razpravljajo W. Schumacher [4], I. Bindernagel [10] in R. Döpp, R. Deike ter G. Gettwert [7]. Koristno bi bilo razviti podobne diagrame za druge specifične razmere v livarni.

Primeri G. Gettwerta in soavtorjev o izboljšavah začetne tlačne trdnosti na sliki 3 [11,7], časa uporabnosti na sliki 4 [6,7] in zaostale tlačne trdnosti na sliki 5 [11,7] bi lahko predstavljali močno podporo praktični uporabi CO₂-procesa z vodnim steklom.

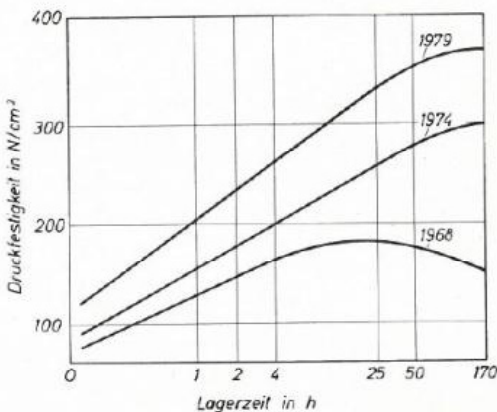
Lastne raziskave R. Deikeja, G. Gettwerta in R. Döppa [7,12] kažejo, da imajo peski, vezani z natrijevim vodnim steklom, večjo tlačno trdnost, a so nekako bolj občutljivi na zračno vlažnost in vlažnost forme v primerjavi s kalijevim vodnim steklom, slika 6 [7]. Praktična razlika je sorazmerno majhna. Večji vpliv imata vrsta

more sensitive to humidity from air and mould compared to sands with K-waterglass Fig.6 [7]. The practical differences are relative small. Stronger influences have type and percentage of binder and storage time [12].



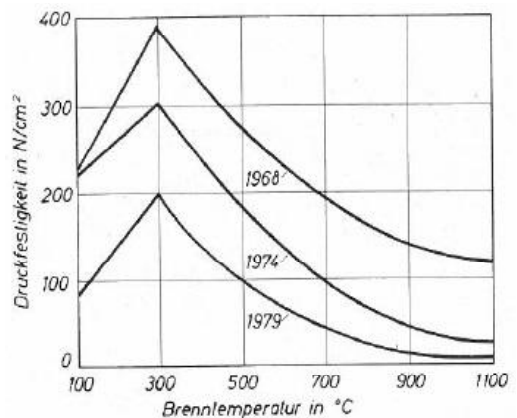
Slika 3. Razvoj trdnosti pri postopku utrjevanja z ogljikovim dioksidom v letih 1968, 1974 in 1979, po [9]

Figure 3. Development of initial compressive strength in carbon dioxide process from 1968 to 1974 and 1979 [9]



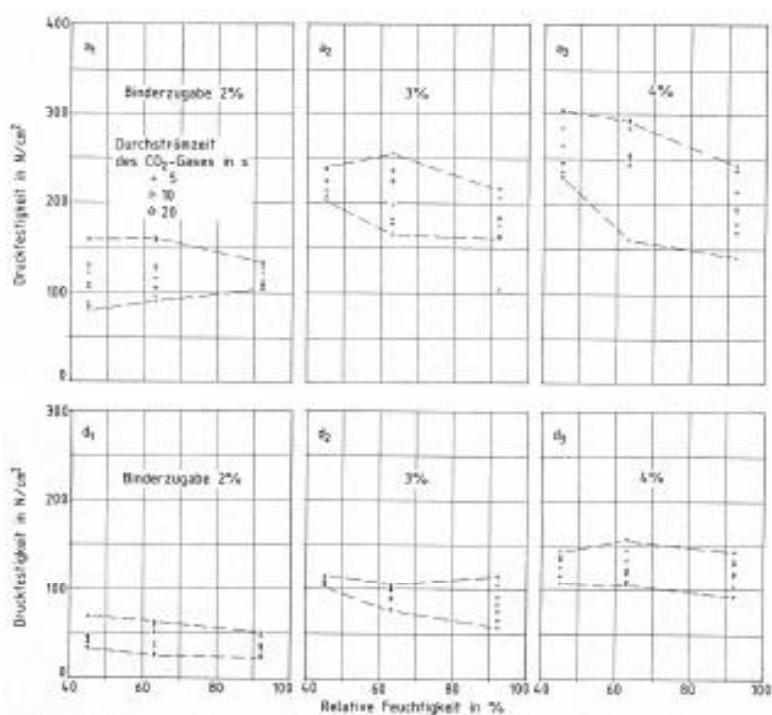
Slika 4. Izboljšanje roka uporabe veziva z vodnim steklom s hidrofobnimi lastnostmi [8]; primerjaj razpredelnico 2, vezivo 1

