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Nova oblika mini napajalnika TELE za večjo toplotno učinkovitost

A New Shape of Tele Mini-Riser for Increased Thermal Efficiency

Povzetek

Svet livarn si nenehno prizadeva zmanjšati količino odpadkov, povečati učinkovitost in izboljšati proizvodne tehnike v okviru občutljivih trajnostnih ciljev. Raziskave za zmanjšanje ogljičnega odtisa in s tem povezan proces optimizacije vključujejo tudi nove inovativne sisteme dovajanja, ki morajo biti v skladu z vse močnejšim upoštevanjem okoljskega vidika. Na podlagi tega je družba Chemex na zadnjem sejmu GIFA 2023 predstavila nov teleskopski mini napajalnik. Ima kroglasto geometrijo, ki združuje prednosti teleskopske tehnologije z izboljšano toplotno učinkovitostjo, s čimer se doseže še lažji in bolj kompakten mini napajalnik. Med vsemi trdnimi oblikami z določeno prostornino je krogla tista z najmanjšo površino; med vsemi trdnimi oblikami z določeno površino je krogla tista z največjo prostornino. Zato ima krogla najmanjše razmerje med površino in prostornino.

Ta študija raziskuje rezultate uporabe novega eksotermnega tulca TELE SF v livarni Kovis-Livarna. V projektu je bila primerjana učinkovitost mini napajalnikov TELE v klasični eksotermni različici (modul 2,1 cm, prostornina dovajanja 155 cm^3) z novo sferično tehnologijo (modul 1,9 cm, prostornina dovajanja 110 cm^3). Rezultati proizvodnje so pokazali, da ta nova tehnologija omogoča optimizacijo dovajalnega sistema, kar dokazuje povečanje toplotne učinkovitosti zaradi nove sferične geometrije in zmanjšanje teže samega tulca. Tako je bilo mogoče doseči cilj manjšega, lažjega in zmogljivejšega mini napajalnika, ki združuje značilne vidike receptur Chemex: ekološka cold-box veziva, recepture brez fluora ter ničelno degeneracijo grafita.

Ključne besede: dovajanje, okolje, teleskopski, krogla, eksotermno, brez fluora.

Abstract

The Foundry World is constantly aiming at minimizing scraps, maximizing performances, and improving production techniques in the framework of sensitive sustainability goals. The research for a reduced carbon footprint and related optimization process also involves new innovative feeding systems which need to be in line with the growing attention to the environmental aspect. On this basis, Chemex presented a new telescopic mini-riser at the last GIFA 2023. It is provided with a spherical geometry capable of combining the advantages of telescopic technology with improved thermal efficiency, thus obtaining an even lighter and more compact mini-riser. Indeed, among all solids with a given volume, the sphere has the smallest surface area; among all solids with a given surface area, the sphere has the greatest volume. Therefore, the sphere has the minimum surface/volume ratio.

This study explores the results of the new exothermic TELE SF sleeve application at Kovis-Livarna foundry. The project has compared the efficiency of TELE mini-risers in its classic exothermic version (modulus 2.1 cm, feeding volume of 155 cm^3) with the new spherical technology (modulus 1.9 cm, feeding volume of 110 cm^3). The production results showed that this new technology allows the optimization of the feeding system, proving the increase in thermal efficiency thanks to the new spherical geometry, as well as a decrease in the weight of the sleeve itself. It has thus been possible to achieve the target of a smaller, lighter, and more performing mini-riser, combining the characteristic aspects of Chemex recipes: ecological cold-box binders, fluorine-free recipes, and zero graphite degeneration.

Keywords: feeding, environment, telescopic, sphere, exothermic, fluorine-free.

