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Optimizacija ulivno-napajalnega sistema ulitka kape izolatorja iz bele temprane litine

Design Optimization of Gating System for Insulator Cap from White-Heart Malleable Iron

Povzetek

Ulivno-napajalni sistem za vertikalno litje v peščene forme mora biti dimenzioniran na način, da je tok taline čim manj turbulenten, da plini iz peščene forme in okoliški zrak niso ujeti v toku ter da med litjem ne prihaja do erozije peščene forme. Talina mora vstopiti v livno votlino na način, da povzroči temperaturno razliko, ki spodbuja usmerjeno strjevanje ulitka.

Med masovno proizvodnjo se lahko pri litju v peščene forme pojavijo številne napake, kot so plinska in krčilna poroznost, hladni spoji, vključki žlindre, razpoke v vročem, pripečen pesek, odkrušena forma itd. Računalniško podprte simulacije litja in strjevanja so dandanes ključne za optimizacijo parametrov procesa litja ter za predvidevanje možnih napak in tveganj, še preden te nastopijo. Z njimi lahko že v fazi razvoja orodja določimo najbolj optimalne pogoje litja in konstruiramo primeren ulivno-napajalni sistem glede na specifikacije ulitka. V tem članku je opisana optimizacija elementov ulivno-napajalnega sistema kape izolatorja, izdelane iz bele temprane litine. V podjetju Livarna Titan d.o.o. v Kamniku so namreč na tem artiklu beležili velik delež kakovostno neskladnih ulitkov. Korektivni ukrepi so bili izvedeni na podlagi enostavne termične analize »in situ« in računalniško podprtih izračunov litja in strjevanja z uporabo programskega paketa ProCAST.

Ključne besede: gravitacijsko litje, ulivno-napajalni sistem, temprana litina, simulacija, ProCAST

Abstract

The gating system for the vertical sand mold casting process must be dimensioned in such a way that the melt flows through it with as low turbulences as possible, that gases and ambient air are not trapped in the flow and that erosion of the sand mold does not occur during filling. The melt must also enter the casting cavity in a way that promotes directional solidification from the casting's hot spot through the feeder neck up to the feeder.

During mass production, casting defects such as gas and shrinkage porosity, cold shuts, slag inclusion, hot tears, burnt on the sand, mold defects, etc. can occur. Nowadays, computer-aided simulations of filling and solidification are crucial for optimizing the parameters of the casting process and for predicting possible errors and risks before they occur. With them, we can determine the most optimal casting conditions already in the tool development phase and construct a suitable gating system, according to the specifications of the casting.

This work describes the gating system optimization of insulator caps, made from white-heart malleable iron. To reduce the large number of scraped castings in the company

Livarna Titan, d.o.o. in Kamnik, a change was made to the casting tool based on “in-situ” thermal analysis and computer-aided calculations of filling and solidification using ProCAST simulation software package.

Keywords: gravity casting, gating system, malleable iron, simulation, ProCAST

1 Uvod

Zasnova ulivno-napajalnega sistema je v proizvodnem procesu vsake livarne ključnega pomena, saj le-ta neposredno vpliva na izplen taline (razmerje bruto/neto), delež izmeta in s tem tudi na produktivnost proizvodnje. Danes je med podjetji znižanje proizvodnih stroškov ključni cilj, h kateremu stremijo prav vsa. Visoke cene energentov (elektrika, plin) in vhodnih surovin (jekleni odpad, železove zlitine itd.) ter težave s pridobitvijo ustreznega kadra na trgu dela so vsa podjetja postavile v težek položaj. Livarne morajo zato proizvajati ulitke s čim nižjimi stroški in sočasno zagotavljati ustrezno kakovost. Pravilna zasnova ulivno-napajalnega sistema je zahtevna, a zelo pomembna naloga, zato je že med njegovim načrtovanjem pomembno zagotoviti, da litina pravočasno in enakomerno zapolni livno votlino. Vse parametre je kljub dolgoletnim izkušnjam težko upoštevati in pravilno oceniti, zato se tudi male in srednje livarne vse pogosteje odločajo za uporabo računalniško podprtih izračunov livarskih procesov.

Dimenzije ulivnih kanalov je treba izračunati glede na geometrijo izdelka, saj je lahko nepravilna zasnova glavni vzrok za napake, ki jih je mogoče zaznati na površini ali večinoma v notranjosti ulitkov. Slika 1 prikazuje obstoječi ulivno-napajalni sistem ulitka kape izolatorja z označenimi območji prisotne krčilne poroznosti.