Figure 4. Improvement of storage capability by waterglass binders with hydrophobe properties [8], compare table 2, binder 1



Slika 5. Razvoj razpadanja jeder, izdelanih po CO₂ postopku v letih 1968, 1974 in 1978 [9]

Figure 5. Decrease of residual compressive strength from 1968 to 1974 and 1979 [9, 11, 7]



Slika 6. Vpliv relativne vlažnosti na tlačno trdnost pri različnih časih pretoka; čas skladiščenja 1 dan; sestava veziva: a) 100 % natrijevo vodno steklo, b) 70 % natrijevo in 30 % kalijevo vodno steklo, c) 30 % natrijevo in 70 % kalijevo vodno steklo, d) 100 % kalijevo vodno steklo

Figure 6. Influence of relative humidity of air on compressive strength after different CO₂-gassing times. Storage time 1 day. Composition of binder: upper row 100 % Na-waterglass, lower row 100 % K-waterglass. In both rows left 2 %, middle 3 %, right 4 % [7, p. 632]

in odstotek veziva ter čas skladiščenja [12].

Poleg tega rabljeni peski za jedra ne motijo preveč osnovnega formarskega peska, vezanega z bentonitom. Obnovljivost peska po različnih postopkih, predvsem mehanskih in v hladnem, je možna in se je sistematično izboljševala do sedanje visoke ravni.

Ta prispevek skuša dati pregled nekaterih raziskovalnih rezultatov v zadnjih 20 letih na Tehniški univerzi Clausthal ob sodelovanju livarn, dobaviteljev livarnam, tj. izdelovalcev veziv in trdil, skupaj z drugimi inštituti in strokovnimi skupinami.

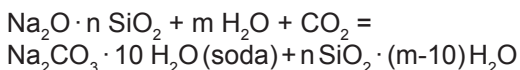
Furthermore, used core sands do not disturb severely the basic bentonite bonded sand for the moulds. Reclamation by different procedures, preferably mechanically and cold, is possible and was improved systematically up the present high level.

This work tries to summarize some results of about 20 years of research conducted at the Technical University Clausthal together with foundries and foundry suppliers, f. i. producers of binders and hardeners and together with other institutes and professional groups.

2 Fizikalni in kemični vidiki ter vidiki zgradbe

G. Gettert, F. Richard in W. Schumacher [6] trdijo, da alkalno vezivo vodno steklo kot natrijev silikat reagira s CO₂ kot trdilom, pri čemer nastaja gel SiO₂, ki veže zrna kremena. Na₂CO₃ kot drugi produkt reakcije ni želen, a ne predstavlja težav. Nasprotno, mogoče ima celo prednost, ker aktivira bentonit.

Celotna reakcija [6] se lahko zapiše:



To je bilo potrjeno v doktorski disertaciji H. Schneiderja [13,14]. Rentgenske difraktometrijske raziskave so pokazale, da Na₂CO₃ nastane že po kratkotrajnem preprihovanju s plinom. Po daljših časih preprihovanja nastane NaHCO₃, verjetno po naslednji reakciji [13]:



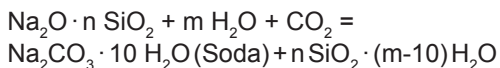
Na₂CO₃ tvori mostičke veziva iz SiO₂-gela, medtem ko NaHCO₃ mostičke ruši in zmanjšuje njihovo število.

Preiskave H. Schneiderja [13,14] z elektronskim mikroskopom (slika 7) so pokazale, da so po 10 s preprihovanja s plinom in segretju na 200 °C nastali drobni mostički veziva. Ko je temperatura dosegla 600 °C so postali mostički grobi in krhki, nad 700 °C pa so mostički veziva postali tekoči. Večja odpornost jeder proti lomljenju po litju se lahko pojasni s steklastim strjevanjem tekočega veziva. Zanimivo je vezivo iz vodnega stekla, modificirano z natrijevim polifosfatom. Slika 8 kaže, da je mostiček iz veziva po segretju na 1100 °C droben, vendar ne tako stekleno prozoren kot pri standardnih vezivih, verjetno zaradi štirih fosfatov, ki se niso stalili. M. Kukui in

2 Physical, chemical and structural aspects

Following G. Gettert, F. Richarz and W. Schumacher [6] the alkali binder waterglass as a Na-silicate reacts with CO₂ as hardener, forming a SiO₂-gel, which combines the quartz-grains. Na₂CO₃ as the second resulting product is not wanted, but without disadvantages. In contrary, perhaps it has advantages concerning bentonite activation.