1 Uvod

Razumevanje strjevanja ima ključno vlogo pri zagotavljanju pravilne opredelitve sistema dovajanja v postopku litja. Med strjevanjem kovina preide iz tekočega v trdno stanje, kar bistveno vpliva na končno kakovost izdelka. Dobro poznavanje tega procesa omogoča predvidevanje in nadzor nad morebitnimi napakami, kot so poroznost in vključki, s tem pa je zagotovljena enakomerna porazdelitev materiala in homogena struktura. To znanje omogoča načrtovanje učinkovitejših sistemov dovajanja, ki zagotavljajo pravo količino tekoče kovine ob ustreznem času, s čimer se izboljšajo mehanske in strukturne lastnosti končnega izdelka. V naslednjih odstavkih bomo opozorili na nekatere temeljne pojme za razumevanje procesa strjevanja litega železa in na pojme, ki omogočajo pravilno opredelitev dobrega sistema za dovajanje.

1.1 Strjevanje in napajalni sistem

Strjevanje ulitka je odvisno od:

- toplotnih lastnosti zlitine;
- toplotnih lastnosti materiala orodja;
- oblike in mer ulitka.

Med ohlajanjem in strjevanjem večine kovinskih zlitin pride do zmanjšanja volumna kovine, znanega kot krčenje (Slika 1).

1 Introduction

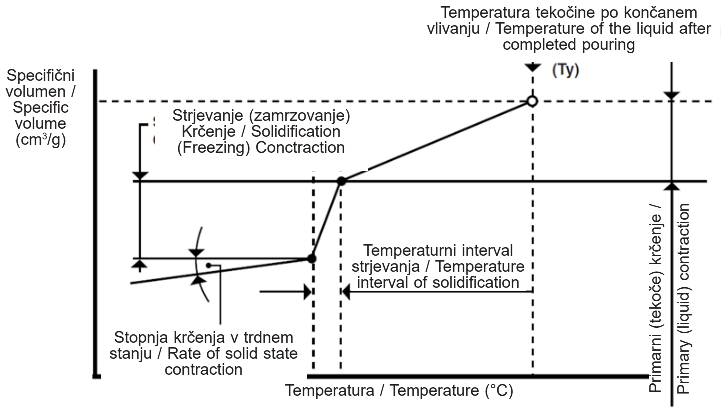
Understanding solidification plays a crucial role in ensuring the correct definition of the feeding system in a casting process. During solidification, the metal transitions from a liquid to a solid state, significantly affecting the product’s final quality. A solid knowledge of this process allows the prediction and control of defects that may arise, such as porosity and inclusions, thus ensuring a uniform distribution of the material and a homogeneous structure. This knowledge enables the design of more efficient feeding systems that provide the right amount of liquid metal at the appropriate time, thereby improving the mechanical and structural properties of the final product. In the following paragraphs, some fundamental concepts for understanding the solidification process of cast iron will be recalled, as well as the concepts that allow for the correct definition of a good feeding system.

1.1 Solidification and Feeding System

The solidification of a casting is a result of the:

- thermal properties of alloy;
- thermal properties of mould material;
- shape and dimensions of the casting.

During the cooling and solidification of most metal alloys, there is a reduction in the metal volume known as shrinkage (Fig. 1).



Slika 1. Splošni vzorec spremembe prostornine za kovine (npr. jeklo, belo železo, medenina itd.) [1].

Fig. 1. General volume change pattern for metal (e.g., steel, white iron, brass, etc.) [1].

Da bi se izognili krčilni poroznosti, je treba zagotoviti dodatno tekočo kovino. Teoretično mora biti napajalnik dimenzioniran tako, da vsebuje tekočo maso, uporabno za dovajanje ulitka, ne da bi krčilni stožec segal v sam ulitek. Tako je ob enaki začetni prostornini tekočine njen izkoristek v napajalniku odvisen tudi od njene geometrije. Globina krčenja je odvisna tudi od vseh drugih robnih pogojev, kot je uporaba eksotermnih materialov, ki lahko povečajo izkoristek tudi za več kot 50 % [2].

