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THE FLAWS OF ALUMINIUM-MAGNESIUM ALLOY ELEMENTS – INFLUENCE OF INCLUSIONS[*****]

Abstract

The investigation results of gas removal from smelted metal and the effect on performances of aluminium-magnesium alloy cast elements are presented in this paper. The investigated alloy is based on recycled material. The obtained results define the specific procedure which is used for removal and reduction the presence of inclusions of various types in the cast elements, which is the basic step in achieving the designed quality of cast material and quality final products. Kinetics and mechanisms of degasification process were investigated, parameters of degasification procedures were defined, and the new agents for degasification of alloy cast were implemented. The results of this investigation are significant from the aspect of sustainable development the production of cast elements of aluminium alloys.

Keywords*: aluminium-magnesium alloys, inclusions, cast quality, secondary raw materials*

1 INTRODUCTION

The goal of modern casting procedure is to meet the proposed requirements for composition, structure, properties, and quality of cast material. The final product should not have any flaws which could limit its usage [1]. The structure of cast material is shaped by cooling conditions, and in addition it affects the final properties of cast elements. On the other hand, the quality of cast is significantly affected by the parameters of casting technology. Detection and evaluation of flaws in casts has to be performed systematically during developmental phase of the process, using preventive measures to avoid them [2]. Aluminuim- magnesium alloys are a significant group of alloys, primarily because their high mechanical strength was achieved without thermal processing, then their high corrosion resistance, good wetability, etc. [3, 4]. The investigation the effect of non-metal inclusions and gases on the quality of elements made of aluminium AlMg3 alloy, obtained by semi-continuous casting, was conducted. Since the recycled raw materials were used in production of the Al-Mg alloy, the certain flaws of gas type or inclusions occurred in the casts. Flaws were positioned internally as a substructure of the

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surface, or within entire cast element. All flaws were relatively small, individually scattered or grouped. The main problem, caused by gas content, being trapped within metal, is porosity which might reduce the capability of plastic processing of hot aluminum.

The main objective of smelting technology is to provide a cast of adequate metal or alloy with the lowest possible content of gases and non-metal ingredients. In aluminum and its alloys, it is hydrogen that increases the quantity of rejects. Hydrogen content in the cast aluminum is usually in the range of 0.5-1.1 cm^3/100 g metal, whilst the content is lower in the alloys. Solubility of hydrogen is affected by presence of the following alloying components: Si, Cu, Zn, Pb, Ag, Bi, Cd that decrease the solubility of hydrogen, whilst Mg increases it [5]. The most common non-metal ingredient in aluminum and its alloys is aluminium-oxide which affects the presence of hydrogen in the cast. Aluminum-oxide actively absorbs hydrogen decreasing the concentration of solute hydrogen. However, the additional dissolution of H occurs due to the absorption of steam from atmosphere on oxide film on liquid metal. Then decomposition with Al occurs increasing in this way concentration of hydrogen until saturation of the cast. By superheating of the cast and afterwards cooling it down, the hydrogen saturation occurs because oxides are becoming passive related to hydrogen [6]. Removal of non-metal components is efficiently performed by filtration of the cast [7, 8]. Alloying elements have different effect on hydrogen content in the cast: 1% of Ca, Ba or Be might decrease the hydrogen concentration; 0.1% of Fe or Si adversely effects degasification; Na increases hydrogen content from 0.05 to 0.45 cm^3/100g; Cu, Sn, Si lower solubility of hydrogen in liquid Al; H content increases with increase of Mg in the alloy [9-11]. Better effect of degasification is always achieved without utilization of salt and with air curing and treatment of melt with intergases [12, 13].

2 MATERIALS AND METHODS

AlMg3 alloy was investigated due to the appearance of small cracks and bubbles during cold processing, which were probably caused by gases and non-metal inclusions residual from the casting process. All series of semi-continuous casting of elements made of $AlMg_3$ alloy were performed in the laboratory environment. Smelting of the metal for all series was performed in the melting furnace "FXM-45", Shanghai Fortune Electric, with automatic temperature regulation. Degasification was performed with inert gas, nitrogen and argon being degasification agents. Casting temperature was 700 °C and casting rate: 40±2 mm/min. The effect of gas quantity and non-metal inclusions on porosity, structure and mechanical properties were monitored. Table 1 shows the parameters of semi-continuous casting process per series. Three elements with different dimensions were casted for each series.