The sum-equation following [6] is:

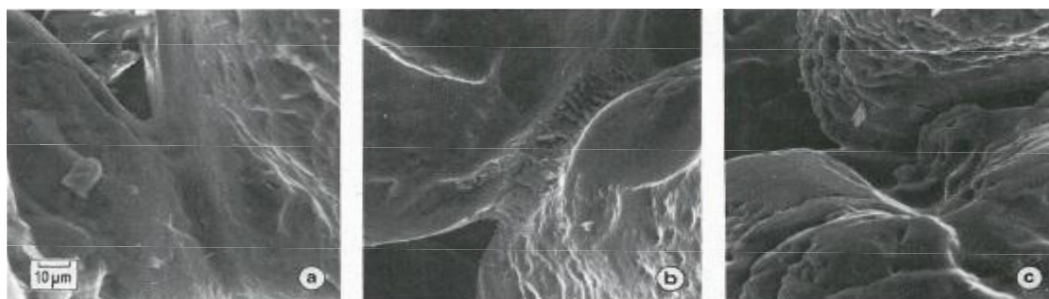


This was confirmed in the thesis of H. Schneider [13, 14]. X-ray-diffractometric investigations showed that Na₂CO₃ · 10H₂O was built at short gassing time. With longer gassing time NaHCO₃ occurs, perhaps following [13] according to



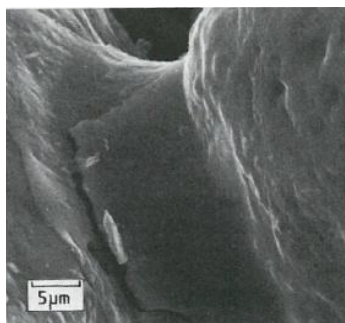
Na₂CO₃ is harmonically involved in the binder-bridge of SiO₂ gel. But NaHCO₃ separates from the binder bridge and reduces it.

Electronic-microscope-investigations of H. Schneider [13, 14] f. i. Fig.7 showed smooth binder bridges after 10 s gassing time and heating on 200 °C. After 600 °C the binder bridge becomes rough and brittle. From 700 °C upwards the binder bridge becomes liquid. The higher resistance of cores against breakdown after pouring may be explained by a glass-type solidification of the liquid binder. Interesting is a waterglass binder modified with sodium-polyphosphate. Fig.8 shows a binder bridge after heating to 1100 °C, smooth, but not so glass-clear as the normal binders, probably due to the phosphates, which were not melted. M. Kukui and his Russian colleagues - see



Slika 7. Mostički veziva iz 100 % natrijevega vodnega stekla po 10 s preprihovanja s plinom in pri segretju na a) 200 °C, b) 600 °C in c) 1100 °C

Figure 7. Binder bridges of sands with 100 % Na-waterglass after 10 sec gassing time and heating to a) 200 °C, b) 600 °C and c) 1000 °C [13, 14]



Slika 8. Mostički veziva iz natrijevega vodnega stekla z dodanim fosfatom po 10 s preprihovanja s plinom in segretju na 1100 oC

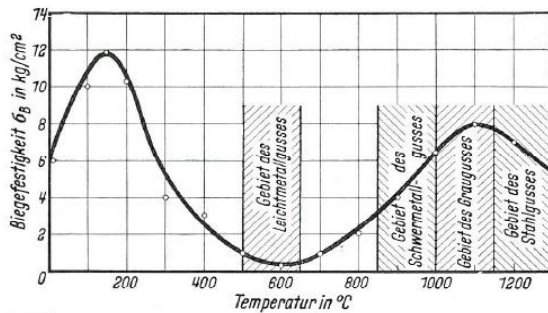
Figure 8. Binder bridges of Na-waterglass-sand with phosphate addition after 10 sec gassing time and heating to 1100 °C [13, 14]

njegovi ruski kolegi – glej citirano literaturo 8 v [14] – poročajo, da so taka jedra po litju močno nagnjena k lomljenju.

V literaturi, ki sledi, od W. Schumacherja [4] do F. W. Nielda in D. Epsteina [15], je glavna težava v tem, da modul, razmerje $\text{SiO}_2/\text{Na}_2\text{O}$, določa fizikalne lastnosti peščenih mešanic popolnoma različno. Npr. modul M, manjši od 2,5, zmanjša začetno trdnost, vendar podaljša čas skladiščenja in zaostalo trdnost, kar pomeni več težav pri drobljenju jeder. Na drugi strani M, večji od 2,5, poveča začetno trdnost, a skrajša čas skladiščenja in zaostalo trdnost, kar pomeni, da so jedra po litju bolj nagnjena k zdrobitvi, kar je željeno. Zato je pogosto srednji modul okoli 2,5 dober kompromis.