Dovajanje mora biti ustrezno za vsako točko ulitka in na kateri koli razdalji od dovajalnika. Usmerjeno strjevanje v smeri dovajalnikov ne zagotavlja dovajanja območij na določeni razdalji od območja spoja. To je posledica nizkih toplotnih gradientov in velikega upora pri gibanju tekočine skozi material, ki z večanjem trdnega deleža postaja vse bolj viskozen in s tem vse manj prepusten. Hidrostatični tlak, ki je edina gonilna sila pri gravitacijskem litju, se postopoma zmanjšuje, saj dendriti omejujejo pretok tekočine [2]. Numerični rezultati, ki nam najbolj pomagajo oceniti to težavo pri ulitkih s kompleksno geometrijo, so predvsem toplotni gradient in njegov izračun, ki ga dobimo, če ga delimo s

To avoid shrinkage porosity, it is necessary to supply additional liquid metal. Theoretically, the riser must be sized to contain the liquid mass useful for feeding the casting without the shrinkage cone extending into the casting itself. The liquid yield of a riser thus also depends on its geometry, given the same initial liquid volume. The depth of shrinkage is also a function of all other boundary conditions, such as the use of exothermic materials which can increase the yield even more than 50% [2].

Feeding must be adequate for every point of the casting and at any distance from the feeder. Directional solidification towards the feeders does not guarantee the feeding of areas at a certain distance from the junction zone. This is due to low thermal gradients and the high resistance to fluid movement through a material that becomes increasingly viscous as the solid fraction grows, thus becoming less permeable. Hydrostatic pressure, the only driving force behind feeding in gravity casting, progressively decreases as dendrites limit fluid flow [2]. Numerical results that most help us to evaluate this problem in complex geometry castings are mainly the thermal gradient and its elaboration, obtained by kvadratnim korenom hitrosti ohlajanja, imenovanim kriterij Niyama (enačba 1) [3]:

$$N_y = G/\sqrt{\dot{T}} \tag{1}$$

kjer:
G je temperaturni gradient [°C/cm];
$\dot{T}$ je hitrost hlajenja [°C/s].

Vse vrednosti so blizu začetne temperature taljenja. Verjetnost nastanka poroznosti se povečuje z zmanjševanjem vrednosti. Če je kriterij Niyama nižji od kritične vrednosti, je nastanek poroznosti zagotovljen [4].

Na srečo ali žalost, ko govorimo o litem železu, imamo grafit, katerega obarjanje lahko nadomesti krčenje kovine zaradi njegovega raztezanja med strjevanjem. V procesu obarjanja lahko tudi elementi, kot je silicij, pomagajo pri nastajanju in raztezanju grafita.

V prvi fazi ohlajanja se tekoča kovina najprej skrči, nato pa se razširi zaradi raztezanja grafita. Proti koncu strjevanja se zadnja preostala tekočina strdi s krčenjem.

1.1.1 Chvorinovo pravilo

Teža ulitka ali debelina stene nista dovolj natančna podatka za opis hitrosti ohlajanja, saj se na primer preproste oblike (kocka, plošča, palica itd.) ohlajajo različno hitro, čeprav imajo enako debelino (Slika 2). Zato je za opis ohlajanja natančnejša metoda uporaba modula (M) [1].

dividing it by the square root of the cooling rate, called the Niyama criterion (Eq. 1) [3]:

$$N_y = G/\sqrt{\dot{T}} \tag{1}$$

where:
G is the temperature gradient [°C/cm];
$\dot{T}$ is the cooling rate [°C/s].

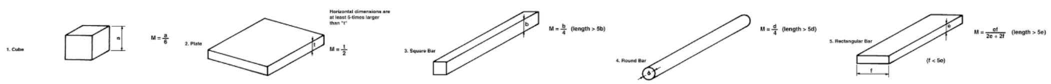
All the values are taken near the solidus temperature. The probability of porosity formation increases with a decrease in value. If the Niyama criterion is lower than the critical value, then the formation of porosity is guaranteed [4].

Fortunately, or unfortunately, when we speak about cast iron, we have graphite and its precipitation can compensate for the metal shrinkage thanks to its expansion during solidification. In the precipitation process, also elements such as silicon can help promote graphite formation and expansion process.

In the first cooling phase the liquid metal initially contracts, then it expands due to graphite expansion. Towards the end of solidification, the last remaining liquid solidifies with contraction.