Table 1 *Parameters of semi-continuous casting process*

Variable process parameters		
Sample	**Block dimension, m**	**Degasification time, min**
T_1	0.3x0.5x0.5	10
T_2	0.3x0.5x0.5	15
T_3	0.3x0.5x0.5	30
T_4	0.4x0.5x0.5	10
T_5	0.4x0.5x0.5	15
T_6	0.4x0.5x0.5	30

Pre-alloy (Al (4%Ti; 2%B)), as a modification agent, was added into the casting furnace 10 min before casting, after which the cast was mixed. Nitriding was performed in smelting furnace before casting and it lasted 15 min. Argon was used for degasification in conditional furnace and, before pouring, ALPUR was applied. ALPUR is an apparatus which can prolong degasification. Temperature is maintained by automatic heating. Argon was induced into liquid metal under 2 bar pressure. Air curing with argon was performed using a special long tube immersed to the bottom of furnace. The aim of argon induction was to remove non-metal inclusions and harmful gases. Degasification effect of argon is based on absorption and diffusion. The initial speed of diffusion was fast, with decreasing tendency over time, proportionally to partial pressure of hydrogen within argon bubble. Once partial pressures are equalized, the diffusion stops. Non-metal inclusions are stick to bubbles and surface from the cast. In this way, the cast is cleaned from slag. This degasification did not remove total quantity of gas, but its presence was reduced up to 50 % compared to the quantity of gas that metal contains whilst entering into ALPUR.

Chemical composition of the alloy was tested on samples extracted from the cast just before casting. Investigation of mechanical properties of the casts was performed on test-tubes with diameter of ϕ10 mm. Special samples were taken from cut parallelepiped slabs and machined for solidity testing. Tensile strength and relative elongation were tested on electronic testing machine with power of 400 kN, brand Karl Frank GMBH, type 81105. Solidity was measured using the Brunel's method HB (2.5/62.5/30), 2.5 mm ball and 625 kN load in time of 30 s. Research was performed on apparatus Karl Frank GMBH, type 38532. Testing was performed on casted samples. Quantity of present hydrogen in the casts was measured whilst metal was still in a liquid state, i.e. channel just before pouring using device Alskan, ABB Inc from Canada. Measuring period was 10 min. Table 2 shows the cast motion rate and cooling water flow during crystallization of the cast.

Table 2 *Cast motion rate and water flow during crystallization*

Alloy	Dimensions, m	Rate 1, cm/min	Flow 1, m^3/h	Rate 2, cm/min	Flow 2, m^3/h	Water temperature °C
$AlMg_3$	0.3x1	5.0	80	7.0	120	20
	0.4x1.5	5.0	90	7.0	130	20

3 RESULTS AND DISCUSSION

The values of mechanical properties of all casted samples (T_1-T_6) are given in Table 3, and Figure 1.

Table 3 *Mean values of mechanical properties of casts obtained by semi-continuous casting*

Samples	Degasification time, min	E module, MPa	Rm, MPa	HB, 2.5/62.5/30	A50, %
T_1, T_3	10	69.16	235.26	51.45	24.25
T_2, T_4	15	68.95	240.68	54.30	26.91
T_3, T_6	30	67.23	247.50	55.25	29.05

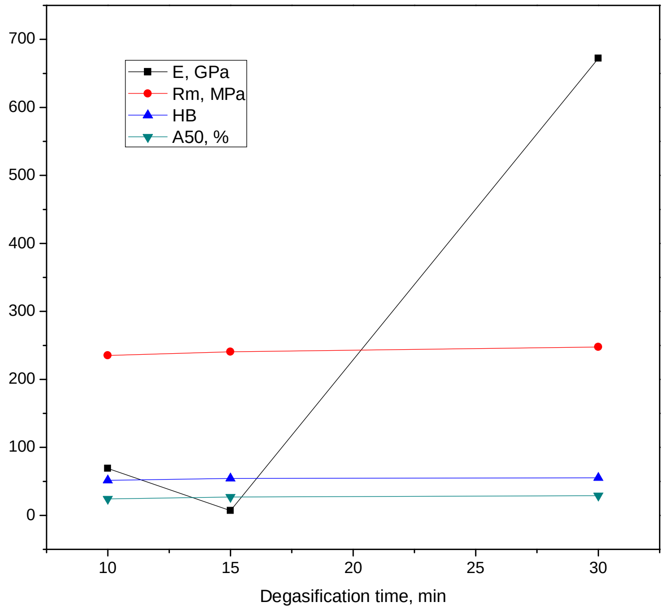

Figure 1 *Changes of E, Rm, HB and A50 in a function of degasification time*

It can be seen that lower values of mechanical properties are obtained due to the insufficient degasification time. Namely, samples obtained by casting with insufficient degasification contain more gas, i.e. have the increased porosity. The change of gas concentration with increase of degasification time is given in Figure 2.

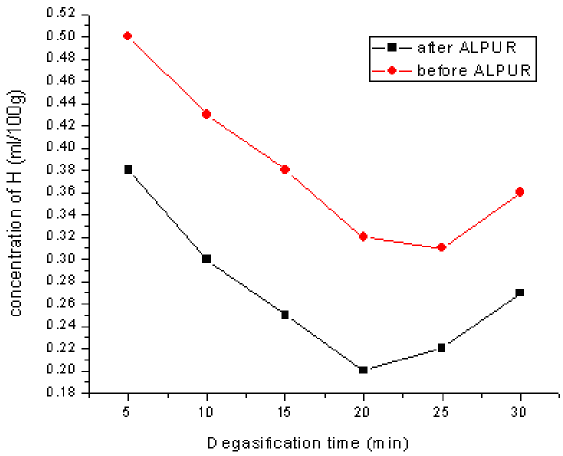

Figure 2 *Changes of gas concentration with increase of degasification time*

The results of investigation the hydrogen concentration in liquid metal, before pouring into mould, show noticeable differences depending on degasification time. If degasification time is short, the gas is removed only partially from metal. Disregarding of the fact that ALPUR performs afterward removal of present gas, it will lapse in higher concentrations in metal, what is confirmed by measured concentrations.

