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Preiskava trdnostnih lastnosti ulitkov za avtomobilsko industrijo, izdelanih iz livnih Al-Si zlitin

The examination of the strength properties on the vehicle industry castings produced from Al-Si foundry alloys

Izvleček

Na dinamično razvijajočem se področju izdelave ulitkov za avtomobilsko industrijo se srečujemo z vse strožjimi zahtevami glede obratovalnih razmer. Danes se v livarsko proizvodnji vse več uporabljajo zlitine iz sekundarnih surovin, vendar vpliv nečistot na te zlitine ni dobro znan. Pomembno je vedeti, da je količina nečistot v zlitinah Al-Si povezana s kakovostjo osnovnega materiala. Za modificiranje silicijeve faz v teh zlitinah se uporabljata predvsem dva elementa, nekatere livarne uporabljajo za to stroncij, druge antimon. Po recikliranju odpadkov se oba elementa nahaja v talini skupaj in lahko pride do nastanka intermetalnih spojin. Cilj naše raziskave je bil ugotoviti skupni vpliv antimona in stroncija v aluminij-silicijevih zlitinah in grafično prikazati nastanek intermetalnih spojin v talini ter njihov vpliv na kakovost končnih izdelkov. Članek prikazuje vpliv antimona in stroncija na mehanske lastnosti ulitkov pri različnih debelinah sten.

Ključne besede: aluminijeve zlitine, modifikacija silicija, debeline sten, mehanske lastnosti

Abstract

In the dynamically developing casting production area the vehicle casting productions must be met for more conditions in the interest of the performance of the increasingly stringent requirements. Nowadays secondary alloys are most frequently used in casting production, but the effects of the impurity elements on secondary alloys are not well known. It's very important to know that the quantity of impurity elements in the Al-Si alloys are related with base material quality. Mainly two elements are used to modify the eutectic silicon phase in these alloys, some foundries apply strontium, others modify with antimony. After the scrap recycling these elements are together in the melt, and the stroncium and antimony together may be a cause for forming intermetallic compounds. The aims of the our research work were the examination of joint effects of antimony and strontium in aluminum-silicon alloys and to chart intermetallic compounds formating in melt and influencing quality in the final product. This paper presents the influence of antimony and strontium on mechanical properties in case of different wall thicknesses.

Keywords: aluminium alloys, silicon modification, wall-thicknesses, mechanical properties

1 Uvod

Izraz modifikacija opisuje postopek, s katerim se dodaja v talino aluminija cepivo v obliki predzlitin, da se spodbudi nastajanje nitastega evtektičnega silicija med strjevanjem [1]. Modifikacija silicija je splošen postopek, ki se uporablja pri aluminij-silicijevih livarskih zlitinah predvsem za izboljšanje mehanskih lastnosti, v največji meri raztezka, s spodbujanjem udrobnjenja prvotno krhke silicijeve faze. Znano je, da dodatki stroncija v sledovih podevtektskim aluminij-silicijevim zlitinam povzročijo pretvorbo morfologije evtektičnega silicija iz grobe ploščičaste oblike v zelo drobno nitasto obliko [2]. Nečistote lahko poslabšajo učinek modifikacije in s tem mehanske lastnosti.

Pri našem delu smo ulili vrsto vzorcev z različnimi koncentracijami antimona in stroncija. Območji koncentracij sta bili 0 – 300 ppm stroncija in 0 – 340 ppm antimona. Izdelali in preskusili smo modelne ulitke različnih debelin sten (6 mm, 8 mm, 12 mm, 25 mm) ter iz njih izdelali natezne preizkušance.

2 Eksperimentalni del

2.1 Konstruiranje kokile za ulivanje

Da bi lahko primerjali vzorce z industrijskimi ulitki, smo konstruirali geometrijo ulitkov z različnimi debelinami sten. Kot se to vidi na shematičnem prikazu kokile (slika 1), so imeli vzorci 4 različne debeline stene, iz njih pa so bili narejeni natezni preizkušanci (premera 6 mm). Geometrijo ulitkov smo konstruirali z računalniškim programom Solid Edge. Nato smo z različnimi geometrijami ulitkov in napajalniki pripravili simulacije litja in iz dobljenih rezultatov izbrali najustreznejšo geometrijo. Računalniška oprema za