1.1.1 Chvorinov's Rule

Casting weight or wall thickness is not sufficiently accurate to describe cooling rate, for instance, simple shapes (cube, plate, bar, etc.) cool at different rates even if they have the same thickness (Fig. 2). For



Slika 2. Izračun modula za preproste geometrijske oblike. Razen kocke veljajo vse druge geometrijske oblike za neskončno dolge [1].

Fig. 2. Modulus calulation for simple geometris. Except for the cube, all other geometric shapes are considered infinitely long [1].

M lahko opredelimo kot razmerje med prostornino in učinkovito hladilno površino. Kompleksne geometrijske oblike je treba razdeliti na enostavnejše komponente in izračunati modul za vsako od njih [1].

Makroskopsko lahko dinamiko strjevanja in ohlajanja kovinske zlitine teoretično obravnavamo tako, da ocenimo različne prispevke k prenosu toplote iz tekočine v orodje in zunanje okolje [5]. Odpornost proti toplotnemu toku, ki prihaja iz notranjosti ulitka, lahko na splošno pripišemo strjevanju kovine, vmesniku med ulitkom in orodjem ter orodju samemu; medtem ko lahko toplotni tok v tekočini, pogojen s konvekcijskimi gibanji in pretaljevanjem, ter toploto, ki jo absorbira zunanje okolje, razen v očitnih primerih zanemarimo. Chvorinovo enačbo lahko obravnavamo kot poenostavitev zapletenega problema, ki lahko upošteva te vidike izmenjave toplote, ki bi sicer zahtevali opredelitev številnih diferencialnih enačb, rešljivih le s sodobno simulacijsko programsko opremo.

Zato Chvorinova enačba (Enačba 2) velja za preproste oblike in kaže neposredno povezavo med časom strjevanja kovine in kvadratom modula prek konstante, ki je odvisna od pogojev kovine in orodja; torej od difuznosti in kemijsko-fizikalnih lastnosti materialov.

$$t = k \cdot M^2 \qquad (2)$$

kjer je:

t čas strjevanja;
k konstanta, ki je odvisna od lastnosti kovine in orodja (npr. gostota, specifična toplota, toplotna prevodnost itd.);
M toplotni modul.

Pri enostavnih ulitkih je na podlagi Chvorinovovih študij mogoče zagotoviti dobro dovajanje z oblikovanjem dovajanja s toplotnim modulom, ki je vsaj za 20 % večji od kritičnega toplotnega modula ulitka.

this reason, it is a more accurate method to use modulus (M) to describe cooling [1].

M can be defined as the ratio between volume and the effective cooling surface area. Complex geometries should be divided into simpler components, and the modulus for each component must be calculated [1].

In macroscopic terms, the dynamics of solidification and cooling of a metal alloy can be theoretically treated by evaluating the different contributions to heat transfer from the liquid to the mould and the external environment [5]. The resistance to the heat flow comes from within the casting can be generally ascribed to the solidification of the metal, the interface between the casting and the mould, and the mould itself; whereas the heat flow within the liquid, conditioned by convective movements and remelting, and the heat absorbed by the external environment, can be neglected with the obvious exceptions. We can consider Chvorinov's equation as a simplification of the complex problem capable of taking these aspects of heat exchange into account that would otherwise require defining numerous differential equations solvable only through modern simulation software.

Therefore, Chvorinov's equation (Eq. 2) is valid for simple shapes, it indicates a direct relationship between the solidification time of the metal and the square of the modulus through a constant that depends on the conditions of the metal and the mould; hence on the diffusivity and the chemical-physical properties of the materials.

$$t = k \cdot M^2 \qquad \text{(Eq. 2)}$$

where:

t is the solidification time;
k is a constant depending on the properties of the metal and the mould (e.g., density, specific heat, thermal conductivity, etc.);
M is the thermal modulus.