The large quantity of gas presence largely affects the quantity of casts and it is easily visible during analysis of microstructure. Porosity of sample with the shortest time of degasification is given in Figure 3.

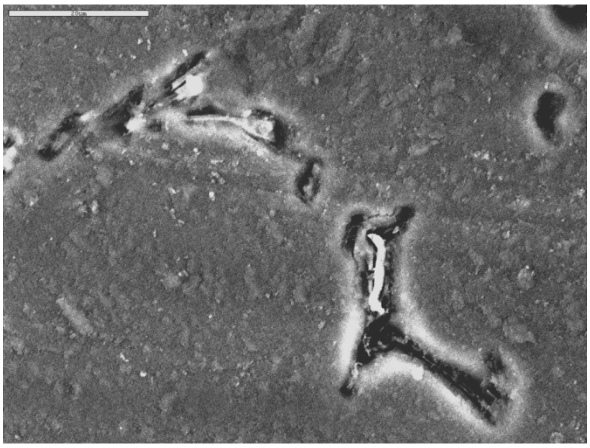

Figure 3 *Porosity of sample with the shortest degasification time*

The best results of measured gas concentration occurred during degasification which lasted for 15 min with the constant standing periods. Prolonging of degasification in the conditional furnace influences a slight increase of gas concentration. This can be explained by increase of total gas pressure in the furnace atmosphere and that gas, previously removed from metal, again returns to metal in the standing period. Microstructure of samples with different degasification times is given in Figure 4 – 6.

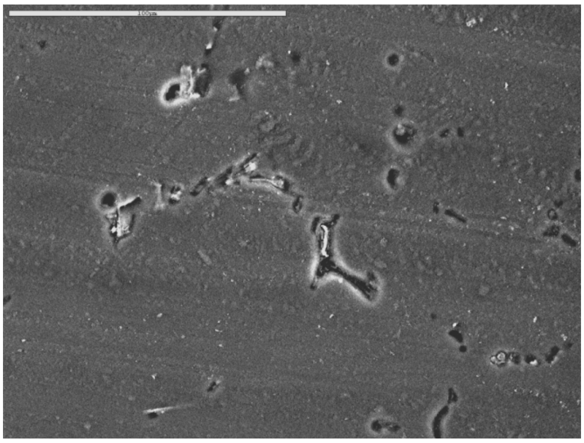

Figure 4 *Microstructure of sample with maximum degasification time*

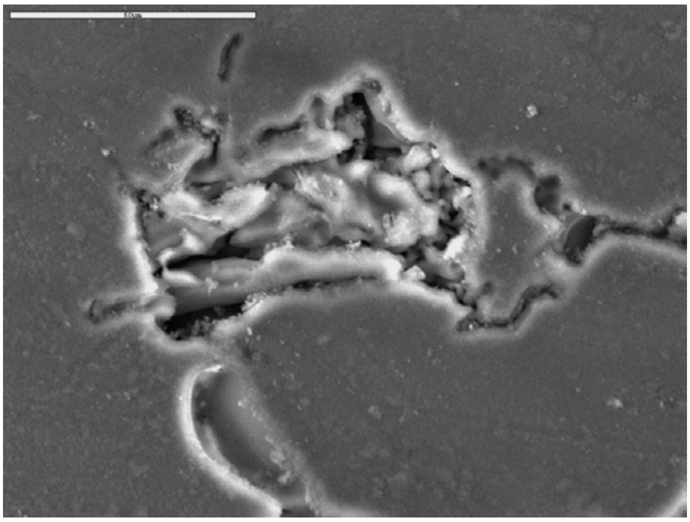

Figure 5 *Microstructure of sample with minimum degasification time*

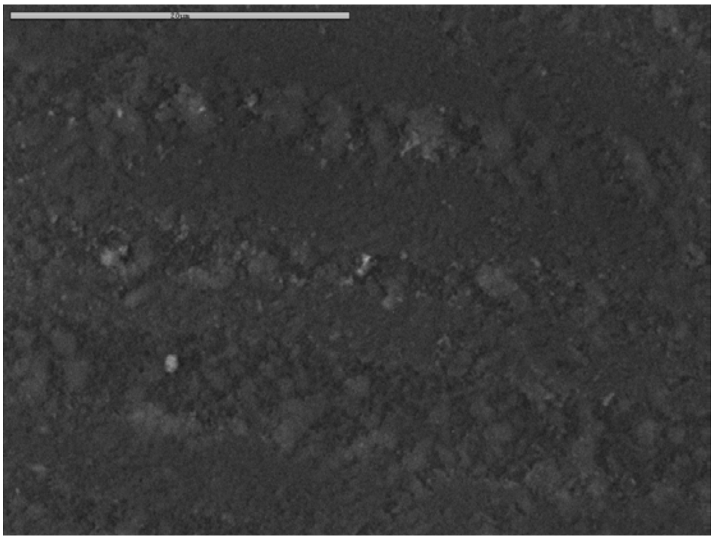

Figure 6 *Microstructure of sample with optimal degasification time*

During crystallization process of the casts, motion of gas from cast surface toward the center is performed pushing the growing crystals until gas forms bubbles whose motion rate through metal becomes slower than crystallization rate and they are trapped in metal. This explains the increased porosity during transitional period. Gas residue reaches the center of cast that last solidifies. Some gas, however, remained in the cast which can be confirmed by analysis of microstructure. It is proved that quantities of present gas found in microstructure depend on degasification time.

