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Simulacija nagibnega litja

The Simulation of Tilt Casting Process

Izvleček

Ulivanje je del proizvodnega procesa, med katerim na ulitku nastane največ napak. Rešitve nagibnega litja za gravitacijsko ulivanje lahko opišemo kot urjenje v omejevanju škode. V našem primeru smo za simulacijo nagibnega litja bakrenega ulitka pipe uporabili model nadzornih prostornin. Cilj poskusov je bil prepoznati kritične parametre procesa in vzpostaviti simulacijski protokol s pomočjo več procesov nagibnega litja ter tako osnovati modele in proučiti geometrije.

Ključne besede: simulacija, metoda nadzornih prostornin, nagibno litje, pipa

Abstract

The filling process is the point in manufacture when most of the defects are introduced into the cast part. Tilt casting solutions for gravity pouring could be described as damage limitation exercises. Here a Control Volume model is used to simulate the tilt casting process of a copper based faucet casting. The target of the experiments were to identify the critical process parameters and build a simulation protocol by the help of which several tilt casting processes and geometries can be modelled and examined.

Key-words: simulation, control volume method, tilt casting, faucet

1 Nadzorovano nagibno litje

Najpogostejša oblika nagibnega litja je proces, ki ima edinstveno lastnost, saj lahko tekočo kovino v formo prenesemo s preprostim mehanskim načinom ob pomoči gravitacije, vendar brez površinske turbulence (Durvillov postopek). Zato lahko z njim potencialno proizvedemo visoko kakovostne ulitke. Različne metode prenosa tekoče kovine so shematsko prikazane na slikah 1 in 2.

Pri Durvillovem postopku sta talilni lonček in forma pritrjena drug nasproti drugega na vrtljivi ploščadi. Povezana sta s kratkim kanalom. Lonček se segreva, napolni s kovino, s katere poberejo peno, pri tem pa se ploščad vrti.

1 Controlled Tilt Casting

The most common form of tilt casting is a process with the unique feature that liquid metal can be transferred into a mould by simple mechanical means under the action of gravity, but without surface turbulence (Durville process). It therefore has the potential to produce very high-quality castings. The various methods of liquid metal transfer are schematically illustrated in Figure 1-2.

In the Durville process a melting crucible and a mould are fixed opposite of each other on a rotatable platform. A short channel section connects the two. The crucible is heated, charged with metal, and

Pri tem procesu se kovina stopi v lončku, ki je pritrjen na nagibni livni stroj. Ni razlivanja zaradi gravitacije. Med procesom prenosa nadzor zagotavlja, da se kovina premika s kotaljenjem v svoji oksidni kožici, kožica pa se ne naguba zaradi motenj, kot je valovanje. Najpomembnejši del prenosa je kot nagiba, ki je najbližji vodoravnemu položaju. V tem položaju sprednja stran taline napreduje tako, da se njena oksidna kožica širi, medtem ko njena vrhnja površina vselej ostane v vodoravnem in mirnem položaju. Na tej ključni stopnji pretoka kovine mora biti hitrost vrtenja minimalna. Če ta stopnja ni dobro izvedena, se kovina v formo prelije v obliki vala, pljuskne navzgor proti zadnji strani forme, med padcem pa jo poškodujejo ujeti oksidi.

Če za nagibno litje obstaja razdelilni sistem, ta ne upošteva nujno pravil zasnove za gravitacijsko litje, saj ima gravitacija v tem postopku zgolj minimalen vpliv. Na hitrost polnjenja litine vpliva hitrosti nagiba polnilnega sistema in ne nujno kanali. Ko je forma napolnjena, se lahko polnilni kanali uporabijo kot dovodni kanali, zato morajo biti ustrezne velikosti.

Koncept nagibnega litja se uporablja tudi za ulivanje aluminijevih zlitin v oblikovane trajne forme. Pregledali smo zasnove dovodnih kanalov in prednosti nagibnega ulivanja pred gravitacijskim ulivanjem [1–3]. Prednosti so naslednje:

Nadzorovanje hitrosti polnjenja pomaga preprečevati nastanek obrobkov. To je posledica dejstva, da je hitrost povečevanja tlaka zaradi padca kovine nizka, začne se pri nič, kar je v nasprotju z običajnimi gravitacijskimi ulitki, za katere so značilni visoki dinamični tlaki in visoka hitrost doseganja polnega hidrostatičnega tlaka. Zmanjšana količina obrobkov je pomembna za odlitke, kot so rešetke in žari, ki jih je sicer težko prevleči.

skimmed clear of dross, and the platform is rotated.