1 Introduction

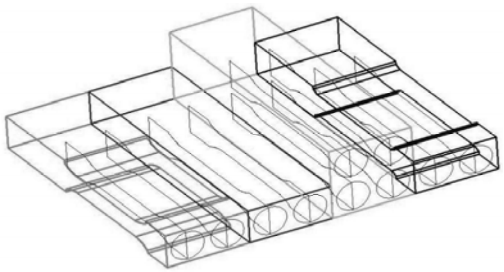
The term »modification« describes the method in which inoculants in the form of master alloys are added to an aluminum melt in order to promote the formation of a fine and fibrous eutectic silicon structure during the solidification process [1]. Eutectic modification is a common process performed in aluminium–silicon based foundry alloys primarily to improve mechanical properties, particularly tensile elongation, by promoting a structural refinement of the inherently brittle eutectic silicon phase. It is well known that trace additions of strontium to hypoeutectic aluminium–silicon alloys result in a transformation of the eutectic silicon morphology from a coarse plate-like structure to a well-refined fibrous structure [2]. The impurities can deteriorate modification effect, thereby mechanical properties.

During our work we casted series from melt with different contents of antimony and strontium. The ranges of contents were between 0-300 ppm strontium and 0-340 ppm antimony. We constructured and tested a casting geometry with variable wall thicknesses (6mm, 8mm, 12mm, 25mm), and by using it we poured castings and tensile rods were processed from it.

2 Experimental conditions

2.1 Designing the casting die

In order to comparability with industrial castings we designed a casting geometry with different wall thicknesses. It can be seen on the schematic casting die with 4 different wall-thicknesses (Fig. 1.) and inside it there are the tensile rods (6 mm diameter). We designed the casting geometry by using simulacije je bila NovaFlow in Solid. Po simulacijah smo izdelali kokilo za litje.



Slika 1. Shematični prikaz ulitka za natezne preizkušance.

Figure 1. Schematics of the casting with tensile rods

2.2 Parametri in faze preskušanja

Za poskusno ulivanje smo uporabili ingote kupljene zlitine kakovosti AlSi9Cu3 ter predzlitino AlSr10 v obliki žice in bloke predzlitine AlSb10.

Stalili smo 100 kg blokov zlitine AlSi9Cu3 ter ulili štiri poskusne serije. Predzlitine smo dodajali v vsaki poskusni seriji (25 kg) v štirih korakih. Razpredelnica 2 prikazuje koncentracijo stroncija in antimona v vsaki od 4 serij. Antimon se je dodajal talini na začetku procesa litja in v vsaki od poskusnih serij se je koncentracija stroncija povečevala od 0 do 300 ppm. Po vsakem dodatku modifikatorja (Sb, Sr) smo talino pustili stati pri konstantni temperaturi 15 minut.

Razpredelnica 3 prikazuje parametre poskusov za vsako serijo.

Solid Edge software. We made casting simulations with some different geometries of casting and feeders, and by right of results we selected the best one. The simulation software was NovaFlow and Solid. After the simulation processes the casting die was produced.

2.2 Parameters and steps of the experiment

During the experimental casting we used manufacturer quality AlSi9Cu3 alloy ingots, the chemical composition is given in Table 1.. We used AlSr10 (Al-10%Sr, wire) and AlSb10 (Al-10%Sb, ingots) master alloys.

A total amount of 100 kg of the AlSi9Cu3 alloy ingots was melted and casted in 4 experimental series, and we alloyed every experimental series (4x25 kg) in 4 steps. The strontium and antimony alloying matrix of the 4 experimental series can be seen in Table 2. The antimony was added to melt at the beginning of the 4 casting processes, and in every experimental series the strontium content increased from 0 to 300 ppm. After every modifier element (Sb, Sr) addition the melt was holding at unvarying temperature for 15 minutes.

In Table 3. the experimental parameters can be seen which are unvarying at every casting series.