Analysis of the results indicates the certain causes of flaws in $AlMg_3$ alloy cast elements: foremost they are related to occurrence of segregation layer; porosity in transitional phase; and porosity in the center of cast, i.e. element. Presence of gas in the casts can be regulated taking actions and permanent control, with fundamental process in a form of degasification where degasification element has a special role, as proven by the research conducted on microstructure. Results of microstructural analysis showed that the quality of cast elements is affected by numerous parameters of the process and phenomena occurring during smelting and casting process. It is showed that batching and melting of batch components should be performed in one sequence with increase of affinity for oxygen, melting temperature, volatility and reduction of quantity of components. Batch components with high values of affinity for oxygen, melting temperature and volatility can be batched and melted together.

4 CONCLUSIONS

The main conclusions deducted from the performed investigation are as follows:

- Basic reason for selecting aluminium-magnesium alloy was the occurrence of cracks and bubbles which appeared during cold processing. It was assumed that this is caused by gases and non-metal inclusions left behind after casting process. Since gas is very harmful, it is necessary to know its concentration in the alloy, thus special attention was paid to the measuring concentration of hydrogen in the cast.
- Nitrogen and argon were chosen as degasification agents. Nitriding was performed in a smelting furnace before casting, in duration of 15 min. Inert gas argon was used in a conditional furnace and ALPUR (before pouring). The best results are achieved with degasification of the cast with argon in duration of 15 minutes. During prolonged degasification in the conditional furnace, the gas concentration in the cast slightly increases, what can be explained by increase of total gas pressure in the atmosphere, so gas previously removed from metal is returned to metal in the standing period.
- Microstructural analysis showed that the quantity of present gas depends on degasification time. Insufficient degasification time results in obtaining lower values of mechanical properties of cast blocks. These values are somewhat lower than values proscribed in standards. With longer degasification time, mechanical properties are at lower limits proscribed in standards for this type of alloy. Namely, the samples obtained from casting with insufficient degasification, as well as samples with prolong degasification contain larger quantity of gas, i.e. they have higher porosity which reflected on occurrence of flaws - tiny cracks, bubbles during cold processing of these blocks.

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GREŠKE NA ELEMENTIMA OD ALUMINIJUM-MAGNEZIJUM LEGURE - UTICAJ UKLJUČAKA*****

Izvod

Rezultati ispitivanja uticaja uklanjanja gasa iz tečnog metala na kvalitet livenih elemenata od aluminijum-magnezijum legure, a na bazi recikliranih materijala su dati ovom radu. Dobijeni rezultati praktično definišu proceduru livenja kojom se može umanjiti prisustvo uključaka i gasova u livenim elementima, što je osnovni preduslov za postizanje projektovanog kvaliteta livenog materijala i krajnjih proizvoda. Ispitivani su kinetika i mehanizmi procesa degasifikacije, zatim su definisani parametri procesa degasifikacije, i na posletku primenjeni novi agensi za degasifikaciju legura. Rezultati ovog ispitivanja su značajni sa ekološkog aspekta i sa aspekta održivog razvoja proizvodnje livenih elemenata od aluminijumskih legura.

Ključne reči*: aluminijum-magnezijum legure, ukljički, kvalitet odlivaka, otpadne sirovine*

1. UVOD

Cilj u savremenom livarstvu je ispunjenje zahteva u pogledu sastava, strukture, svojstava, i kvaliteta odlivka. Odlivak ne sme imati nikakve greške koje bi mogle da ograniče njegovu upotrebu [1]. Struktura koja se formira pod različitim uslovima hlađenja, u nekoj određenoj metodi livenje, utiče na razilčita krajnja, upotrebna svojstva dobijenih odlivaka. Isto tako, na kvalitet odlivaka utiču i parametri tehnologije livenja. Otkrivanje i evaluacija grešaka pri livenju mora da se obavlja sistematično u razvojnoj etapi procesa kako bi se izbegle greške [2]. Aluminijum-magnezijum legure su značajna grupa legura, najpre zbog visoke mehaničke čvrstoće postignute bez termičke obrade, a zatim i zbog visoke otpornosti na koroziju, dobre prionljivosti, itd [3, 4]. Ispitivan je uticaj nemetalnih uključaka i gasova na kvalitet aluminijumskih elemenata dobijenih na bazi AlMg3 legure metodom polukontinualnog livenja. Pošto su u proizvodnji Al-Mg legura korišćene reciklažne sirovine, određene greške kao što su zarobljeni gasovi ili uključci, su se pojavljivale u odlivcima tokom ispitivanja. Greške su pozicionirane

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interno - kao substruktura površine ili greške rasprostranjene po celom elementu. U pogledu veličine greške su bile male, ili pojedinačno rasute, ili u grupama. Osnovni problem koji prouzrokuje prisustvo gasa u metalu je nastanak različitih oblika poroznosti koji umanjuju sposobnost plastičnog presovanja vrućeg aluminijuma.