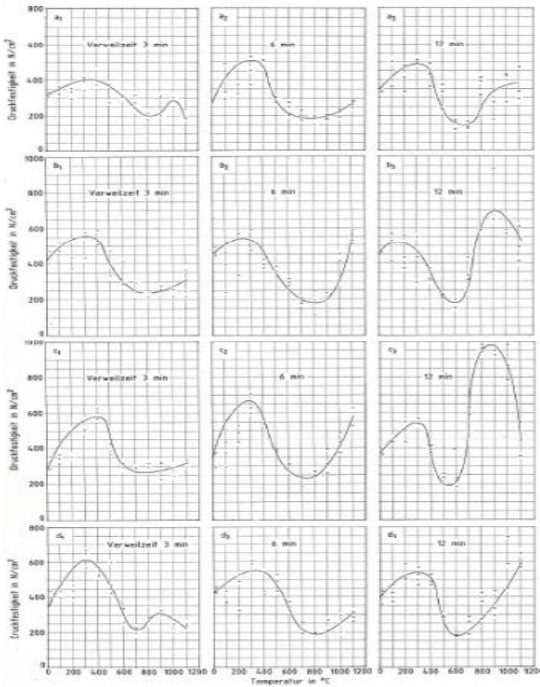
literature 8 in [14] - reported, that similar cores had a good tendency to break down after casting.

Following literature, f. i. W. Schumacher [4], according to F. W. Nield and D. Epstein [15], one main problem is that the “module”, the ratio $\text{SiO}_2/\text{Na}_2\text{O}$, determines the physical properties of the sand mixtures quite differently. For instance a module M below 2,5 reduces the initial strength, but increases storage capability and residual strength, that means more difficulties in collapsibility of cores. On the other hand an M above 2,5 increases the initial strength, but reduces storage capability and residual strength, that means higher tendency of cores to breakdown after pouring, as wanted.



Slika 9. Spreminjanje upogibne trdnosti v odvisnosti od temperature

Figure 9. Change of bending strength with increasing temperature [4]



Slika 10. Vpliv toplotne obremenitve na merjeno tlačno trdnost pri sobni temperaturi. Dodatek veziva 4 %, čas preprihovanja 5 s, sestava veziva: a) 100 % natrijevo vodno steklo, b) 70 % natrijevo vodno steklo in 30 % kalijevo vodno steklo, c) 30 % natrijevo vodno steklo in 70 % kalijevo vodno steklo, d) 100 % kalijevo vodno steklo

Figure 10. Influence of preheating amount and time of temperature on compressive strength (measured at room temperature) with waterglass bonded sands: 4 % binder, 5 sec gassing time. a) 100 % Na-waterglass b) 70 % Na, 30 % K, c) 30 % Na, 70 % K, d) 100 % K-waterglass [7]

Znamenit je diagram W. Schumacherja [4] z dvema območjema večje trdnosti vezanja. Okoli 200 °C in 800—1200 °C (slika 9). Ti dve območji največje trdnosti podrobno pojasnjujejo G. Gettwert, F. Richarz in W. Schumacher [6], kar je eksperimentalno potrdil v svojem diplomskem delu R. Deike skupaj z G. Getwertom pri podjetju Woellner v Ludwigshafnu [7] za različne vrste natrijevih in kalijevih veziv. Nekaj rezultatov je prikazanih na sliki 10. Sklepi glede temperatur taljenja in litja so: prednosti so

Therefore frequently a medium module M of about 2,5 gives a good compromise.

One famous diagram is Fig.9 of W. Schumacher [4] with the two regions of higher bending strength: about 200 °C and 800-1200 °C. These maxima-regions, with details explained by G. Gettwert, F. Richarz and W. Schumacher [6], were confirmed experimentally in the diploma work of R. Deike together with G. Gettwert at Woellner in Ludwigshafen [7] for different binder types on Na and K basis. Some results are shown

pri zlitinah lahkih kovin, kot sta aluminij in magnezij, in večje slabosti pri zlitinah na osnovi bakra in železa.

Vsaj dve nalogi sta pri tem potrebni:

- A. Merjenje temperatur ulitka in jedra
- B. Zmanjšanje drugega maksima

Laboratorijski poskusi A, kijih je naredil H. Schneiderjem [16] v Clausthalu, so pokazali kvantitativne razlike pri temperaturah: slika 11 - ohlajevalne krivulje za litino GJL in slika 12 – najvišje temperature za litine AISi, GJL in GS (jeklena litina). Nekaj ustreznih rezultatov za lastnosti jeder kaže slika 13. Prednosti pri litini AISi so zelo očitne.