In this process the metal is melted in the crucible fixed in the tilt machine. No pouring under gravity takes place at all. During the whole process of the transfer, careful control ensured that the melt progressed by rolling in its skin of oxide avoiding any folding of its skin by disturbances such as waves. The most sensitive part of the transfer is at the tilt angle close to the horizontal. In this condition the melt front progresses by expanding its skin of oxide, whilst its top surface at all times remains horizontal and tranquil. At this critical stage of metal flow the rate of rotation must be a minimum. If this stage is not kept under good control, the metal surges into the mould as a wave, splashes upwards against the rear face of the mold, and is damaged during its fall by entraining oxides.

The running system for tilt castings, if any, does not necessarily follow the design rules for gravity casting, since gravity is only marginally influential in this process. The filling rate of the casting is under the control of the tilt rate , not necessarily the channels of the filling system. Furthermore, after the mould is filled the filling channels can be used as feeding channels, and thus be sized appropriately.

The concept of tilt pouring is also popularized for pouring aluminum alloys into shaped permanent molds. The gating designs and the advantages of tilt pouring over gravity top pouring have been reviewed [1-3]. The benefits are the following:

The control over the rate of filling helps to control flash. This is because the rate of increase of pressure due to the head of metal is rather slow, starting from zero, in contrast to normal gravity-poured castings, where there are high dynamic pressures and a high rate of attaining the full hydrostatic pressure. The reduced flash is important for

Avtomatizirano litje lahko vzpostavimo razmeroma preprosto, zagotavlja pa dosledne rezultate.

Zelo velike odlitke lahko z lahkoto proizvede en livar. To je edinstvena prednost nagibnega litja, ki je v primerjavi z običajnimi gravitacijskimi odlitki bistveno bolj ekonomična.

Nastavitev jeder je prilagodljiva, tako da jih lahko izvedemo vodoravno ali navpično ali celo v nekaterih osrednjih položajih, odvisno od zahtev za jedra.

Pri izmetu odlitka ima upravljavec podobno možnost vodoravnega ali navpičnega izmeta.

Priprava za nagib z dovodnim kanalom na spodnji strani in rešitev s stranskim dovodnim kanalom sta prikazana na sliki 1. Lijak je tukaj v spodnjem delu forme, preostanek razdelilnega kanala in dovajalni sistem ter livna votlina pa so v zgornjem delu forme. Z nagibno kokilo je treba ravnati previdno, da zagotovimo prosto odzračevanje zračnih žepkov v ozračje. Prav tako mora imeti stranica kokile, ki drži ulitek, izmetače, če so ti potrebni.

Kokila s stranskimi kanali je zasnovana tako, da omogoča padec taline v livno votlino. Sistemu za nagibno litje bi ustrezala livna votlina predvsem v zgornji polovici kokile, castings such as gratings and grills that are otherwise difficult to dress.

Automated casting can be arranged relatively easily, with the benefit of consistent results.

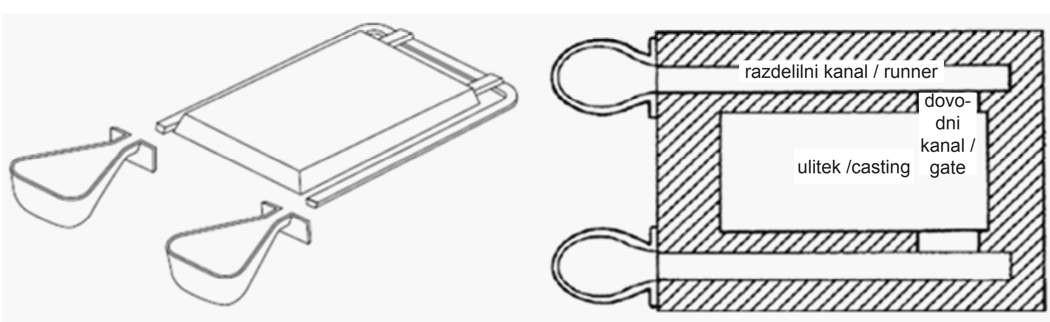
Very large castings can be easily produced by one caster. This seems to be a unique benefit for tilt casting, making for considerable economies compared to normal gravity-poured molds.

The setting of cores has the flexibility of being carried out in either the horizontal or vertical attitude, or even in some intermediate position, depending on the requirements of the cores.