Jedan od glavnih ciljeva tehnologije topljenja je: dobiti rastop metala ili legure sa najnižim mogućim sadržajem gasa i nemetalnih konstituenata. U aluminijumu i njegovim legurama, vodonik direktno utiče na formiranje škartova. Sadržaj vodonika u livenom aluminijumu je obično u granicama 0,5-1,1cm^3/100 g metala, dok je u legurama sadržaj nešto niži. Rastvorljivost vodonika je određena prisustvom sledećih legirajućih kompomentui: Si, Cu, Zn, Pb, Ag, Bi, Cd uslovljava smanjenje rastvorljivosti vodonika; dok je Mg povećava [5]. Najčešći nemetalni sastojak u aluminijumu i njegovim legurama je aluminijum-oksid, koji utiče na prisustvo vodonika u rastopu legure. Aluminijum-oksid aktivno apsorbuje vodonik u toku livenja, što dalje umanjuje koncentraciju rastvorenog vodonika. Međutim, dolazi do dodatnog rastvaranja H usled apsorpcije pare iz atmosfere na filmu oksida koji se formirao na na rastopu metala. Zatim dolazio do njegovog razgrađivanje sa Al, povećavajući na taj način koncentraciju vodonika do saturacije. Pregrevanjem rastopa i potom hlađenjem dolazi do saturacije, jer oksidi postaju pasivni prema vodoniku [6]. Uklanjanje nemetalnih sastojaka se efikasno obavlja filtracijom odlivka [7, 8]. Legirajući elementi imaju različiti uticaj na sadržaj vodonika u odlivku: 1% Ca, Ba ili Be utiče na umanjenje sadržaja vodonika; 0,1 % Fe ili Si ima suprotan efekat na degasifikaciju; Na utiče na povećavnje sadržaja vodonika u količini 0,05 do 0,45 cm^3/100 g; Cu, Sn, Si smanjuju rastvorljivost vodonika u tečnom Al. Sadržaj vodonika se povećava sa povećanjem sadržaja Mg u leguri [9-11]. Bolji efekat degasifikacije se postiže bez primene soli i tretiranjem rastopa internim gasovima [12,13].

2. MATERIJALI I METODE

AlMg3 legura je ispitivana zbog pojave sitnih pukotina ili mehurića u toku hladne obrade legure, koji su najverovatnije prouzrokovani zaostatkom gasova i nemetalnih uključaka u toku livenja. Sve serije polukontinualo livenih elemenata od legure AlMg3 spravljene su u laboratorijskim uslovima. Topljenje metala za sve serije obavljeno je u peći za “FXM-45”, Shanghai Fortune Electric, sa automatskom regulacijom temperature. Degasifikacija je obavljena pomoću inertnog gasa, azot i argon su korišćeni kao degasifikacioni agensi. Temperatura livenja je bila 700 °C a brzina livenja 40±2 mm/min. Praćen je uticaj količine gasa i nemetalnih uključaka na pojavu poroznosti, strukturu i mehanička svojstva. U Tabeli 1. su dati procesni parametri polu-kontinuiranog livenja po serijama. Za svaku seriju livena su po tri elementa različitih dimenzija.

Tabela 1. *Parametri procesa polu-kontinualnog livenja*

Promenjivi parametri procesa		
Uzorci	**Dimenzije, m**	**Vreme degasifikacije, min**
T_1	0.3x0.5x0.5	10
T_2	0.3x0.5x0.5	15
T_3	0.3x0.5x0.5	30
T_4	0.4x0.5x0.5	10
T_5	0.4x0.5x0.5	15
T_6	0.4x0.5x0.5	30

Predlegura (Al (4%Ti; 2%B)) kao modifikujući agens je dodata u peći za livenje 10 min pre početka livenja, nakon toga je rastop mešan. Azotiranje je izvršeno u peći za topljenje neposredno pred izlivanje i trajalo je 15 min. Argon je upotrebljen za degasifikaciju u kondicionoj peći i neposredno pred ulivanje upotrebljen je ALPUR. ALPUR je aparat koji može da produži degasifikaciju. Temperatura je održavana uz pomoć automatskog zagrevanja. Argon je u tečni metal ubacivan pod pritiskom od 2 bara. Produvavanje sa argonom je obavljeno pomoću specijalne duge cevi, uranjanjem do dna u peć. Cilj uvođenja argona bio je odstranjivanje nemetalnih uključaka i štetnih gasova. Degasifukujuće dejstvo argona zasniva se na adsorpciji i difuziji. Početna brzina difuzije je velika, sa tendencijom padanja sa vremenom proporcionalno parcijalnom pritisku vodonika unutar mehurića argona. Kada se parcijalni pritisci izjednače difuzija prestaje. Nemetalni uključci se lepe za mehuriće i izlaze na površinu rastopa čisteći rastop od šljake. Degasifikacijom nije uklonjena ukupna količina gasa, ali je njegovo njegovo prisustvo umanjeno do 50% u odnosu na količinu gasa koju metal nosi u sebi pri ulasku u ALPUR.