1.2 Razmerje med površino in prostornino (SA:V)

V znanosti o materialih je razmerje med površino in prostornino (SA:V) pomembna količina, ki pomaga razložiti termofizikalne procese, ki potekajo prek površine in prostornine [6], na primer, toplotna prevodnost, ki jo opisuje Fourierjev zakon (Ek. 3), ki pravi, da je toplotni tok zaradi toplotne prevodnosti sorazmeren z velikostjo temperaturnega gradienta in z nasprotnim predznakom [7]:

$$\vec{q} = -k\nabla T \quad (3)$$

kjer je:
$\vec{q}$ toplotni tok [W/m^2];
k toplotna prevodnost [W/(m·K)];
∇T temperaturni gradient [K/m].

Veliko razmerje SA:V pomeni večjo površino na enoto prostornine, skozi katero lahko material difundira, zato je difuzija ali toplotna prevodnost hitrejša, veliko razmerje SA:V pa pospešuje termodinamične procese, ki zmanjšujejo prosto energijo.

S primerjavo razmerja SA:V za različne geometrijske oblike (preglednica 1) lahko opazimo, da krogla kaže najmanjše razmerje in ker so toplotne izgube manjše pri majhnem razmerju SA:V, to pomeni, da krogla kaže največji toplotni izkoristek.

In the case of simple castings, based on Chvorinov's studies, it is possible to ensure good feeding behaviour by designing a feeder with a thermal modulus of at least 20% greater than the critical thermal modulus of the casting.

1.2 Surface Area-to-Volume Ratio (SA:V)

In material science the Surface-to-Volume ratio (SA:V) is an important quantity helpful to explain thermo-physical processes which occur through the surface and the volume [6], for example, the heat conduction described by Fourier's law (Eq. 3) which states that the heat flux resulting from thermal conduction is proportional to the magnitude of the temperature gradient and opposite to it in sign [7]:

$$\vec{q} = -k\nabla T \quad (3)$$

where:
$\vec{q}$ is the heat flux [W/m^2];
k is the thermal conductivity [W/(m·K)];
∇T is the temperature gradient [K/m].

A large SA:V ratio means there is more surface area per unit volume through which material can diffuse, therefore, the diffusion or heat conduction, will be faster as well as a high SA:V ratio speeds up thermodynamic processes that minimize free energy.

Comparing SA:V ratio for different geometries (Tab. 1), it is possible to note that the sphere shows the lowest ratio and because the heat loss is lower with small

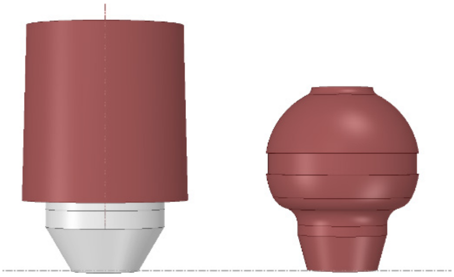
Preglednica 1. Izračun razmerja med površino in prostornino (SA:V) za dve preprosti telesi: kocko in kroglo.

Tab. 1. Calculation of Surface-to-Volume ratio (SA:V) for two simple geometries: cube and sphere.

Oblika / Shape	Površina / Surface Area	Prostornina / Volume	SA:V
Kocka / Cube	$SA = 6l^2$	$V = l^3$	$6l^2 / l^3 = 6/l$
Krogla / Sphere	$SA = 4\pi r^2$	$V = 4/3\pi r^3$	$4\pi r^2 / 4/3\pi r^3 = 3/r$

2 Eksperimentalni del

V tej študiji je bila eksperimentalno ovrednotena toplotna učinkovitost novega kroglična mini napajalnika TELE SF v primerjavi s klasičnim mini napajalnikom Chemex TELE (Slika 3).



Slika 3. CB 43-21 TELE 195 22 38 in CB 31 TELE SF 100 18 40. Opazen je prihranek višine in optimizacija prostornine.

Fig. 3. CB 43-21 TELE 195 22 38 and CB 31 TELE SF 100 18 40. It is noticeable the height saving as well as the optimization of volume.

Tehnični podatki mini napajalnikov, primerjanih v tej študiji, so navedeni v preglednici 2.