Skupaj z H. Jürgensom, K. Eigenfeldom in A. Keidisom smo napravili praktične poskuse v livarni BMW v Münchnu [17] z vročimi jedrniki po postopku, podobnem hotbox postopku. Že z dodatkom 2 % vodnega stekla in veziva F1 je bila dosežena upogibna trdnost 300 N/cm² (slika 14). Jedra za glave valjev motornih koles (slika

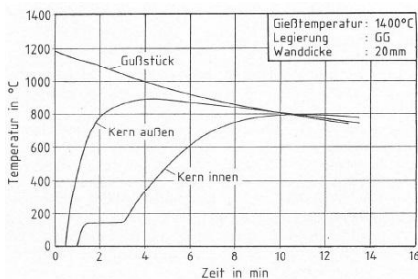
in Fig.10. The conclusions concerning melting and pouring temperatures were: advantages for light metal alloys like aluminium and magnesium and increasing disadvantages for copper and iron based alloys.

At least two tasks occur:

- A. Measuring of temperatures in casting and core.
- B. Reduction of the second maximum.

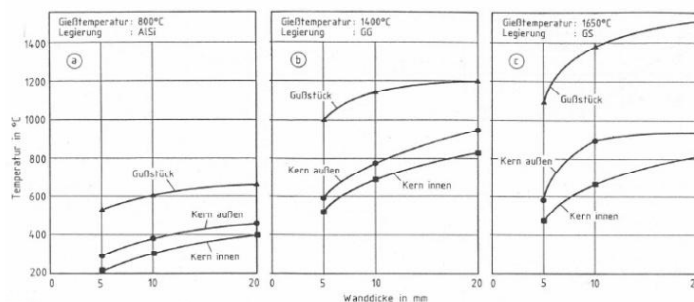
Labor tests to A in Clausthal with H. Schneider [16] showed quantitative differences in temperatures: Fig.11 cooling curves GJL and Fig.12 maxima temperatures for GAISi, GJL and GS (cast steel). Some corresponding results of core properties shows Fig.13. The advantage for GAISi is quite clear.

Practical tests together with H. Jürgens, K. Eigenfeld and A. Keidies at the BMW foundry Munich [17] were performed with heated core boxes similar to the Hotbox process. Already with 2 % waterglass and



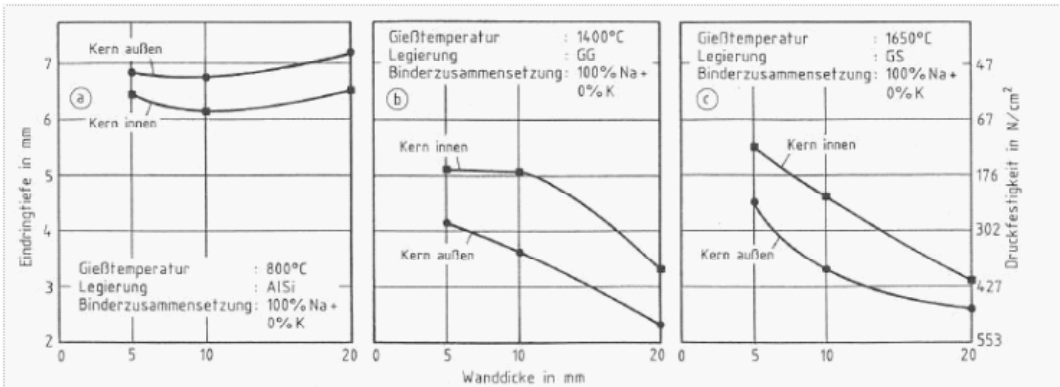
Slika 11. Ohlajevalna krivulja ulitka in jedra (znotraj in zunaj)

Figure 11. Cooling curves of casting and core (inside and outside). GJL (cast iron with flake graphite), wall thickness 20 mm, pouring temperature 1400 °C [16]



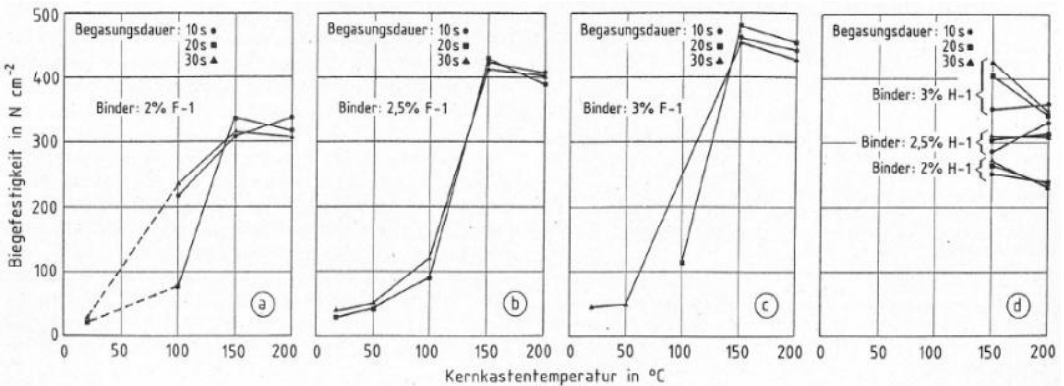
Slika 12. Najvišje temperature v odvisnosti od debeline stene, a) aluminijeva litina G-AISi, b) siva litina z lamelastim grafitom, c) jeklena litina