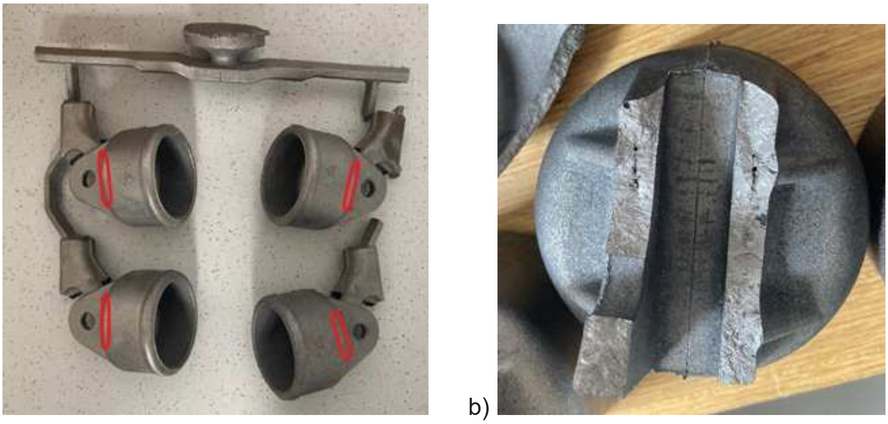
Preiskovan ulitek je kapa izolatorja, ki je sestavni del izolatorja za uporabo na visokonapetostnih daljnovodih. Ti so del prenosnega električnega omrežja,

1 Introduction

The design of the pouring and feeding system is of key importance in the production process of every foundry, as it directly affects the yield of the melt (gross/net ratio), the amount of scrap, and thus the productivity of production. Today, the reduction of production costs is a key goal for companies to strive towards, mainly due to the high prices of energy supply (electricity, gas) and input raw materials (steel scrap, ferroalloys, etc.) and problems with obtaining suitable personnel on the labor market. Foundries must therefore produce castings with the lowest possible costs and at the same time ensure the highest quality. The correct design of the gating system is a difficult but very important task. Therefore, already during its planning, it is important to ensure that the cast iron fills the casting cavity in a timely and uniform manner. Despite many years of experience, all parameters are difficult to take into account and correctly evaluate, which is why even small and medium-sized foundries are increasingly choosing to use computer-aided calculations of foundry processes.

The dimensions of the casting channels must be calculated according to the geometry of the product since improper design can be the main cause of defects that can be detected on the surface or mostly inside the castings. Figure 1 shows an existing gating system of an insulator cap with marked areas of shrinkage porosity.

The investigated casting is an insulator cap, an integral part of an insulator for use



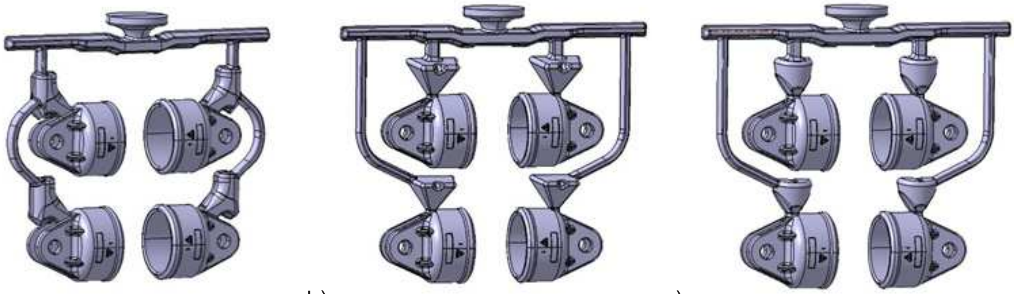
a) b)

Slika 1. Obstoječi ulivno-napajalni sistem z označenimi območji krčilne poroznosti (a), porušen ulitek z vidno poroznostjo (b)

Figure 1. Existing gating system with marked areas of shrinkage porosity (a), casting with visible porosity (b)

ki povezuje elektrarne z razdelilnimi transformatorskimi postajami. Izolacijski nosilci oz. izolatorji so potrebni na mestih, kjer so nadzemni vodi pritrjeni na kovinske nosilce. Izolatorji zagotavljajo potrebno izolacijo med vodniki in nosilci ter preprečujejo uhajanje toka iz vodnikov v zemljo.

on high-voltage transmission lines. These are part of the transmission power network that connects power plants with distribution transformer stations. Insulation supports or insulators are required in places where overhead lines are attached to metal towers. Insulators provide the necessary insulation



a) 17 kg b) 20 kg c) 16,8 kg

Slika 2. Potek sprememb ulivno-napajalnega sistema kape izolatorja, izhodiščno stanje (a); prva optimizacija (b), druga optimizacija (c)

Figure 2. The course of changes to the gating system of insulator cap; existing (a), first optimization (b), second optimization (c)

Slika 2 prikazuje potek optimizacije končnega ulivno-napajalnega sistema. Pri prvi optimizaciji smo s prestavitvijo lokacije napajalnikov uspešno odpravili krčilno poroznost v ulitku, ampak pri tem povečali bruto težo sistema s 17 kg na 20 kg. V drugem delu optimizacije smo zaradi težnje po dosegu večjega izplena taline optimizirali obliko napajalnikov na najmanjšo mero, ki še zagotavlja usmerjeno strjevanje. Pri tem smo bruto težo zmanjšali z 20 kg na 16,8 kg in tako povečali izplen taline za 16 %. Ob kapaciteti proizvodnje 200 izdelanih form na uro to pomeni prihranek 4800 kg taline na izmeno.

