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ABRASIVE WEAR OF THE AlSi12Mg WITH Al-Si ALLOY FOR CASTING MACHINE PARTS

Tomasz Lipiński, Mirosław Bramowicz, Paweł Szabracki, Paweł Mikołajczyk, Marcin Cudakiewicz

Department of Materials Technology
University of Warmia and Mazury in Olsztyn

K e y w o r d s: Al-Si alloys, silumin, mechanical properties, structure, abrasive wear.

A b s t r a c t

This work present results modification AlSi12%Mg alloy with modifier contained Al and Si. It modifier was has taken down was with components Al, Al7%Si i Al12%Si. homogenous modifier obtained by fast cooling of homogenous modifiers at V=200ºC/s The components were put into a crucible containing liquid Al-Si alloy and kept there for one minute. The influence of modifier in reference to pulp of worked alloy on abrasive wear was introduced in graphic mould. The analysis modification process of hypo eutectic alloy AlSi12%Mg with compound modifier showed the modifying influence on structure and abrasive wear.

ZUŻYCIE ŚCIERNE STOPU AlSi12Mg PO MODYFIKACJI STOPEM Al-Si PRZEZNACZONEGO NA CZĘŚCI MASZYN

Tomasz Lipiński, Mirosław Bramowicz, Paweł Szabracki, Paweł Mikołajczyk, Marcin Cudakiewicz

Katedra Technologii Materiałów i Maszyn
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: stopy Al-Si, silumin, właściwości mechaniczne, struktura, zużycie scierne.

A b s t r a k t

W pracy przedstawiono wyniki badań zużycia ściernego stopu AlSi12Mg po modyfikacji modyfikatorem homogenicznym. Modyfikator przygotowywano przez chłodzenie z prędkością 200 K/s ciekłego stopu złożonego z Al, Al-7%Si i Al-12%Si. Odpowiednio rozdrobniony modyfikator dodawano do tygla wraz z ciekłym stopem AlSi12Mg na 1 minutę. Wpływ modyfikatora w odniesieniu do masy obrabianego stopu na wagowe zużycie ścierne przedstawiono w formie graficznej. Badanie zużycia prowadzono na maszynie Shoppera. Stwierdzono, że modyfikacja modyfikatorem o składzie zbliżonym do składu obrabianego stopu wpływa na strukturę i zużycie ścierne stopu AlSi12Mg.

Introduction

Al-Si alloys despite dynamic development of constructional materials designed on part of machines are still very popular. Its popularity is mainly results the low temperature of melting and proper weight as well as resistance on corrosion. Silumins has defekt, too. Main defect raw siluminów is susceptibility to creating of coarse-grained structures with low tensile strength and elongations. For improvement its proprieties silumins are modified. The modification depends on introduction to liquid alloy of additions which not changing in principal way its chemical composition, but cause crumbling the structure, and the same rise of mechanical proprieties of alloy. For machines parts produced by industry from eutectic Al-Si alloys most often were applied the process of modification with thoroughly well-chosen mixtures with sodium and strontium. The modification process, run with the chemical elements, improves in principal way the mechanical proprieties of alloy. The problems begin on stage of recycling. The used in exploitation phase casts are as dirtied of different chemically modifiers, which in renewed processing can effect unforeseen chemical reactions. With this reason purposeful is study method of making better the mechanical propriety of Al-Si alloys which will not exert on later process of recycling the negative influence on improvement process properties of alloys (BORKOWSKI 1999, GUZIK, KOPYCIŃSKI 2006, KRUPIŃSKI, DOBRZYŃSKI, SOKOŁOWSKI 2008, LIPIŃSKI 2000, 2008, LJUTOVA, VOLCHOK 2008, NOVA, EXNER, HOSEK, NOVAKOVA 2004, PEZDA 2007, PIETROWSKI 2001, ROMANKIEWICZ, ROMANKIEWICZ 2006, WOŁCZYŃSKI 1990).

The processing of Al-Si alloys what is fulfilling technological requirements is modification with chemical compositions consisting with basic silumin components (homogenous modifier). The eutectic Al-Si alloy after modification with homogeneous modifier has crumbled structure in comparison with raw alloy. The structure eutectic Al-Si alloy with homogenous modifier is not fibrous structure as after modification process with chemical elements. Its consists from small silicon needles on background α-phase. Apart of that the mechanical properties treatment silumin with homogenous modifiers are comparable with proprieties of alloy after modification with typical chemical elements. However the chemical elements did not were introduce to alloy come from modifier in result of modification process, different than native classic components of alloy (Al and Si) (LIPIŃSKI 2006, 2008, 2008).

The abrasive wear is one of proprieties of alloys. It depends from a lot of number of factors. But the structural of alloy is the main factor, its effect of modification process (ELMADAGLI, PERRY, ALPAS 2007, YASMIN et al. 2004).

The abrasive wear eutectic silumin AlSi12Mg with homogenous modifier (ecological modifier) is main research problem in this work.