During the experiment we have used thermal analysis, dichte-index and spectral analysis. In order to monitoring the heat equilibrium the temperature of the casting

Razpredelnica 1. Kemična sestava aluminijevih zlitih AlSi9Cu3, uporabljenih za poskuse

Table 1. Chemical composition of the AlSi9Cu3 aluminum alloys used in experiments

Elementi / Elements	Si	Cu	Sr	Sb	Fe	Cr	Mn	Ca	P	Pb	Sn	Mg	Ni	Ti
mas. %	9,32	3,00	0,0005	0,0041	0,51	0,02	0,37	0,0014	0,0017	0,047	0,014	0,31	0,037	0,097

Razpredelnica 2. Koncentracija stroncija in antimona v poskusnih zlitinah

Table 2. The strontium and antimony alloying matrix of the experiment

serija / casting series	Stroncij / **Strontium** (ppm)	Antimony / **Antimony** (ppm)			
1.	5 (osnovna zlitina) / (base alloy)	40	140	240	340
2.	100				
3.	200				
4.	300				

Pri poskusu smo uporabili termično analizo, ugotavljali indeks gostote ter napravili spektralno analizo. Za nadzorovanje toplotnega ravnotežja smo s termodvojico zvezno merili temperaturo kokile za litje.

3 Rezultati analize mehanskih lastnosti

Za ugotavljanje mehanskih lastnosti smo izdelali iz ulitih vzorcev natezne preizkušance, kot kaže slika 2. Mehanske lastnosti smo ugotavljali z elektromehanskim nateznim strojem Instron 5982 pri natezni hitrosti 0,004 mm/mm/s.

Vpliv Sr-Sb na rezultate nateznih preskusov je verjetno manjši kot na druge parametre litja, zato se tega vpliva pri naših razmerah litja ne more ugotoviti. Vidimo, da smo najboljše mehanske rezultate dosegli pri debelini stene 8 mm. To se da razložiti z dejstvom, da je bilo napajanje najbolj učinkovito ravno pri debelini stene 8 mm. Pri debelinah stene 6 mm in 8 mm učinka Sr-Sb ni bilo opaziti zaradi hitrega strjevanja pri veliki strjevalni hitrosti. Pri debelini stene 25 mm pa poslabšanje mehanskih lastnosti verjetno povzroči vpliv Sr-Sb.

Razpredelnica 3. Parametri poskusov

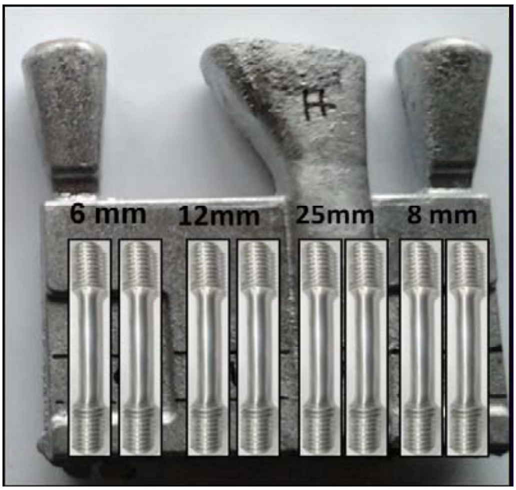
Table 3. The experimental parameters

Temperatura taljenja in legiranja / Melting and alloying temperature	(775±5)°C
Temperatura litja / Casting temperature	(765±5)°C
Predgrevanje kokile za litje / Preheating temperature of the casting die	400 °C
Čas zadrževanja taline po legiranju / Holding time after the alloying	15 min

die was measured by thermocouple continually.

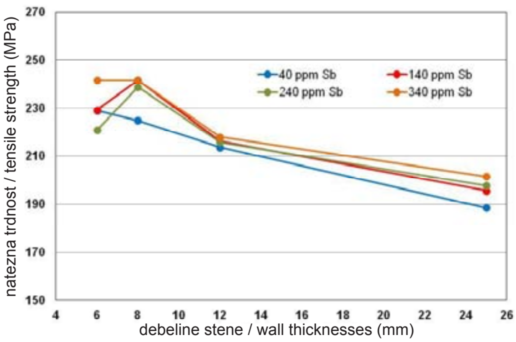
3 Results of the Mechanical Properties Analysing

To determine the mechanical properties tensile rods were processed from the places you can see in Fig.2. For analysing we used Instron 5982 electromechanical tensile test machine and the tensile speed was 0.004 mm/mm/s.