2 Eksperiment

Preiskovani ulitek kape izolatorja je izdelan iz bele temprane litine kakovosti EN-GJMW-550-04 (DIN EN 1562:2019), njegova neto teža je 2,6 kg. Zaradi same geometrije ulitka in želje, da se za izdelavo votlih delov uporabi eno jedro za več ulitkov, je bil obstoječi ulivno-napajalni sistem konstruiran, kot prikazuje slika 2 a). Izbrani so bili napajalniki cilindrične oblike, ki napajajo ulitek skozi ušesa kape izolatorja. Ta postavitev je ugodna, saj je tako omogočeno brušenje vratu napajalnika po ravni površini.

Litje začetnih vzorcev je bilo realizirano pri temperaturi 1420 °C in kemični sestavi, podani v Preglednici 1.

Tabela 1. Kemična sestava taline

Table 1. Chemical analysis of the melt

	C	Si	S	Mn	Cr
[mas. %]	2,83	1,00	0,04	0,85	0,08

Slika 1 b) prikazuje porušen ulitek v litem stanju, kjer je po celotnem preseku

between power lines and supports and prevent leakage of current into the ground.

Figure 2 shows the flow of optimization of the gating system. In the first optimization, by moving the location of the feeders, we successfully eliminated shrinkage porosity in the casting, but at the same time increased the gross weight of the system from 17 kg to 20 kg. In the second part of the optimization, due to the tendency to achieve better yield , we optimized the shape of the feeders to the smallest possible extent, which still ensures directional solidification. In doing so, we reduced the gross weight from 20 kg to 16,8 kg and thus increased the yield of melt by 16 %. With a production capacity of 200 molds per hour this amounts to 4800 kg less material needed per shift.

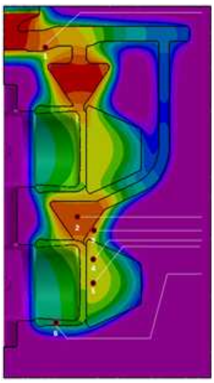
2 Experimental

The investigated insulator cap casting is made of white-heart malleable cast iron, quality EN-GJMW-550-04 (DIN EN 1562:2019) with a net weight of 2.6 kg. Due to the geometry of the casting and the desire to use one core for two castings for the production of a hollow inside part, the existing gating system was constructed as shown in Figure 2 a). Cylindrical-shaped feeders were chosen that feed the casting through the »ears« of the insulator cap. This arrangement is advantageous, as it enables the feeder neck to be round on a flat surface.

The casting of the initial samples was realized at a temperature of 1420 °C and the chemical composition is given in table 1.

Figure 1 b) shows casting in an as-cast state, where a crystalline shine characteristic of cementite is visible throughout the cross-section, which means that the casting has completely solidified "white" according to the metastable system Fe – Fe_3C. During viden kristalni lesk, značilen za cementit, kar pomeni, da se je ulitek v celoti strdil »belo« po metastabilnem sistemu Fe – Fe3C. Z žarjenjem oz. tempranjem pa ledeburitni (evtektski) Fe3C razpade, pri čemer se ogljik odlaga v obliki kompaktnih delcev, imenovanih temprani ogljik.

Da bi bil izračun livarskih procesov kar najbolj natančen, so bili določeni robni pogoji, eksperimentalno opredeljeni z meritvami temperatur na posameznem mestu ulitka, napajalnika in v peščeni mešanici. Na osnovi eksperimentalno pridobljenih ohlajevalnih (litina) in segrevalnih (peščena mešanica) krivulj je bila izvedena ponastavitev koeficienta prenosa toplote v odvisnosti od temperature. Meritve temperature so bile izvedene na 6 različnih mestih, kot to prikazuje Slika 3. Podatke smo zajemali z analogno-digitalnim pretvornikom proizvajalca National Instruments tip NI9213 in programom Labview. Frekvenca meritev je bila 50 Hz. Uporabljeni so bili termočleni tipa K (Ni – Cr – Ni), oplaščeni z inoksom ali steklenimi vlakni. Plašč iz inoksa je bil uporabljen v primeru neposrednega stika s talino. Termoelementi, ki so bili v peščeni mešanici, pa so imeli plašč iz steklenih vlaken.