Figure 12. Maximum temperatures of castings with wall thicknesses 5, 10 and 20 mm. Castings; a) AISi, pouring temperature 800 °C, b) GJL, pouring temperature 1400 °C, c) Cast steel, pouring temperature 1650 °C; Core outside and inside [16]



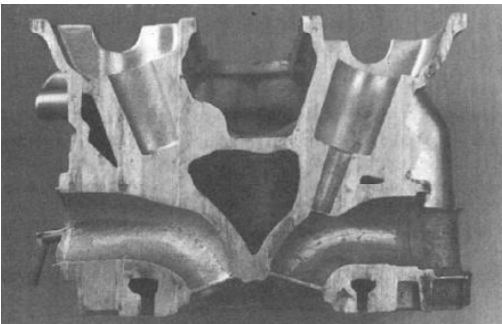
Slika 13. Globina vtiska oz. tlačna trdnost v odvisnosti od debeline stene, a) aluminijeva litina G-AlSi, b) siva litina z lamelastim grafitom, c) jeklena litina

Figure 13. Depth of impression as inverted measure for compressive strength of 100 % Na-waterglass cores for castings with wall thicknesses 5, 10 and 20 mm. Castings: a) AlSi, pouring temperature 800 °C, b) GJL, pouring temperature 1400 °C, c) Cast steel, pouring temperature 1650 °C, Core outside and inside (like Fig. 12) [16]



Slika 14. Odvisnost upogibne trdnosti od temperature jedrnika za različna veziva

Figure 14. Influence of core box temperature on bending strength of cores with different types and amounts of waterglass binders [17]



Slika 15 Glava valja motornega kolesa iz litine GK-AlSi9Cu3, prerez na višini srednjega zgorevalnega prostora

Figure 15. Motor-cycle cylinder heads (GK-AlSi9Cu3) cast with waterglass bonded cores, produced in heated core boxes. Sections in height of middle combustion chamber [17]

15) so omogočila izvrstne ulitke iz litine GK- AlSi_9Cu_3 .

Cilj zmanjšati drugi maksimum (B) je bil dosežen z modificiranjem trgovskih veziv. Nekaj rezultatov je prikazanih na sliki 16 [18]. Prvi maksimum (dehidracija vodnega stekla) ni kritičen, ker so temperature jeder navadno višje od 200 °C [16].

3 Obnova peska

Obnova peskov je široko področje. A. Alekassir in B. Xiao [21] sta napravila poskuse po P. Pohlu [19, 20] (slika 17) v železo- in jeklovilarni Pleissner pri Herzbergu/Harz in na našem inštitutu Tehniške univerze Clausthal. Lastnosti mešanic z obnovljenim peskom predvsem z vezivi iz umetnih smol in vodnega stekla se dobro ujemajo z lastnostmi mešanic s

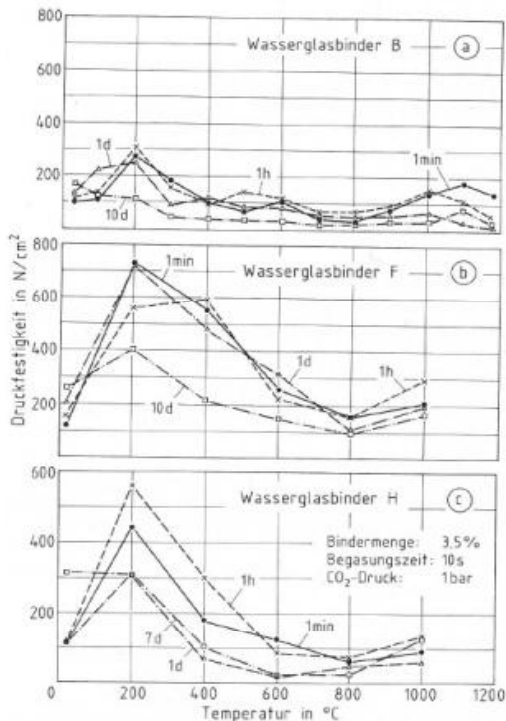
binder F1 a bending strength of 300 N/cm² was reached Fig.14. The cores for motorcycle cylinder heads (Fig.15) gave excellent castings GK- AlSi_9Cu_3 .