For the ejection of the casting the operator similarly has the option of carrying this out vertically or horizontally.

A bottom-gated tilt arrangement and a side gated solution are shown in Figure 1. Here the sprue is in the drag, and the remainder of the running and gating system, and the mold cavity, is in the cope. Care needs to be taken with a tilt die to ensure that the remaining pockets of air in the die can vent freely to atmosphere. Also, the die side that retains the casting has to contain the ejectors if they are needed.

The die with side gates is arranged so as to allow the melt to fall inside the mould cavity. Tilt pour system that would have



Slika 1. Dvojna nagibna kokila in kokila s stranskim ulivnim sistemom

Figure 1. Twin-poured tilting die and die with side gates

kar bi preprečilo padec kovine iz dovodnega kanala. Potrebni bi bili oddušniki.

Občasno se kovina uliva neposredno v livno votlino, s čimer se v celoti odpravi potreba po razdelilnih kanalih ter zagotavlja najugodnejšo spremembo temperature, vendar najslabše polnjenje. Pot pretoka zarisujejo oksidne sledi. Te značilnosti lahko predstavljajo težavo, saj nakazujejo prisotnost cevi, kar lahko predstavlja resne napake.

Da bi bolje razumeli postopek, smo simulirali vodne modele pretoka tekočine [4] in izvedli računalniške simulacije nagibnega litja [5]. Ugotovili smo, da na pretok zaradi nagiba vplivajo gravitacijska, centrifugalna in vztrajnostna sila. Vendar pri nizkih hitrostih vrtenja, ki se uporabljajo pri večini procesov nagibnega litja, centrifugalna in vztrajnostna sila prispevata manj kot 10 % skupnega učinka zaradi gravitacijske sile in se ju zato lahko običajno zanemari. Kotna hitrost vrteče forme je prav tako nekoliko prispevala k linearni hitrosti sprednjega dela tekočine, vendar je bilo to ponovno zanemarljivo, saj os vrtenja običajno ni bila zelo oddaljena od središča forme.

Prvo podrobno študijo nagibnega litja z uporabo tukaj predstavljenih konceptov kritične hitrosti in površinske turbulence so izvedli v Univerzitetnem tehnološkem centru Rolls-Royce [6]. Uporabili smo računalniško nadzorovano programabilno livno kolo, na katero se lahko pritrdijo peščene forme za proizvodnjo odlitkov iz aluminijeve zlitine. Pretok kovine med polnjenjem forme smo beležili z uporabo rentgenske radiografije. Ugotovili smo, da pri nizkih hitrostih vrtenja ne moremo zanemariti mehanskega učinka površinske napetosti in/ali površinskih filmov na meniskusu tekočine. V vseh začetnih pogojih pri nizkih hitrostih nagiba na pretok pomembno vpliva površinska napetost. Zato se pod hitrostjo vrtenja približno 7° na sekundo hitrost taline, ki prihaja proti

benefited from the mould cavity mainly in the upper half of the die, avoiding the fall of metal from the gate. Vents would then have been necessary.

Occasionally the metal will be poured directly into the mould cavity, eliminating runners entirely and giving the best temperature gradient but poorest filling. The appearance of the flow path is outlined by streaks of oxide. Such features are a concern since they indicate the presence of flow tubes, thus possibly constituting serious defects.

In an effort to understand the process in some depth, water models of liquid flow were simulated [4], and computer simulations of the tilt casting process carried out [5]. It was detected that a combination of gravity, centrifugal, and inertia forces governs tilt-driven flow. However, for the slow rates of rotation such as they are used in most tilt casting operations, centrifugal and inertia effects contribute less than 10% of the effects due to gravitational forces, and could therefore normally be neglected. The angular velocity of the rotating mould also made some contribution to the linear velocity of the liquid front, but this again was usually negligible because the axis of rotation was often not far from the center of the mould.

The first detailed study of tilt casting using the recently introduced concepts of critical velocity and surface turbulence was carried out in the Rolls-Royce University Technology Centre [6]. A computer-controlled, programmable casting wheel was used onto which sand moulds could be fixed to produce castings in an aluminium based alloy. The flow of the metal during the filling of the mould was recorded using X-ray radiography. It is worked out that at the slow rotation speeds the mechanical effect of surface tension and/or surface films on the liquid meniscus could not be neglected.

koncu razdelilnega kanala, zmanjšuje zelo nepredvidljivo. Gravitacija prevzame nadzor šele po nagibu prek zadosti velikega kota.