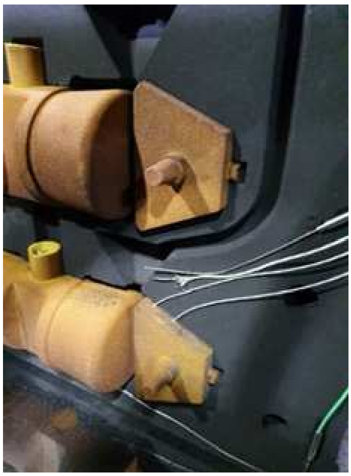


Slika 3. Postavitev termočlenov v peščeni formi

Figure 3. Placement of thermocouples in a sand mold

heat treatment - tempering, the ledeburite (eutectic) Fe3C breaks down, whereby the carbon is deposited in the form of compact particles called tempered carbon.

To make the calculation of the foundry processes as accurate as possible, boundary conditions were experimentally defined by temperature measurements at individual places of the casting, the feeder, and in the sand mixture. Based on the experimentally obtained cooling (casting) and heating (sand mixture) curves, the heat transfer coefficient was reset as a function of temperature. Temperature measurements were made at 6 different places, as shown in Figure 3. Data were collected with an analog-digital converter manufactured by National Instruments, type NI9213, and the Labview program. The measurement frequency was 50 Hz. Thermocouples type K (Ni – Cr – Ni) coated with stainless steel or fiberglass was used. A stainless steel jacket was used where there was direct contact with the melt. The thermocouples, which were in the sand mixture, had a fiberglass jacket.



Slika 4. Termočleni v peščeni formi

Figure 4. Thermocouples in a sand mould

3 Rezultati

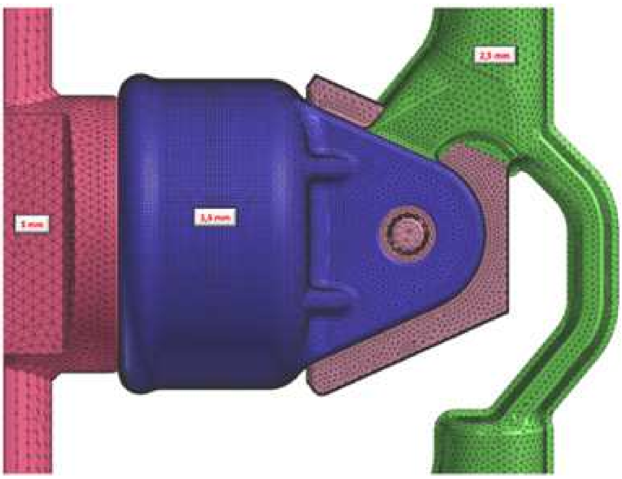
Na izrisanem 3-D modelu smo izvedli numerično simulacijo litja in strjevanja. Za geometrije ulitka in ulivno-napajalnega sistema, jeder in peščene forme smo izdelali površinsko mrežo, ki je sestavljena iz preprostih celic, s katerimi opišemo celotno geometrijo. Natančnost izdelave mreže in izračunane simulacije je odvisna od velikosti površinskih elementov. Izdelano površinsko mrežo predstavlja Slika 5. Na ulitku smo izbrali velikost površinskih elementov 1,5 mm, saj nas je zanimala prisotnost livarskih napak. Za ulivno-napajalni sistem smo nastavili velikost 2,5 mm in za jedra 5 mm. Peščeno formo smo razdelili na površinske elemente z velikostjo 12 mm. Poleg površinske mreže smo izračunali še volumsko mrežo. Skupno je tako bilo pripravljenih 5.270.162 volumskih elementov. Čas računanja je znašal 2 h 50 min.

Na Sliki 6 je prikazan posnetek simulacije strjevanja v trenutku, ko ulitek izgubi povezavo z napajalnikom. To območje v ulitku predstavlja zadnje strjevalno področje. Napajalnik ni zmožen zagotavljati zadostne količine taline skozi

3 Results

Numerical simulation of casting and solidification was carried out on the drawn 3-D model. For the geometries of the casting and gating system, cores, and sand form, a surface mesh grid was created, which consists of simple cells that describe the entire geometry. The accuracy of the mesh creation and the calculated simulation depends on the size of the surface elements. Figure 5 shows the produced surface mesh. The size of the surface elements on the casting was determined at 1.5 mm, as we were interested in the presence of casting defects here. A size of 2.5 mm was chosen for the gating system and 5 mm for the cores. The sand mold was divided into surface elements with a size of 12 mm. After the surface mesh was computed, the volume mesh was created. A total of 5,270,162 volume elements were thus prepared. The calculation time was 2 h 50 min.