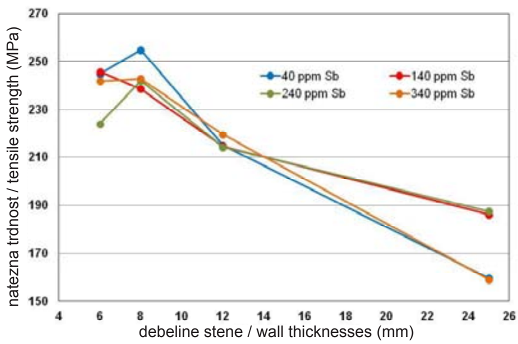
Slika 2. Ulitek in natezni preskušanci

Figure 2. Casting with tensile rods



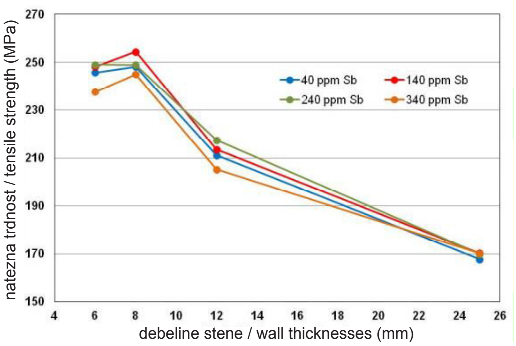
Slika 3. Povprečne natezne trdnosti v odvisnosti od debelin stene pri dodatku 5 ppm Sr

Figure 3. Average tensile strength values in function of wall thickness in case of 5 ppm Sr



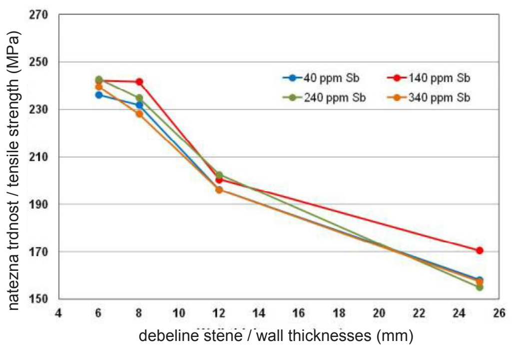
Slika 4. Povprečne natezne trdnosti v odvisnosti od debelin stene pri dodatku 100 ppm Sr

Figure 4. Average tensile strength values in function of wall thickness in case of 100 ppm Sr



Slika 5. Povprečne natezne trdnosti v odvisnosti od debelin stene pri dodatku 200 ppm Sr

Figure 5. Average tensile strength values in function of wall thickness in case of 200 ppm Sr



Slika 5. Povprečne natezne trdnosti v odvisnosti od debelin stene pri dodatku 300 ppm Sr

Figure 6. Average tensile strength values in function of wall thickness in case of 300 ppm Sr

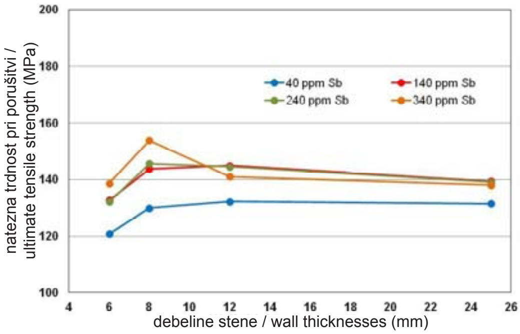
3.1 Rezultati meritev natezne trdnosti

Slike 3 do 6 kažejo rezultate meritev natezne trdnosti v odvisnosti od debeline stene pri koncentracijah stroncija 5 ppm, 100 ppm, 200 ppm in 300 ppm.