Tako kot pri drugih procesih litja, če jih izvedemo prepočasi, lahko zaradi prezgodnjega zmrzovanja nastanejo nepravilni ulitki. Pri višjih hitrostih se lahko prezgodnjemu zmrzovanju izognemo, vendar se poveča nevarnost površinske turbulence.

Poskusi so pokazali, da je lahko pretok tekoče kovine v formo med nagibnim litjem miren ali kaotičen, odvisno do nagiba forme ob začetku litja in nagibne hitrosti. Kakovost ulitkov je neposredno povezana s kakovostjo pretoka v formo.

Napredovanju taline med nagibnim litjem lahko sledimo. Najprej se napolni livarski lonec ob ustju razdelilnega kanala. Samo takrat je nagib forme aktiviran [7]. Oblikovali smo naslednje trditve:

Če proces začnemo, ko je forma že nagnjena navzdol, postane ta nestabilna, takoj ko kovina vstopi v lijak in steče navzdol. Hitrost napredovanja taline se zaradi gravitacije pospešuje in talina doseže skrajni konec razdelilnega kanala pri hitrosti, ki povzroča pljuskanje. Pljuskanje prehaja po površini taline. Rezultat so ulitki slabe zanesljivosti.

Če pa proces začnemo, ko je forma v vodoravnem položaju, livarski lonec s kovino običajno ni napolnjen do roba in se zato kovina ne preliva prek roba lonca, v dovajalni kanal pa vstopi šele, ko doseže zadosten kot nagiba. Na tej stopnji je razlika navpičnega padca med začetnim in skrajnim koncem razdelilnega kanala najverjetneje večja od kritične razlike padca. Čeprav je mogoče izdelati nekoliko boljše ulitke, nevarnost slabe zanesljivosti ostaja. Ta nezadovoljiv način prenosa je značilen za veliko priprav za nagibno litje, kot lahko vidimo na sliki 2.

For all starting conditions, the flow at low tilt speeds is significantly affected by surface tension. Thus below a speed of rotation of approximately 7° per second the speed of the melt arriving at the end of the runner is reduced in a rather erratic way. Gravity only takes control after tilting through a sufficiently large angle.

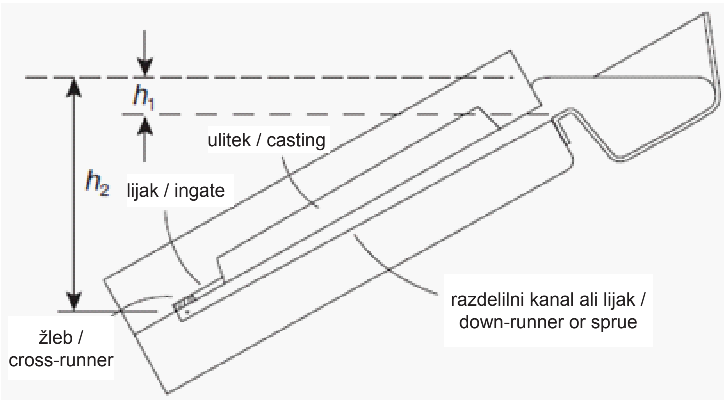
As with all casting processes, if carried out too slowly, premature freezing will lead to misrun castings. At higher speeds, however, although premature freezing could be avoided, the considerable danger of surface turbulence increased.

The experiments revealed that the molten metal could exhibit tranquil or chaotic flow into the mold during tilt casting, depending on the angle of the mold's tilt at the beginning of the casting and the tilting speed. The quality of the castings could be linked directly to the quality of the flow into the mould.

The progress of the melt during the tilt casting process can be followed. Initially, the pouring basin at the mouth of the runner is filled. Only then is the tilting of the mold activated [7]. The following statements were determined:

If the mold starts from some position in which it is already tilted downward, once the metal enters the sprue it is immediately unstable, and runs downhill. The melt accelerates under gravity, hitting the far end of the runner at a speed sufficient to cause splashing. The splash action entrains the melt surface. Castings of poor reliability are the result.