Figure 6 shows a snapshot of the solidification simulation at the moment when the casting loses its connection with the feeder. This area in the casting thus represents the last solidification area, and since the feeder is not able to provide enough melt throughout the entire solidification time and thus compensate for shrinkage, a high probability of shrinkage porosity can be expected here. The reason for this is that the feeder is designed in such a way that it feeds the casting through the "ears". In doing so, it places a heavy thermal load on the smaller



Slika 5. Površinska mreža

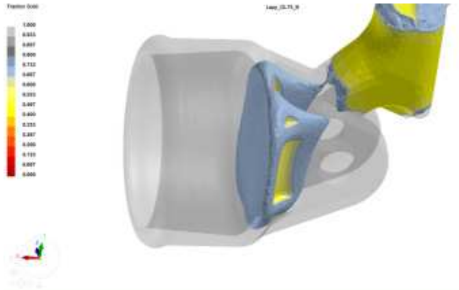
Figure 5. Surface mesh

celoten čas strjevanja in tako kompenzirati krčenja, zato je tukaj pričakovati veliko verjetnost pojava krčilne poroznosti. Vzrok za to je, da je napajalnik konstruiran na način, da napaja ulitek skozi »ušesa«. Pri tem močno toplotno obremeni manjše jedro (Slika 7) in ta del ulitka se zato ohlaja počasneje. Posledično ima tukaj ulitek tudi največji termalni modul. Ker se ohlaja počasneje, je čas do temperature solidus na tem delu okoli 270 s, medtem ko se vrat napajalnika strdi po 220 s.

Slika 9 prikazuje izračun toplotnega modula za ulitek kape izolatorja. Opaziti je, da je modul na sredini ulitka največji, in sicer okoli 0,52 cm, medtem ko je najmanjši modul ulitka 0,28 cm. Modul

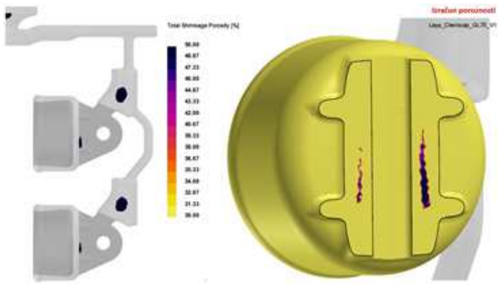
core (Figure 7) and this part of the casting, therefore, cools more slowly. As a result, the casting here also has the highest thermal modulus. Because it cools more slowly, the time to solidus temperature is around 270 s, while the neck of the feeder solidifies after 220 s.

Figure 9 shows the thermal modulus calculation for an insulator cap casting. It can be seen that the module in the middle of the casting is the largest, namely around 0,52 cm, while the smallest module of the casting is 0,28 cm. The modulus of the feeder's neck varies between 0,44 cm and 0,47 cm, which is not sufficient because the modulus of the feeder's neck should be greater than the highest modulus of the



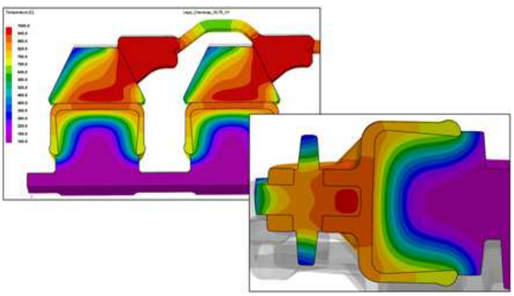
Slika 6. Izračun strjevanja

Figure 6. Calculation of solidification



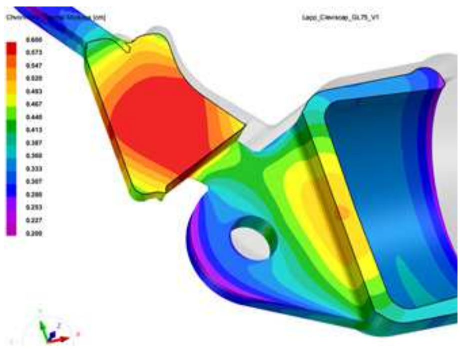
Slika 7. Izračun krčilne poroznosti

Figure 7. Calculation of total shrinkage porosity



Slika 8. Temperaturno polje na koncu strjevanja

Figure 8. Temperature field at the end of solidification



Slika 9. Izračun toplotnega modula ulitka

Figure 9. Calculation of thermal modulus

vratu napajalnika se giblje med 0,44 cm in 0,47 cm, kar pa ni zadostno, saj bi moral biti modul vratu napajalnika večji od najvišjega modula ulitka, da bi dosegli usmerjeno strjevanje iz ulitka skozi vrat napajalnika v napajalnik. To merilo imenujemo merilo modulov, kjer je MU modul ulitka, MV modul vratu napajalnika in MN modul napajalnika.

$$M_U < M_V < M_N \qquad (2)$$

Nov ulivno-napajalni sistem je bil zasnovan na način, da smo ohranili postavitev ulitkov na modelni plošči. Tako smo se izognili popravilu orodja za izdelavo jeder in orodja za vlaganje jeder v peščeno formo. Napajalnike smo postavili na del ulitka, ki ga je simulacijska programska oprema ProCAST izračunala kot tistega z največjim termalnim modulom in kot območje, ki se strdi zadnje. Napajalnike smo prav tako povečali, da bi dovajali dovolj taline v ulitek, tako da je njihov modul večji kot modul ulitka, katerega napajajo.