The aim to reduce the second maximum (B) was reached with modified commercial binders. Some results shows Fig.16 [18]. The first maximum (dehydration of waterglass) is not critical, because the core temperatures normally are higher than 200°C [16].

3 Sand Reclamation

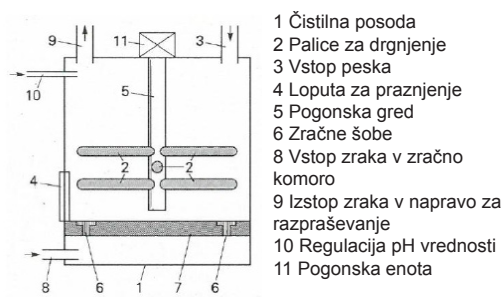
A wide field is the reclamation of sands. Experiments with the mechanical fluid bed cleaner following P. Pohl Fig.17 [19, 20] with A. Alekassir and B. Xiao [21] were conducted in the iron and steel foundry Pleissner at Herzberg/Harz and in our institute at the Technical University Clausthal. The properties of mixtures with reclaimed sand, mostly with synthetic resin and waterglass binders, correspond well to mixtures with new sand. Beneficial to reduction of residual strength are small additions of bentonite (about 1 %) to sand mixtures hardened by ester or CO₂ Fig.18 [21].

A detailed study concerning Resol-CO₂ and waterglass-CO₂ core sands is the thesis of G. Brümmer. a) Influence on the bentonite-bonded moulding sand [22], b) Reclamation [23].



Slika 16 . Tlačna trdnost v odvisnosti od temperature po različnih časih skladiščenja; količina veziva 3,5 %, čas prepipovanja 10 s, tlak CO₂ 1 bar (lastne preiskave)

Figure 16. Influence of temperature on compressive strength of cores with different waterglass binder systems, amount 3,5 %, 10 sec gassing time, storage time 1 min, 1 h, 1 d, 10 d [18]



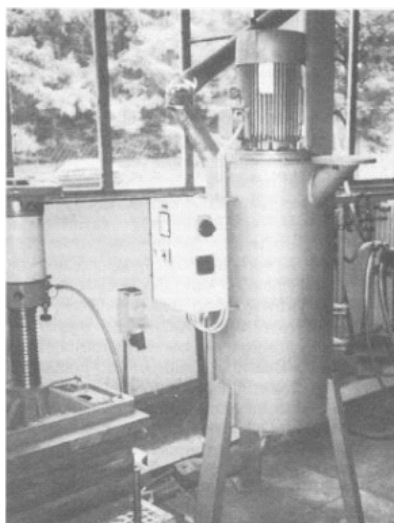
- 1 Čistilna posoda
- 2 Palice za drgnjenje
- 3 Vstop peska
- 4 Loputa za praznjenje
- 5 Pogonska gred
- 6 Zračne šobe
- 8 Vstop zraka v zračno komoro
- 9 Izstop zraka v napravo za razprševanje
- 10 Regulacija pH vrednosti
- 11 Pogonska enota

Slika 17a. Funkcijska shema čistilne naprave z zvrtno plastjo

Figure 17a. Function scheme of mechanical fluid bed cleaner following P. Pohl [19, 20]

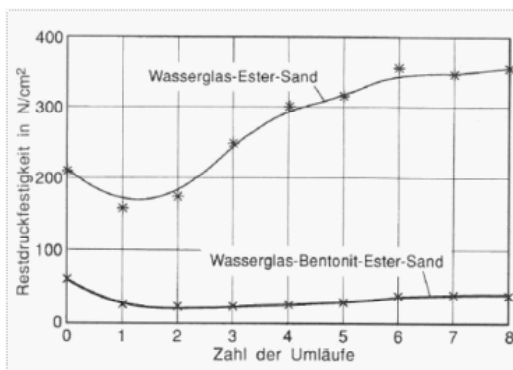
svježim peskom. Na zmanjšanje zaostale trdnosti ugodno vplivajo majhni dodatki bentonita (okoli 1 %) v peščene mešanice, utrjene z estrom ali CO_2 [21] (slika 18).

Podrobnosti o peskih za jedra Resol, utrjenih s CO_2 , in peskih z vodnim steklom, utrjenih s CO_2 , so v doktorski dizertaciji G.