If the mold starts from a horizontal position, the metal in the basin is not usually filled to the brim, and therefore does not start to overflow the brim of the basin and enter the runner until a significant tilt angle has been reached. At this stage, the vertical fall distance between the start and the far end of the runner is likely to be greater than the



Slika 2. Metoda nagibnega litja

Figure 2. Tilt casting method

Če pa je na začetku procesa forma med polnjenjem posode nagnjena nekoliko navzgor, obstaja verjetnost, da bo do takrat, ko bo sprememba kota zadostovala za začetek prelivanja taline iz posode, kot razdelilnega kanala še vedno nekoliko nad vodoravnim položajem. Ob začetku polnjenja razdelilnega kanala se meniskus dejansko dviga po nekoliko dvignjenem naklonu. Tako je njegovo napredovanje povsem stabilno, saj njegovo gibanje naprej nadzoruje dodaten nagib.

Edinstvena značilnost prenosa, če se ta začne nad vodoravnim položajem, je, da je površina tekoče kovine ves čas prenosa v skoraj vodoravnem položaju. Zato v nasprotju z vsemi drugimi vrstami gravitacijskega ulivanja tovrstno nagibno litje ne vključuje prostega navpičnega padca.

Zaključki glede nagibnega litja so naslednji:

Če se postopek nagibnega litja začne v nagnjenem položaju ali položaju, ki je nižji od vodoravnega, tekoča kovina po razdelilnem kanalu pospešuje navzdol s hitrostjo, ki je upravljavec ne more nadzorovati. Kovina teče v obliki ozkega curka in oblikuje vztrajno oksidno cev. Prav tako hitrost tekočine na skrajnem koncu razdelilnega kanala skoraj zagotovo preseže kritični critical fall distance. Thus although slightly better castings can be made, the danger of poor reliability remains. This unsatisfactory mode of transfer typifies many tilt casting arrangements as seen in Figure 2.

If, however, the mould is initially tilted slightly uphill during the filling of the basin, there is a chance that by the time the change of angle becomes sufficient to start the overflow of melt from the basin, the angle of the runner is still somewhat above the horizontal. When the filling of the runner starts the meniscus is effectively climbing a slight upward slope. Thus its progress is totally stable, its forward motion being controlled by additional tilt.

The unique feature of the transfer when started above the horizontal in this way is that the surface of the liquid metal is close to horizontal at all times during the transfer process. Thus in contrast to all other types of gravity pouring, this condition of tilt casting does not involve a free vertical fall at all.

In summary, the conclusions for tilt casting are:

If tilt casting is initiated from a tilt orientation at, or below, the horizontal, during the priming of the runner the liquid metal accelerates downhill at a rate out of the operator's control. The metal runs as a narrow jet, forming a persistent oxide flow pogoj za površinsko turbulenco. Če je forma že na začetku nagnjena za več kot 10° pod vodoravnim položajem, zanesljiva proizvodnja ulitkov z nagibnim litjem ni več mogoča.

Velika prednost nagibnega litja je uporaba zadosti pozitivnega začetnega kota, tako da talina napreduje po navzgor nagnjenem razdelilnem kanalu. Tako je njeno napredovanje stabilno in nadzorovano. Za ta način polnjenja je značilen vodoraven prenos tekoče kovine, ki ustvarja pogoje za polnjenje forme brez površinske turbulence.

Polnjenje forme naj bo v začetnih stopnjah počasno, da se izognemo visokim hitrostim na skrajnem koncu razdelilnega sistema. Ko pa tekoča kovina steče po razdelilnem kanalu, pomaga pospeševanje hitrosti vrtenja forme preprečevati vsakršno posledično nepolnjenje ulitkov.

2 Poskusi

Tehnološki koraki simuliranega nagibnega litja so razvidni s slike 3.

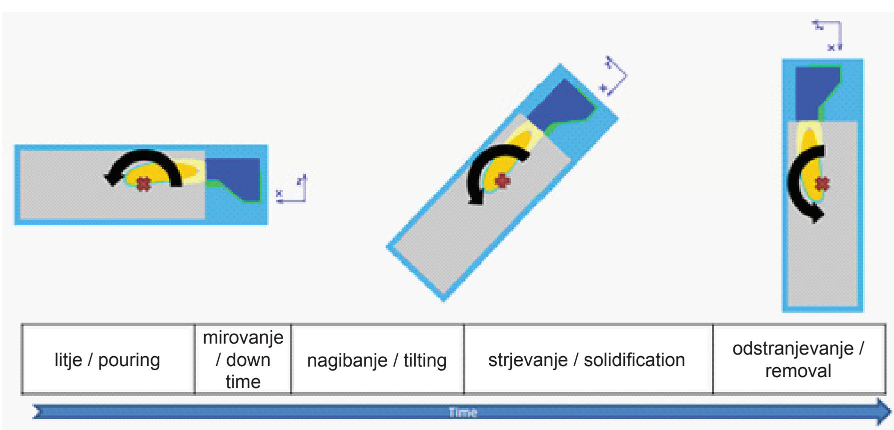
tube. In addition, the velocity of the liquid at the far end of the runner is almost certain to exceed the critical condition for surface turbulence. Once the mold is initially inclined by more than 10° below the horizontal at the initiation of flow, it is no longer possible to produce reliable castings by the tilt casting process.