Rezultati meritev temperatur v ulitku, jedru in peščeni mešanici so podani na Sliki 10 in Sliki 11. S termočlenom 1 smo izmerili maksimalno temperaturo 1419 °C, ki smo jo potrdili tudi s sondo za merjenje temperature na vlivnem avtomatu. S spreminjanjem temperature skozi čas lahko spremljamo ohlajanje taline do konca formarske linije, kjer se ulitki ločijo od peščene mešanice. Takrat smo termočlene odklopili in ulitke pobrali iz forme. Proga, na kateri se ulitki ohlajajo v peščeni mešanici, preden padejo v hladilni boben in se od peščene mešanice ločijo, je dolga 12 m. To pot ulitki dosežejo po 12 minutah, temperatura po tem času znaša 818 °C. To pomeni, da je hitrost ohlajanja okoli 50 °C/min.

Termočlen T2 je bil lociran v sredini napajalnika spodnjega ulitka (zaradi poteka dovodnega kanala termočlenov nismo mogli postaviti v zgornji ulitek). Za okoli 30 s je termočlen izgubil povezavo, vendar se je ta nato vrnila. Opazimo, da temperatura

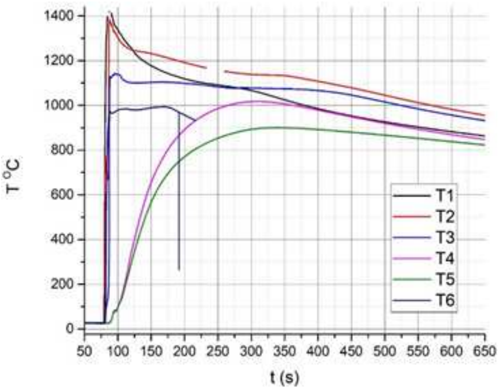
casting to achieve directional solidification from the casting through the feeder's neck into the feeder. This is called the modulus criterion, where MU is the modulus of the casting, MV is the modulus of the feeder neck, and MN, is the modulus of the feeder.

$$M_U < M_V < M_N \qquad (2)$$

The new gating system was designed in such a way as to preserve the placement of the castings on the model plate, as this avoided the repair of the core-making tool and the core setter. We placed the feeders on the part of the casting that ProCAST calculated as having the highest thermal modulus and as the area that solidifies last. We have also enlarged the feeders to feed enough melt into the casting so that their modulus is greater than the modulus of the casting they feed.

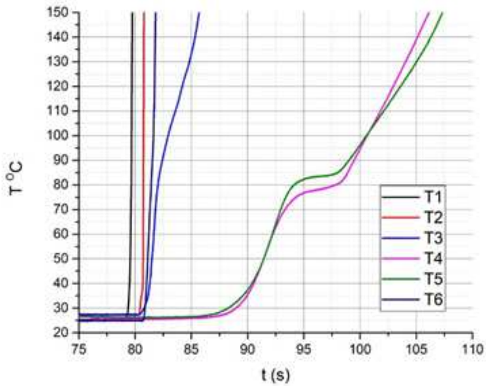
The results of temperature measurements in the casting, core and sand mixture are given in Figures 11 and Figure 12. With thermocouple 1, the maximum temperature was measured at 1419 °C, which was also confirmed with the temperature measuring probe on the pouring machine. By changing the temperature over time, we can monitor the cooling of the melt to the end of the cooling line, where the castings are separated from the sand mixture. At that time, we disconnected the thermocouples and collected the castings from the mold. The line on which the castings are cooled in the sand mixture before falling into the cooling drum and separating from it is 12 m long. The castings reach this path after 12 min, the temperature after this time is 818 °C. This gives us a cooling rate of around 50 °C/min.