Hemijski sastav legura je ispitan na uzorcima izvađenim iz liva pred samo livenje. Mehaničkih svojstava odlivaka su ispitana na epruvetama kružnog preseka ø 10 mm. Epruvete su izrezane iz sredine ploče i mašinski obrađene. Zatezna čvrstoća i relativno izduženje su ispitivani na elektronskoj kidalici snage 400 kN, marke Karl Frank GMBH, tipa 81105. Tvrdoća je izmerena Brinelovom metodom HB (2.5/62.5/30), kuglicom od 2,5 mm i opterećenjem 625 kN u trajanju od 30 s. Ispitivanje je obavljeno na aparatu Karl Frank GMBH - 38532. Ova ispitivanja su urađena na uzorcima u livenom stanju. Količina prisutnog vodonika u odlivcima merena je dok je metal u tečnom stanju, tj. u kanalu pred samo ulivanje uređajem Alskan ABB Inc Kanada. Vreme merenja je 10 min. U Tabeli 2. prikazana je brzina kretanja odlivaka i brzina protoka vode za hlađenje u toku kristalizacije odlivaka.

Tabela 2. Brzina kretanja odlivaka i protoka vode u toku kristalizacije

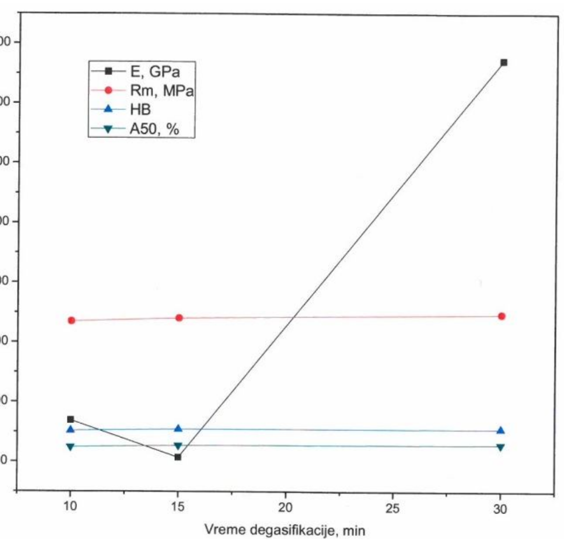
Legura	**Dimenzije, m**	**Brzina 1, cm/min**	**Protok 1, m^3/h**	**Brzina 2, cm/min**	**Protok 2, m^3/h**	**Temperatura vode, °C**
AlMg3	0,3x1	5,0	80	7,0	120	20
	0,4x1.5	5,0	90	7,0	130	20

3. REZULTATI I DISKUSIJA

U Tabeli 3. i na Slici 1. je dat prikaz srednjih vrednosti mehaničkih svojstava uzoraka (T_1-T_6).

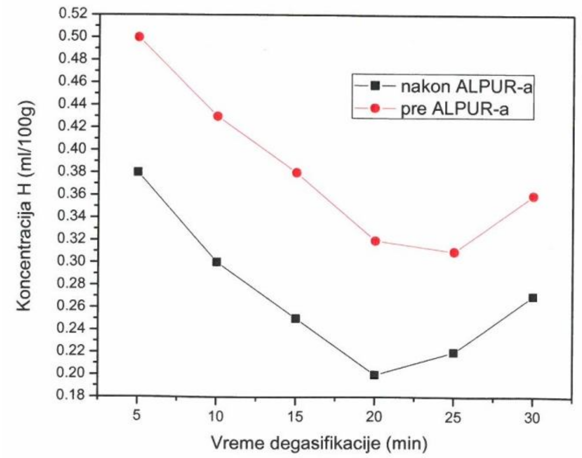
Tabela 3. *Srednje vrednosti mehaničkih svojstava odlivaka*

Uzorci	**Vreme degasifikacije, min**	**E modul, MPa**	**Rm, MPa**	**HB**	**A50, %**
T_1, T_3	10	69,16	235,26	51,45	24,25
T_2, T_4	15	68,95	240,68	54,30	26,91
T_3, T_6	30	67,23	247,50	55,25	29,05