Tilt casting operations benefit from using a sufficiently positive starting angle that the melt advances into an upward sloping runner. In this way its advance is stable and controlled. This mode of filling is characterized by horizontal liquid metal transfer, promoting a mold filling condition free from surface turbulence.

Tilt filling is preferably slow at the early stages of filling to avoid the high velocities at the far end of the running system. However, after the running system is primed, speeding up the rate of rotation of the mould greatly helps to prevent any consequential non-filling of the castings.

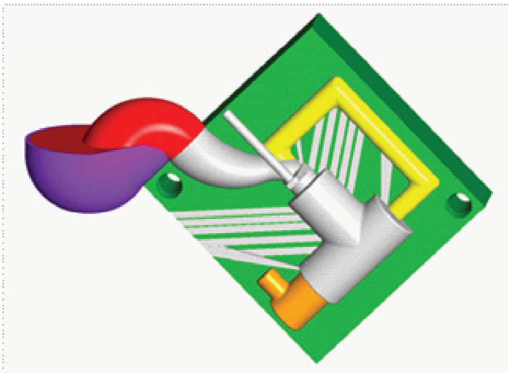
2 Experiments

The technological steps of the simulated tilt casting process can be seen on Figure 3.



Slika 3. Tehnološki koraki procesa

Figure 3. Technological steps of the process



Slika 4. Poenostavljena priprava za nagibno litje (ulivni sistem, odzračniki, jedra, kokilni del)

Figure 4. Simplified tilt casting assembly (gating, vents, cores, die part)

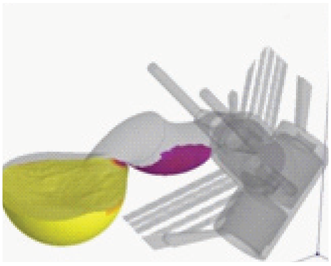
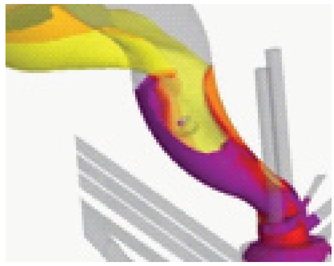
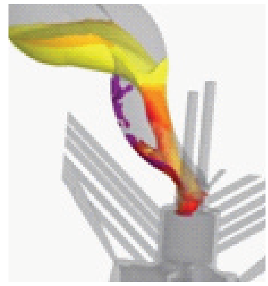
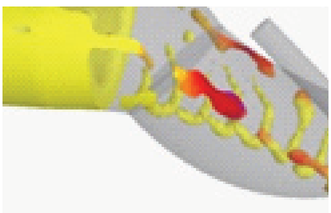
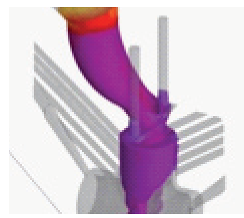
The complete tilt casting assembly must be simplified and the pouring basin has to be enlarged to avoid over pour and it must be modelled separately. The examined casting part is a faucet, which is shown on Figure 4 by the accessories.

Initial parameters for the Control Volume calculations are: CuZn39Pb1AlB_B copper base alloy poured into zirconium bronze mold with the application of furan resin coated sand cores. For the determination of pouring conditions foundry shop experiments were examined and the following parameters were defined: quantity of poured metal (consideration of liquid contraction), pouring temperature, die and core temperature, material and temperature of the basin, gating section of metal, flow