Thermocouple T2 was located in the middle of the feeder of the lower casting (due to the flow of the runners, we could not place the thermocouples in the upper casting). For about 30 s, the thermocouple



Slika 10. Rezultati meritev temperatur

Figure 10. Results of temperature measurements



Slika 11. Povečano območje T4 in T5

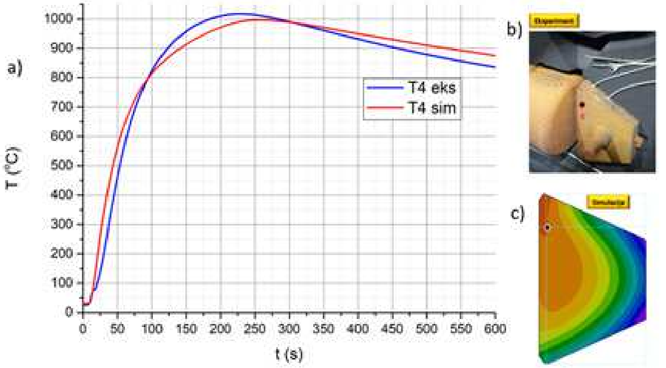
Figure 11. Enlarged view, showing T4 and T5

pada počasneje kot v termočlenu T1. To ni presenetljivo, saj je volumen napajalnika veliko večji kot volumen razdelilnega kanala, zato se ta ohlaja počasneje. Maksimalna dosežena temperatura je znašala 1385 °C, in sicer okoli 6 s po začetku litja, kar se natančno sklada z izračunom litja. Toliko časa je talina potrebovala za pot od livne čaše do spodnjega napajalnika.

Termočlena T4 in T5 sta merila temperaturo v peščenem jedru. Izmerjene temperature termočlena T4 so višje, ker je termočlen bližje napajalniku kot termočlen T5. Iz grafa je razvidno, kako se temperatura v jedru povečuje, ko toplota prehaja iz ulitka

lost connection, but then it came back. We notice that the temperature drops more slowly than in thermocouple T1. This is not surprising, because the volume of the feeder is much larger than the volume of the runner, so it cools more slowly. The maximum temperature reached was 1385 °C, about 6 s after the start of casting, which is exactly in line with the casting calculation. That's how long the melt needed to travel from the pouring basin to the lower feeder.

Thermocouples T4 and T5 measured the temperature in the sand core. The measured temperatures at T4 are higher because the thermocouple is closer to



Slika 12. Primerjava segrevalnih krivulj eksperimenta in simulacije v peščenem jedru (a), pozicija termoelementa T4 (b), mesto določitve izračunane segrevalne krivulje (c)

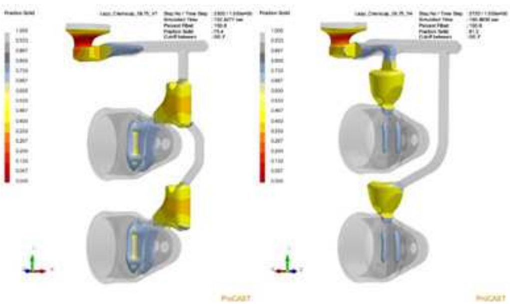
Figure 12. Comparison of the heating curves of the experiment and simulation in the sand core (a), the position of the thermocouple T4 (b), the location of the calculated heating curve (c)

na jedro. Opazna pa je tudi sprememba na krivulji T4 in T5, in sicer pri temperaturi okoli 80 °C, kar je skladno s temperaturo vžiga fenolne smole v jedru Croning.

Slika 12 prikazuje primerjavo med eksperimentalno določeno in izračunano segrevalno krivuljo v peščenem jedru ter položaj termoelementa T4 v peščeni formi in na virtualnem jedru. Opazimo, da je izračunana segrevalna krivulja bolj zvezna, saj ne upošteva vseh pogojev, kot je npr.

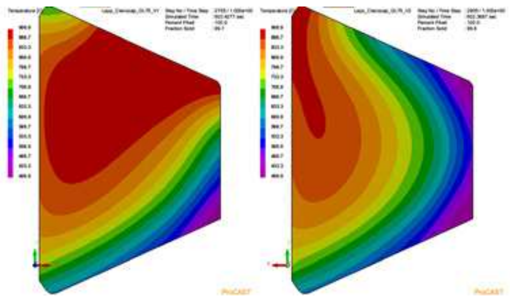
the feeder than the T5 thermocouple. The graph shows how the temperature in the core increases as heat passes from the casting to the core. A change in the T4 and T5 curve is also noticeable at a temperature of around 80 °C, which would correspond to the ignition temperature of the phenolic resin in the Croning core.

Figure 12 shows a comparison between the experimentally determined and calculated heating curve in the sand



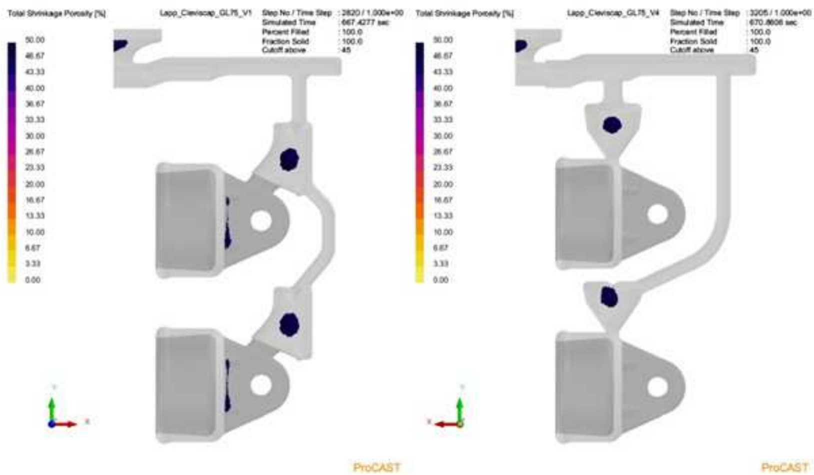
Slika 13. Izračun strjevanja za verzijo 1 (a) in verzijo 3 (b)