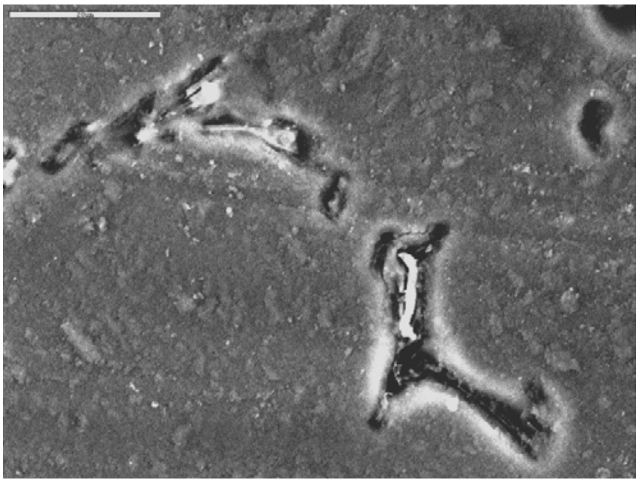
Sl. 1. *Promene parametara E, Rm, HB i A50 u funkciji vremena degasifikacije*

Može se uočiti da se niže vrednosti mehaničkih svojstava dobijaju usled kratkog vremena degasifikacije. Naime, uzorci dobijeni livenjem sa nedovoljnom degasifikacijom sadrže veću količinu gasa i imaju povećanu poroznost. Na slici 2 prikazana je promena koncencentacije gasa sa povećanjem vremena degasifikacije.



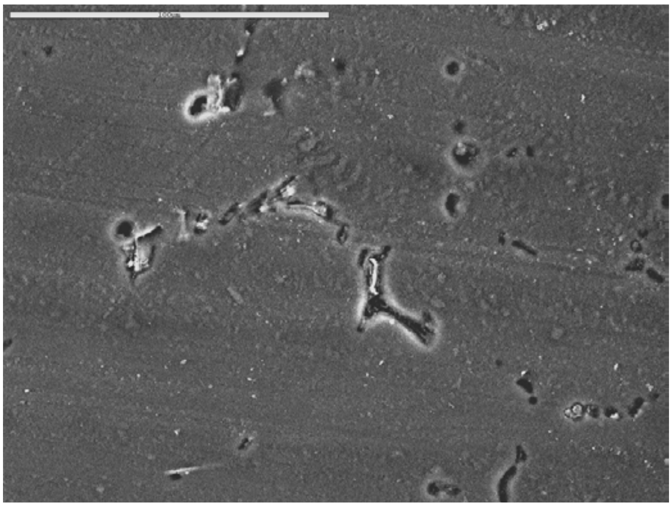
Sl. 2. *Promena koncencentacije gasa sa porastom vremena degasifikacije*

Rezultati ispitivanja koncentracije vodonika u tečnom metalu pred ulivanje u kalup, pokazuju značajne razlike zavisno od vremena degasifikacije. Ako je vreme degazacije kratko gas će u maloj meri biti uklonjen iz metala. Bez obzira što se ALPUR-om izvrši naknadno odstranjivanje prisutnog gasa on će zaostajati u većim koncentracijama u metalu, što se potvrđuje izmerenim koncentracijama. Ovako prisutan gas u velikoj meri utiče na kvalitet odlivaka i može se uočiti mikrostrukturnom analizoma. Na Slici 3. prikazan je izgled poroznosti u uzorku sa najkraćim vremenom degasifikacije.