Vrednosti / Values		Nagib_01 / Tilt_01	Nagib_02 / Tilt_02	Nagib_03 / Tilt_03	Nagib_04 / Tilt_04	Nagib_06 / Tilt_06	Nagib_07 / Tilt_07
Lita kovina / Poured metal	kg	3,16	4,35	4,35	4,60	4,28	4,28
Livna temperatura / Pouring temp.	°C	1000	1000	1100	1100	1100	1100
Kokilna temperatura / Die temp.	°C	250	250	250	250	250	250
Temperatura jedra / Core temp.	°C	30	30	30	30	30	30
Material posode / Basin material	-	jeklo / steel	jeklo / steel	jeklo / steel	jeklo / steel	jeklo / steel	jeklo / steel
Temperatura posode / Basin temp.	°C	950	950	950	950	950	950
Polmer dovajalnega kanala / Gating radius	mm	50	45	45	45	44	40
Višina tlak / Pressure height	mm	5	5	4	4	4	60
Hitrost pretoka / Flow rate	kg/s	6,06	3,47	2,70	2,97	2,97	9,5
Čas nagiba / Time of tilt	s	2,4	2,5	1	1	1	1
Vrednosti / Values		Nagib_10 / Tilt_10	Nagib_11 / Tilt_11	Nagib_12 / Tilt_12	Nagib_14 / Tilt_14	Nagib_15 / Tilt_15	Nagib_16 / Tilt_16
Lita kovina / Poured metal	kg	5,95	4,598	4,598	5,95	5,95	5,95
Livna temperatura / Pouring temp.	°C	1100	1100	1200	1100	1200	1300
Kokilna temperatura / Die temp.	°C	250	250	300	250	250	300
Temperatura jedra / Core temp.	°C	30	30	30	30	30	30
Material posode / Basin material	-	keramika / ceramic	keramika / ceramic	keramika / ceramic	keramika / ceramic	keramika / ceramic	keramika / ceramic
Temperatura posode / Basin temp.	°C	950	950	950	950	950	1000
Polmer dovajalnega kanala / Gating radius	mm	40	44	44	45	45	60
Višina tlak / Pressure height	mm	30	5	5	40	40	50
Hitrost pretoka / Flow rate	kg/s	6,72	3,32	3,32	9,82	9,82	19,53
Čas nagiba / Time of tilt	s	2	2	2	2	2	4

Preglednica 1. Preizkusna matrika

Table 1. Experimental matrix

		
Med polnjenjem livarskega lonca talina vstopi v livno votlino / During basin filling the melt enters to the cavity	Hlajenje taline med nagibom / Melt cooling during tilting	Neustrezni pogoji pretoka v ulivnem sistemu / Improper flow conditions in the gating system
		
Nerealna razpršenost taline / Unrealistic spatter of the melt	Hlajenje taline med nagibom / Melt cooling during tilting	Nenapolnjena livna votlina / Unfilled cavity

Preglednica 2. Učinki napak

Table 2. Error effects

Celotno pripravo za nagibno litje je treba poenostaviti in livarski lonec povečati ter tako preprečiti prelivanje, modelirati pa ga je treba posebej. Ulitek, ki smo ga proučevali, je bil pipa na sliki 4 z dodatki.

Začetni parametri za izračun Bakrova zlitina CuZn39Pb1AlB_B, ulita v cirkonij-bronasto formo, z dodajanjem peščenih jeder, prevlečenih s furanovo smolo. Da bi določili pogoje ulivanja, smo proučili livarske poskuse in določili naslednje parametre: količina lite kovine (ob upoštevanju krčenja tekočine), livna temperatura, temperatura kokile in jedra, temperatura materiala in lonca, dovodni del kovine, pretočni del in loputa med loncem in dovajalnim sistemom ter pogoji nagiba, kot so rotacijski vektor, os, kot in čas. Preizkusna matrika je razvidna v preglednici 1. Nagib_01 – Nagib_16 so znaki poskusov [8].