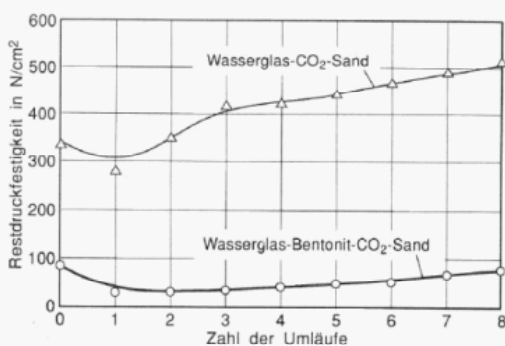
Slika 17b. Čistilna naprava z zvrtno plastjo za mehansko obnovo rabljenih livarskih peskov po P. Pohlu [1]

Figure 17b. Fluid bed cleaner for mechanical reclamation of foundry sands including waterglass bonded sands following P. Pohl [19, 20]



Slika 18 a Vpliv števila obnov peska na zaostalo trdnost vzorcev; primerjava peskov z vodnim steklom in bentonitom, utrjenih z estrom in peskov z vodnim steklom, utrjenih z estrom, za sestavo glej razpredelnico 1

Figure 18a. Influence of number of reclamation cycles on residual compressive strength of waterglass-ester-sands (upper line) and waterglass-bentonite-ester-sands (lower line) [21]. Composition of mixtures see table 1 in [21]



Slika 18 b. Vpliv števila obnov peska na zaostalo trdnost vzorcev; primerjava peskov z vodnim steklom in bentonitom, utrjenih s CO_2 in peskov z vodnim steklom, utrjenih s CO_2 , za sestavo glej razpredelnico 1

Figure 18b. Influence of number of reclamation cycles on residual compressive strength of waterglass- CO_2 -sands (upper line) and waterglass-bentonite- CO_2 -sands (lower line) [21]. Composition of mixtures see table 1 in [21]

Brümmerja: a) Vpliv na formarske peske, vezane z bentonitom [22], b) Obnova [23].

a) Z bentonitom vezani formarski pesek je precej neobčutljiv na preostale dele jeder iz peščenih mešanic Resol, utrjenih s CO₂, in na dele iz peščenih mešanic z vodnim steklom, utrjenih z CO₂.

b) obnova je možna, če so stroški razumni in kakovost dovolj dobra.

b=G. Brümmer [24] tudi predlaga sušenje peščenih mešanic z vodnim steklom namesto preprihovanja s CO₂. Dve drugi obsežni študiji, ki zajemata tudi obnovo, sta doktorski dizertaciji A. Scheya [25] in G. Rötha [26].

4 Povzetek in zahvale

Stalno se po korakih skušajo zmanjšati prejšnje slabosti in omejitve postopka natrijev silikat – CO₂ (npr. tekočnost peska in zaostala trdnost) v praksi. V veliki meri dolgujem zahvale svojim glavnim sodelavcem na Tehniški univerzi Clausthal: R. Deikeju, H. Schneiderju, A. Alekassirju, B. Xiaou in G. Brümmerju. Poleg tega moram hvaležno omeniti dobro sodelovanje z E. Flemmingom in H. Polzinom na Tehniški univerzi BA Freiberg in s člani mednarodne komisije CIATF-WFO 1.6 Anorganska veziva. Težave in uspešne rešitve so bile pogosto objavljene. Aktualni primeri sedanje oživitve in vse večje uporabe sistemov anorganskih veziv sta dve zanimivi objavi, ki zajemata ekonomske vidike veziva ASK INOTEC [27] ter sistematično uporabo sistemov anorganskih veziv v VW-livarni v Hannovru [28]. Obe sta pomemben prispevek k ekonomski in okolju prijazni proizvodnji jeder – upam tudi livarskih form – za visokokakovostne ulitke.

a) The bentonite-bonded moulding sand is fairly insensitive against residual core parts of Resol-CO₂ and waterglass-CO₂ mixtures.

b) Reclamation is possible, provided reasonable costs and sufficient quality.

G. Brümmer [24] also proposes drying waterglass sand mixtures instead of gassing with CO₂.

Two further extensive studies including reclamation tasks are the thesis works of A. Schrey [25] and G. Röth [26].

4 Summary and Acknowledgment

The continuous aim is to reduce the former practical disadvantages and restrictions of sodium-silicate-CO₂ process (f. i. fluidity and residual strength) systematically step by step. I owe many thanks to my main co-workers at TU Clausthal: R. Deike, H. Schneider, A. Alekassir, B. Xiao and G. Brümmer. Already gratefully mentioned was the good cooperation with E. Flemming and H. Polzin at the TU BA Freiberg and with the members of the international CIATF-WFO commission 1.6. Inorganic Binders. Problems and successful results were published frequently. Actual examples for the present revival and growing application of inorganic binder systems are two interesting publications including economical aspects with the ASK-binder INOTEC [27] and systematic use of inorganic binder systems at the VW foundry in Hanover [28]. Both are valuable contributions to economical and ecological- environmental production of cores - and hopefully moulds too - for high quality castings.

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