3.2 Največje natezne trdnosti

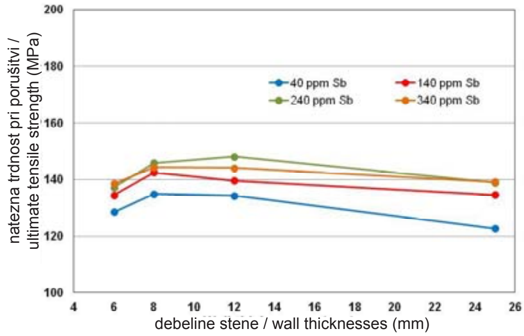
Slike 7 do 10 kažejo natezne trdnosti pri porušitvi v odvisnosti od debelin stene pri

The effect of Sr-Sb on the results of the tensile tests is probably smaller than that of the other casting parameters therefore their effect cannot be examined under present casting conditions. It can be seen that the best mechanical results were observed in castings with 8 mm wall thickness. This can be explained by the fact that the feeding of the casting is the most sufficient at the 8 mm wall-thickness. In the case of 6 mm and 8 mm wall-thicknesses the effect of Sr-Sb cannot be observed due to the rapid



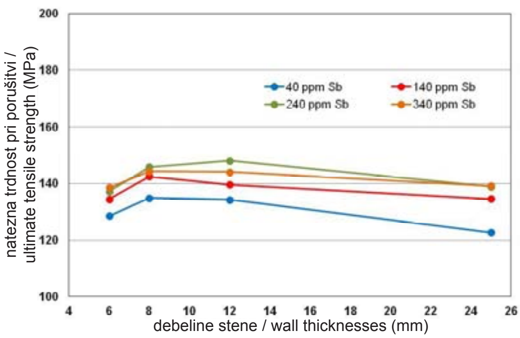
Slika 7. Povprečne natezne trdnosti pri porušitvi v odvisnosti od debelin stene pri dodatku 5 ppm Sr

Figure 7. Average tensile strength values in function of wall thickness in case of 200 ppm Sr



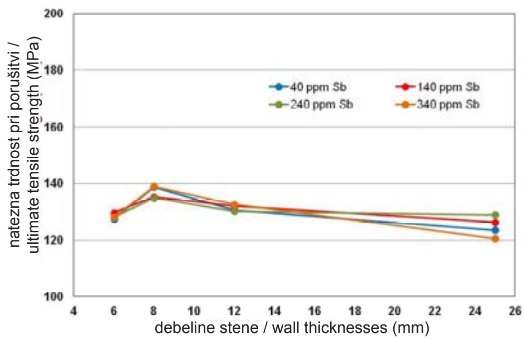
Slika 8. Povprečne natezne trdnosti pri porušitvi v odvisnosti od debelin stene pri dodatku 100 ppm Sr

Figure 8. Average tensile strength values in function of wall thickness in case of 300 ppm Sr



Slika 9. Povprečne natezne trdnosti pri porušitvi v odvisnosti od debelin stene pri dodatku 200 ppm Sr

Figure 9. Average tensile strength values in function of wall thickness in case of 200 ppm Sr



Slika 10. Povprečne natezne trdnosti pri porušitvi v odvisnosti od debelin stene pri dodatku 300 ppm Sr

Figure 10. Average tensile strength values in function of wall thickness in case of 300 ppm Sr

dodatkih 5 ppm, 100 ppm, 200 ppm in 300 ppm stroncija.

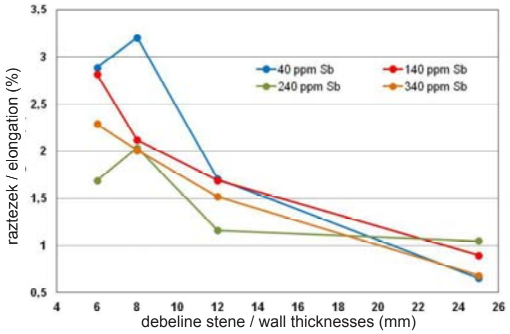
3.3 Rezultati meritev raztezka

Slike 11 do 14 kažejo rezultate meritev raztezkov v odvisnosti od debelin stene za dodatke 5 ppm, 100 ppm, 200 ppm in 300 ppm stroncija.

solidification caused by the high cooling rate. However, in the case of 25 mm wall-thickness the decrease of the mechanical properties is probably caused by the effect of Sr-Sb.