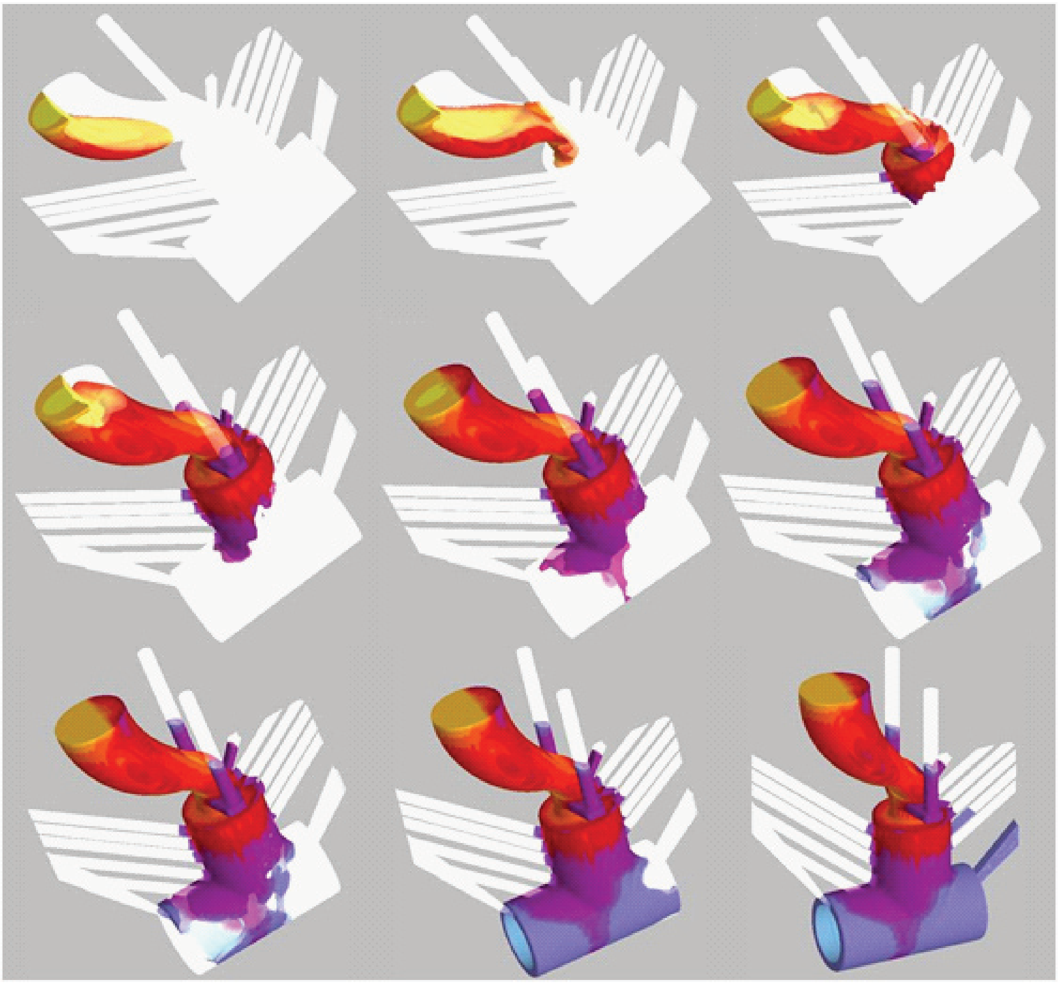
section and choke between basin and gating system and tilting conditions such as rotation vector, axis, angle and time. The experimental matrix can be seen on Table 1. Tilt_01 – Tilt_16 are the signs of the experiments [8].

The characteristic error effects can be seen on Table 2.

The filling process can be seen on figure 6.

3 Summary

Regarding the adequacy of simulation the following factors played the main rules: titling parameters, temperature values and die materials. The most important results of simulation, besides of the determination of technological parameters,



Slika 6. Polnjenje livne votline

Figure 6. Filling of the cavity

Značilni učinki napak so razvidni iz preglednice 2.

Postopek polnjenja je razviden s slike 6.

3 Povzetek

Z vidika ustreznosti simulacije so glavne vloge odigrali naslednji dejavniki: parametri

are the identification of the critical process parameters:

- Geometrical adequacy: height of basin, cross-section of the basin's nose, geometry of the flow channel between the basin and the gating system.
- Pouring conditions: consideration of liquid contraction, cross-section of the melt stream, definition of pressure height to avoid splashing.

nagiba, temperaturne vrednosti in kokilni materiali. Najpomembnejši rezultat simulacije je poleg določanja tehnoloških parametrov določanje parametrov kritičnega procesa:

- Geometrijska ustreznost: višina lonca, prerez nosa lonca, geometrija pretočnega kanala med loncem in dovajalnim sistemom.
- Livni pogoji: upoštevanje krčenja tekočine, prerez toka taline, opredelitev višine tlaka za preprečevanje pljuskanja.
- Opredelitev materiala in temperature lonca, nanos refraktornih premazov za preprečevanje hlajenja taline.
- Pogoji nagiba: merila za zaustavitev polnjenja, možnosti vrtenja, čas prekinitve po polnjenju, čas nagiba, kot nagiba.

- Definition of the material and the temperature of the basin, application of refractory coatings to avoid melt cooling.
- Tilt conditions: filling stop criteria, rotation options, downtime after filling, time of tilt, tilt angle.

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