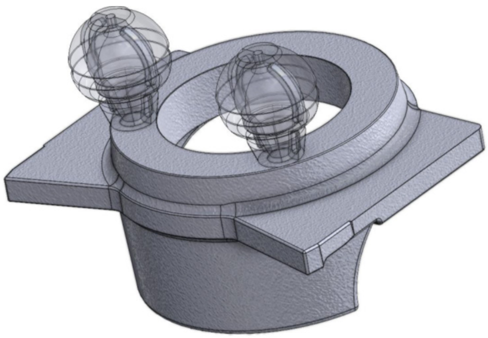
Ta študija je bila izvedena v sodelovanju z livarno Kovis-Livarna na že obstoječem ulitku, ki se redno proizvaja v proizvodnji s standardnimi mini napajalniki Chemex TELE. Prvotni dovodni sistem je bil zasnovan z dvema napajalnikoma TELE

SA:V ratio, this means that the sphere shows the maximum thermal efficiency.

2 Experimental part

In this study, the thermal efficiency of a new spherical mini-riser TELE SF was experimentally evaluated, comparing it with a classic Chemex TELE mini-riser (Fig. 3).

Specifically, the technical data of the mini-risers compared in this study are reported in Tab. 2.



Slika 4. Optimizirana nastavitev dovodnega sistema za ta eksperimentalni poskus; zamenjava napajalnika TELE 195 22 z dvema napajalnikom TELE SF 100 18 na enakih položajih.

Fig. 4. Optimized feeding system set-up for this experimental trial; replacing TELE 195 22 with two TELE SF 100 18 in the same positions.

Preglednica 2. Specifikacije mer dveh mini napajalnikov, vključenih v to študijo. Notranji premer vratu dovodnega sistema: 22 mm in 18 mm; zunanji premer vratu dovodnega sistema: 38 mm in 40 mm.

Tab. 2. Dimension specifications of the two mini-risers involved in this study. The inner diameter feeder neck: 22 mm and 18 mm; the outer diameter feeder neck: 38 mm and 40 mm.

Mini-riser / Mini napajalnik	Modul / Modulus (cm)	Višina / Height (mm)	Volumen / Volume (cm^3)
CB 43-21 TELE 195 22 38	2.1	139	190
CB 31 TELE SF 100 18 40	1.9	104	107

195 22, ki sta zagotavljala trdnost ulitka; v novi konfiguraciji sta bila ta mini napajalnika nadomeščena z dvema napajalnikoma TELE SF 100 18 (Slika 4). Sklop vključuje štiri ulitke na orodje in tako skupaj 8 mini napajalnikov na orodje.

Glavni tehnični podatki o ulitku in njegovi izvedbi so navedeni v preglednici 3.

Vse ulitke smo preverili vizualno, stehtali in pregledali z rentgensko difrakcijo (XRD) s petkratnim testiranjem.

3 Rezultati

Vizualni pregled je pokazal, da so bili vsi ulitki ustrezni, prav tako je analiza z rentgensko difrakcijo (XRD) potrdila, da so bili vsi ulitki brez krčenja. Kot je mogoče videti na sliki 5 in sliki 6, so bili tudi vrati dovajalnikov brez poroznosti.

Uporaba sistema TELE SF 100 18 je omogočila uporabo manjšega sistema dovajanja ter manjšega in lažje odstranljivega vratu sistema dovajanja.

Ti rezultati so omogočili preverjanje večje toplotne učinkovitosti TELE SF, saj je bila kapaciteta dovajanja primerljiva z nekoliko višjim modulom mini napajalnika.

Z globljo analizo optimizacije je uporaba TELE SF 100 18 prihranila 40 % prostornine na mini napajalnik in približno 4 kg na orodje (preglednica 4).

Poleg tega je treba upoštevati tudi okoljske vidike, na primer, napajalnik TELE SF je omogočil učinkovitejše skladiščenje in logistiko. Dejansko lahko TELE SF poveča

This study was performed in collaboration with Kovis-Livarna foundry on an already existing casting which is produced regularly in production with standard Chemex TELE mini-risers. The original feeding system was designed with two TELE 195 22 that ensure the soundness of the casting; these mini-risers were replaced with two TELE SF 100 18 in the new configuration (Fig. 4). The cluster includes four castings per mould and therefore a total of 8 mini-risers per mould.