Figure 13. Calculation of solidification for version 1 (a) and version 3 (b)



Slika 14. Temperaturno polje jedra 10 min od začetka litja za verzijo 1 (levo) in verzijo 3 (desno)

Figure 14. Temperature field of the sand core 10 min after casting for version 1 (left) and version 3 (right)



Slika 15. Izračun krčilne poroznosti za verzijo 1 (levo) in verzijo 3 (desno)

Figure 15. Calculation of total shrinkage porosity for version 1 (left) and version 3 (right)

vžig fenolne smole, kar pa je zaznano na eksperimentalno določeni krivulji. Zaradi manjših razlik med eksperimentom in izračunom smo v programu ProCAST nekoliko spremenili določene parametre jedra Croning (gostota, prevodnost), da smo se čim bolj približali realnemu stanju.

Na Sliki 13 lahko vidimo primerjavo izračuna strjevanja za verzijo 1 in verzijo 3 približno 150 s po začetku litja. Pri verziji 3 s spremenjenim položajem napajalnikov se ulitek strjuje enakomerno v napajalnik in ne izgubi povezave z njim. Prav tako se mesto največjega termalnega modula prestavi na območje pod napajalnikom. Zaradi tega se zmanjša tudi pregrevanje manjšega jedra (Slika 14). Tako smo dobili usmerjeno strjevanje, ki je najučinkovitejši ukrep za odpravo krčilne poroznosti. Pri usmerjenem strjevanju ni bistvena preprečitev nastanka lunkerja, pač pa njegov prenos na neškodljivo mesto, to je v napajalnik (Slika 15).

4 Zaključek

Pri gravitacijskem litju v peščene forme je zasnova ulivno-napajalnega sistema izjemno pomembna, saj njegova geometrija neposredno vpliva na kakovost ulitkov in količino izmeta. Ključni cilj ulivnega sistema je zagotoviti nemoten pretok taline iz livne čaše v livno votlino celoten čas litja in strjevanja.

V članku je bila opisana sprememba postavitve in geometrije napajalnikov za ulitek kape izolatorja. Na obstoječem ulivno-napajalnem sistemu je bilo po litju zaznati povečan delež livarskih napak, predvsem kot posledica krčilne poroznosti. V sklopu optimizacije so bili napajalniki prestavljeni na mesto, kjer so računalniški izračuni določili najvišji termalni modul in ga prepoznali kot območje, ki se strdi zadnje.

core and the position of the thermocouple T4 in the sand mold and on the virtual core. We notice that the calculated heating curve is more uniform as it does not take into account all conditions such as e.g. ignition of the phenolic resin, which is detected on the experimentally determined curve. Due to minor differences between the experiment and the calculation, we slightly changed certain parameters of the Croning core (density, conductivity) in the ProCAST program to get as close as possible to the real situation.

In Figure 13 we can see a comparison of the solidification calculation for version 1 and version 3 approximately 150 s after the start of casting. In version 3 with a changed position of the feeder, the casting solidifies evenly in the direction of the feeder and does not lose its connection with it. Also, the location of the largest thermal module is moved to the area under the feeder. This is also registered on the temperature field calculation of the sand core (Figure 14). Based on the applied changes, directional solidification was obtained, which is the most effective measure to eliminate shrinkage porosity. It is not essential to prevent the formation of a shrinkage defect, but rather to transfer it to a harmless place, i.e., to the feeder (Figure 15).

4 Conclusions

In gravity casting in sand molds, the design of the gating system is extremely important, as its geometry directly affects the quality of the castings and the amount of scrap. The key goal of the gating system is to ensure a smooth flow of melt from the pouring cup to the casting cavity throughout the casting and solidification period.

The article described a change in the layout and geometry of the feeders for

Rezultati teh izračunov so bili potrjeni s stanjem po litju v proizvodnji.

insulator cap casting. On the existing gating system, an increased proportion of casting defects was detected after casting, mainly as a result of shrinkage porosity. As part of the optimization, the feeders were moved to the place where the simulation showed the highest thermal modulus and recognized as the area that solidifies last. The results of these calculations were confirmed with the results after casting in production.

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