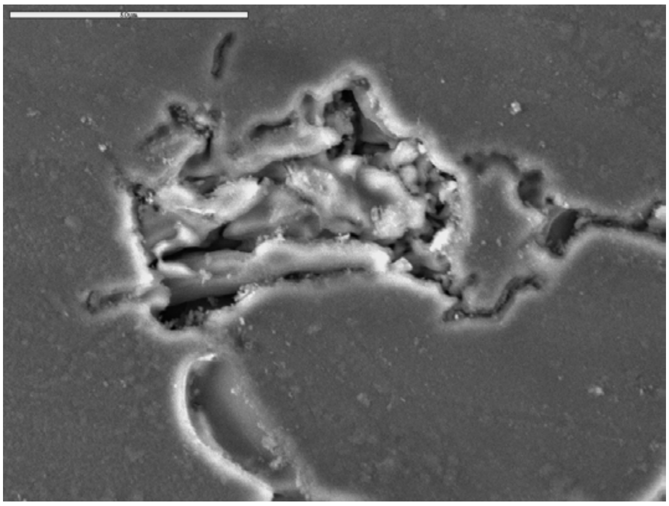


Sl. 3. *Poroznost uzorka sa najkraćim vremenom degasifikacije*

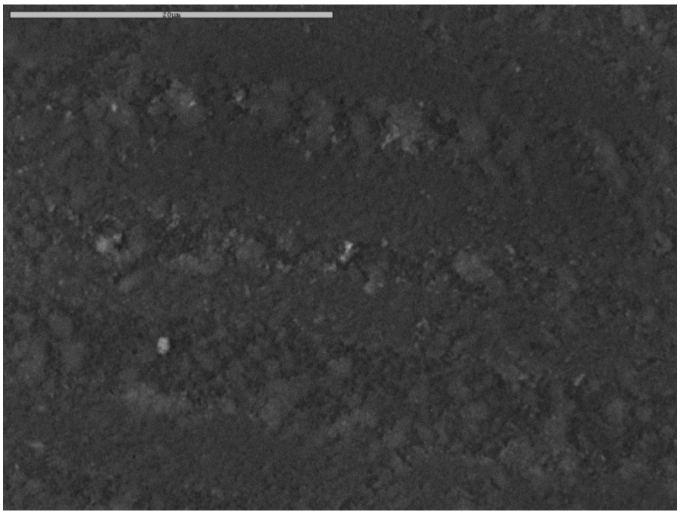
Najbolji rezultati pri merenju koncentracije gasa dobijeni su pri degasifikaciji od 15 min za konstantno vreme odstojavanja. Produženom degasifikacije u kondicionoj peći koncentracija gasa se u manjoj meri povećava. Ovo se može objasniti povećanjem ukupnog pritiska gasa u atmosferi peći, pa se gas predhodno odstranjen iz metala ponovo vraća u metal u periodu odstojavanja. Na sl. 4-6. prikazana je mikrostruktura uzoraka sa različitim vremenima degasifikacije.



Sl. 4. *Mikrostruktura uzorka sa maksimalnim degasifikacionim vremenom*



Sl. 5. *Mikrostruktura uzorka sa minimalnim degasifikacionim vremenom*



Sl. 6. *Mikrostruktura uzorka sa optimalnim degasifikacionim vremenom*

U toku kristalizacije odlivaka kretanje gasa sa površine odlivka ka centru vrši se guranjem od strane rastućih kristala sve do momenta dok gas ne obrazuje mehuriće čija brzina kretanja kroz tečan metal postaje manja od brzine kristalizacije i on biva zarobljen u metalu. Ovo objašnjava pojavu veće poroznosti u prelaznom periodu. Ostatak gasa dospeva do centra odlivka koji zadnji očvršćava odakle sva količina gasa ne stiže da ispliva na površinu već ostaje u odlivku što je potvrđeno mikrostrukturnom analizom. Dokazano je da količina prisutnog gasa koja je konstatovana mikrostrukturnim ispitivanjima zavisi od vremena degasifikacije.

Analiza rezultata ukazuje na izvesne uzroke nastanka grešaka kod livenih elemenata AlMg3 legure: pojava segregacionog sloja; poroznosti; poroznosti u prelaznoj fazi; kao i poroznosti u centru odlivka, tj. elemenata. Prisutstvo gasa u odlivcima se može regulisati određenim merama i stalnom kontrolom procesa, a osnov su postupak degasifikacije pri čemu vrsta degasifikacionog agensa ima posebnu ulogu, što su ispitivanja mikrostrukture i pokazala. Rezultati mikrostrukturnih ispitivanja su pokazali da na kvalitet livenih blokova utiču mnogi parametri procesa i fenomeni koji se odvijaju tokom faze topljenja i livenja. Pokazalo se da šaržiranje i topljenje komponenata šarže treba voditi u jednom redosledu s povećanjem: afiniteta prema kiseoniku, temperaturi topljenja, isparljivosti i smanjenju količine komponenata. Komponente šarže koje imaju velike vrednosti afiniteta prema kiseoniku, temperature topljenja i isparljivosti mogu da se šaržiraju i tope zajedno.

4. ZAKLJUČCI

Glavni zaključci izvedeni na osnovu sprovedenog istraživanja su:

- Osnovni razlog za izbor aluminijum-magnezijum legure je bila pojava sitnih pukotina ili mehurića u toku hladne prerade. Pretpostavka je se da su uzrok gasovi i nemetalni uključci zaostali u toku procesa livenja. Pošto je gas vrlo štetan potrebno je uvek znati njegovu koncentraciju u leguri, pa je posebna pažnja posvećena merenju koncentracije prisutnog vodonika u odlivcima.
- Azot i argon su korišćeni kao agensi za degasifikaciju. Azotiranje je vršeno u peći za topljenje pred izlivanje u trajanju od 15 min. Inertni gas argon se koristio za degasifikaciju u kondicionoj peći i ALPUR-u (pred ulivanje). Najbolji rezultati postignuti su pri degazaciji rastopa sa argonom u trajanju od 15 minuta. Sa produženom degasifikacije u kondicionoj peći koncentracija gasa u rastopu u manjoj meri se povećava. Ovo se može objasniti povećanjem ukupnog pritiska gasa u atmosferi peći, te se gas predhodno odstranjen iz metala ponovo vraća u metal u periodu odstojavanja.
- Mikrostrukturne analize su pokazale da količina prisutnog gasa zavisi od vremena degasifikacije. Nedovoljno vreme degasifikacije ima za posledicu dobijanje nižih vrednosti mehaničkih svojstava izlivenih blokova. Ove vrednosti su nešto niže od vrednosti propisanih standardima. Sa dužim vremenom degazacije mehanička svojstva su na donjim granicama vrednosti propisanih standardom za ovaj tip legure. Naime, uzorci dobijeni livenjem sa nedovoljnom degazacijom, kao i uzorci sa produženim degazacijom u sebi sadrže veću količinu gasa, tj. imaju povećanu poroznost, što se odrazilo na pojavu grešaka - sitne pukotine ili mehuriće u procesu hladne obrade ovih blokova.

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