The main technical data of the casting and its realization are reported in Tab. 3.

All castings had been checked visually, weighted, and XRD examined by doing five repetitions test.

3 Results

The visual inspection showed that all castings were soundness as well as XRD analysis confirmed that all castings were shrinkage free. As it is possible to see on the Fig. 5 and Fig. 6 the feeder necks were also found without any porosity.

The application of TELE SF 100 18 allowed to apply a smaller feeder as well as a smaller and easier to remove feeder neck.

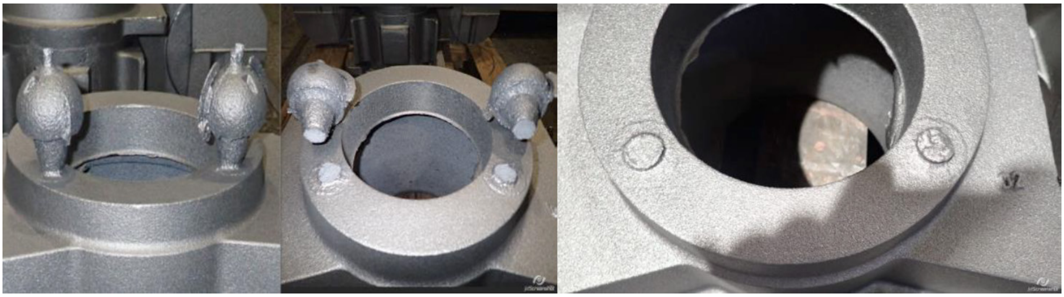
These results have permitted to verify the increased thermal efficiency of TELE SF because the feeding capacity has been comparable to a slightly higher modulus mini-riser.

Analysing deeper the optimization, the application of TELE SF 100 18 has saved

Preglednica 3. Tehnični podatki o pripravi ulitka.

Tab. 3. Technical data details of casting set-up.

Teža ulitka / Casting weight	Nodularna litina / Ductile Iron	Temperatura vlivanja / Pouring temperature	Najv. modul ulitka / Max. casting modulus
40 kg	EN-GJS-400-18	1360±10 °C	2 cm



Slika 5: eksperimentalni rezultati optimiziranega sistema za dovajanje s TELE SF 100 18 po peskanju in izbitju dovajalnikov.

Fig. 5: experimental results of the optimized feeding system with TELE SF 100 18 after shot-blasting and feeders knock off.

Slika 6. Eksperimentalni rezultati iz Kovis-Livarne: prvotni sistem dovajanja s TELE 195 22 na levi; optimizirani sistem dovajanja s TELE SF 100 18 na desni.

Fig. 6. Experimental results from Kovis-Livarna: original feeding system with TELE 195 22 on the left; optimized feeding system with TELE SF 100 18 on the right.

Preglednica 4. Rezultati primerjave teže mini napajalnikov, uporabljenih v tem projektu.

Tab. 4. Weight comparison results between the mini-risers applied to this project.

Mini napajalnik / Mini-riser	Teža (kg/mini napajalnik) / Weight (kg/mini-riser)	Teža (kg/orodje) / Weight (kg/mould)
CB 43-21 TELE 195 22 38	1,20	9,60
CB 31 TELE SF 100 18 40	0,72	5,76

Preglednica 5. Količina na paleto EUR neposredno vpliva na logistične vidike.

Tab. 5. The quantity per EUR-pallet impacts directly on logistic aspects.

Mini napajalnik / Mini-riser	Količina (kosov/EPAL) / Quantity (pcs/EPAL)
CB 43-21 TELE 195 22 38	576
CB 31 TELE SF 100 18 40	1200

za približno +100 % mini napajalnika na EVRO paleto (Preglednica 5).