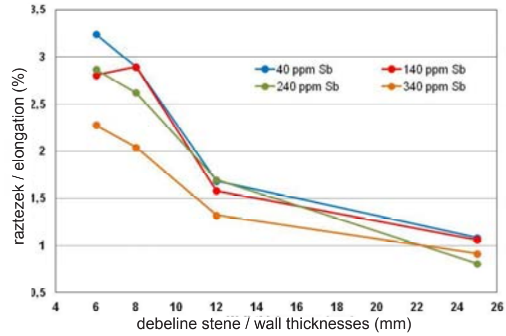
3.1 Tensile Strength Results

In Fig.3 – Fig.6. it can be seen tensile strength results in function of wall-



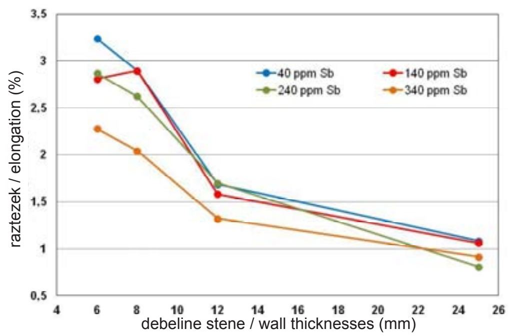
Slika 11. Raztezki v odvisnosti od debelin stene pri dodatku 5 ppm Sr

Figure 11. Average tensile strength values in function of wall thickness in case of 200 ppm Sr



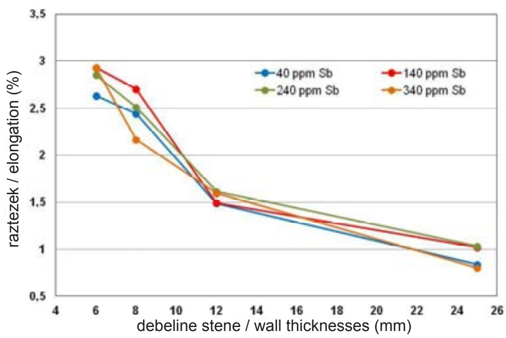
Slika 12. Raztezki v odvisnosti od debelin stene pri dodatku 100 ppm Sr

Figure 12. Average tensile strength values in function of wall thickness in case of 300 ppm Sr



Slika 13. Raztezki v odvisnosti od debelin stene pri dodatku 200 ppm Sr

Figure 13. Average elongation values in function of wall thickness in case of 200 ppm Sr



Slika 14. Raztezki v odvisnosti od debelin stene pri dodatku 300 ppm Sr

Figure 14. Average elongation values in function of wall thickness in case of 300 ppm Sr

4 Sklepi

V tej raziskavi so bili vzorci uliti iz aluminij-silicijeve zlitine z različnimi dodatki stroncija in antimona. Natezni preizkušanci so bili izdelani iz ulitkov. Preiskan je bil vpliv antimona in stroncija na mehanske lastnosti v odvisnosti od debelin stene.

Da bi ugotavljali intermetalne spojine Sr-Sb, bomo prelomnine teh preizkušancev preiskali v prihodnosti. V našem dolgotrajnem načrtu raziskav želimo preiskati mehanizem

thicknesses in case of 5 ppm, 100 ppm, 200ppm and 300ppm strontium.

3.2 Ultimate Tensile Strength Results

In Fig. 7 – Fig.10. it can be seen ultimate tensile strength results in function of wall thickness in case of 5 ppm, 100 ppm, 200ppm and 300ppm strontium.

3.3 Elongation results

In Fig.11 – Fig.14. it can be seen elongation results in function of wall thickness in case vpliva elementov modifikatorja ter analizirati njihove medsebojne vplive. Najprej želimo spoznati osnovne procese zaradi tehnološke optimizacije in s prilagoditvijo parametrov industrijskim procesom zagotoviti, da se lahko s poskusi modelira težave in učinke, ki se pojavljajo med dejansko proizvodnjo.

of 5 ppm, 100 ppm, 200ppm and 300ppm strontium.

4 Conclusion

In this work, samples were cast from different alloys with varying Sr-Sb content. Tensile test specimens were processed from the castings and the influence of antimony and strontium on mechanical properties were examined as a function of different wall thickness. The examination of the fracture surfaces of these samples will be carried out in the future to identify the different Sr-Sb intermetallics. In our long-term research plan we would like to investigate the effect mechanism of modifier elements, and analyse its cross effects. Firstly we want to understand the basic processes in our research work, and to observe the technological options and by adapting the industry process parameters we would like to ensure that with experiments we can model the problems and affects which were occured during the actual production.

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