4 Sklepne ugotovitve

Postopek strjevanja litine je posledica fizikalnih procesov, ki vključujejo krčenje in raztezanje. Za načrtovanje ustreznega sistema za dovajanje je pomembno, da se določi vsaj zahteve glede prostornine in modula. Modul je koristen za razumevanje strjevanja po Chvorinovem pravilu. Danes lahko natančen toplotni modul izračunamo s sodobno simulacijsko programsko opremo.

V tem članku je bilo tudi poudarjeno, zakaj je razmerje med površino in prostornino (SA:V) ključno v toplotni fiziki za razlago termofizikalnih procesov prek interakcij med površino in prostornino. Vpliva namreč na ogrevanje ali hlajenje teh predmetov glede na velikost in material. V znanosti o materialih je razmerje SA:V pomembno za procese, kot je toplotna prevodnost, ki jo opisuje Fourierjev zakon. Krogla z najmanjšim razmerjem SA:V ima največji toplotni izkoristek zaradi manjših toplotnih izgub.

V tej študiji primera smo v Kovis-Livarni opravili primerjalni preizkus med dvema mini napajalnikoma Chemex: CB 43-21 TELE 195 22 38 in CB 31 TELE SF 100 18. Toplotni modul prvega mini napajalnika je 2,1 cm, medtem ko je toplotni modul kroglastega napajalnika TELE SF 1,9 cm. Ker so rezultati pokazali, da so ulitki v obeh konfiguracijah ustrezni, to pomeni, da je napajalnik TELE SF 100 18 pokazal večjo toplotno učinkovitost in je podjetju Kovis-Livarna omogočil, da je prihranilo 40 % tekoče kovine na mini napajalnik, kar pomeni 4 kilograme na orodje.

Ta primer optimizacije omogoča celo zmanjšanje postopka drobljenja, saj ima napajalnik TELE SF manjši vrat dovajalnika.

volume by 40% per mini-riser and about 4 kg per mould (Tab. 4).

Moreover, there are also green aspects to consider, for instance, TELE SF has permitted to have more efficient warehousing and logistics. Indeed, TELE SF can increase by around +100% of mini-riser per euro-pallet (Tab. 5).

4 Conclusions

The Cast Iron Solidification process is driven by physical processes which include shrinkage and expansion. To design the proper feeding system, it's important to define at least volume and modulus request. Modulus is helpful to understand the solidification according to Chvorinov's rule. Nowadays, a precise thermal modulus can be calculated with modern Simulation Software.

In this paper, it has also been underlined why the Surface-to-Volume ratio (SA:V) is crucial in thermal physics for explaining thermophysical processes through surface and volume interactions. It affects both, the heating or cooling behavior of those objects based on size and material. In material science, SA:V is significant for processes like heat conduction described by Fourier's law. The sphere having the lowest SA:V ratio, exhibits maximum thermal efficiency due to reduced heat loss.

In this case study, we performed a comparison test in Kovis-Livarna between two Chemex mini-risers: CB 43-21 TELE 195 22 38 and CB 31 TELE SF 100 18. The first mini-riser has a thermal modulus of 2.1 cm; whereas the spherical one TELE SF has a thermal modulus of 1.9 cm. Because the results showed soundness castings in both configurations, this means that TELE SF 100 18 has shown an increased thermal efficiency, and it has permitted

Poleg tega je treba upoštevati tudi okoljske prednosti: TELE SF povečuje učinkovitost skladiščenja in logistike (+100 % mini napajalnikov na EVRO paleto) ter vsebuje okolju prijazne formulacije brez fluora, varčuje s tekočimi kovinami in zmanjšuje stroške prevoza.

Zahvala

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Kovis-Livarna to save 40% of liquid metal per mini-riser which means 4 kilograms per mould.

This optimization case even allows to reduce the grinding process because TELE SF has a smaller feeder neck. Additionally, there are environmental benefits to consider: TELE SF enhances warehousing and logistics efficiency (+100% mini-risers per euro-pallet) as well as it features fluorine-free and eco-friendly formulations, saves liquid metal, and reduces transportation costs.

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