Aim of the study, and methods

Investigation was conducted on alloy AlSi12Mg with Al+AlSi7+AlSi12. Founding, that studied proprieties are continuous functions considered variables and its can be with sufficient exactitude represented in figure of polynomial in investigations planning experiences was applied active, applying total factoral experiment (2^3) for three independent variables (Tab. 1). The equation (1) was introduced for received plan of investigations the figure of equation of regress.

$$\hat{y} = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3 \quad (1)$$

Table 1

Chemical composition of modifier in basic plan point number

Plan point number	Chemical composition of modifier [%]		
	Al	AlSi7	AlSi12
1	0.2	0.2	0.2
2	0.3	0.2	0.2
3	0.2	0.3	0.2
4	0.3	0.3	0.2
5	0.2	0.2	0.3
6	0.3	0.2	0.3
7	0.2	0.3	0.3
8	0.3	0.3	0.3
9	0.2	0.3	0.3
10	0.2	0.3	0.3
11	0.2	0.3	0.3

The results were analyzed mathematically, which enabled to formulate the factor equation for three variables, for the parameters studied, at the level of significance $\alpha = 0.05$. The adequacy of the above mathematical equation was verified using the Fischer criterion for $p = 0.05$. The methodology of process of modification in detail was described at work (LIPIŃSKI 2006, 2008, 2008).

Abrasive wear tested using Schopper machine by corundum abrasive disk at grainy 400 for parameters:

- abrasive disk diametr $\phi = 0.158$ m
- abrasive disk revolutions $n = 14.1$ r.p.m.
- sample revolutions $n = 0$ r.p.m.
- holding down $F = 200$ N

– unit pressure for area of samples	$N = 3.9$	MPa
– working distance	$l = 400$	m
– running speed	$v = 0.12$	m.p.s.

Measurment of abrasive wear practiced by weight, determine loss in total weight with accurancy ± 0.0005 g by laboratory balance WA-21 manufactured in Zakład Mechaniki Precyzyjnej. For statistical analysis of abrasive wear was taken the value of averages with five measurements.

In aim of assurance of equal surface point of contact during investigation as well as obtainment of equal roughnesses of working surface, samples designed to investigations of abrasive wear was profiled to curvature of counter-samples by polishing. Working surfaces was cleaned after polishing by alcohol.

Result and discussion

The example of AlSi12Mg alloy structure with the modifier according to point 6 plan of investigations (Tab. 1) was showed on Fig. 1. There is fine-needle of eutectic β-phase on background of dendritic α-phase.

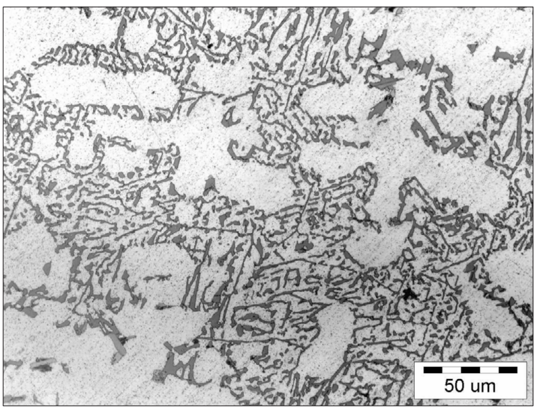

Fig. 1. Structure of AlSi12Mg alloy with 0.3% Al + 0.2% AlSi7 + 0.3% AlSi12 (point 6 of the research design – table 1)

Equation of abrasive wear regress (*zs*) for AlSi12Mg alloy with components: Al∈<0.2, 0.3> [%], AlSi7∈<0.2, 0.3> [%], and AlSi12∈<0.2, 0.3> [%] shows at (2) and its graphic mould at Fig. 2–7.

$$zs = 0.3255 + 0.003x_2 + 0.00775x_3 + 0.00325x_1x_2 + 0.0035x_1x_3 - + 0.00425x_2x_3 - 0.0025x_1x_2x_3 \quad (2)$$

when: F = 17.4, $F_{1\text{–}p}(f_1, f_2)$ = 19.3, then equation (2) is adequate.

Abrassive wear AlSi12Mg alloy with Al = 0.3%, AlSi7 ∧ AlSi12∈<0.2, 0.3>[%] was showed at Figure 2. When the share of AlSi7 and AlSi12 was kept constant at 0.06% (Tab. 1), and when the remaining a three of factors had a 0.2% share of the mixture, abrasive wear reached *zs* = 0.308 g. This is the lowest abrasive wear for analysed plan of investigations. When the share of AlSi7 was increased to 0.3% (high level of investigation plan), abrasive wear increased by 8% to reach 0.334 g. When the also share of AlSi12 was increased from 0.2 to 0.3% (to high level of investigation plan – Tab. 1) and 0.2% AlSi7, abrasive wear increased by 7% to reach 0.330 g. When the share of Al was kept constant at 0.3%, and when the remaining two factors also had a 0.3% share of the mixture, abrasive wear reached *zs* = 0.329 g. Treatment of AlSi12Mg alloy with 0.29–0.3% AlSi12 and 0.2–0.2% AlSi7 did not reason change of level abrasive wear investigations alloy. It similar result was observed in this arrangement of variables, after use about 0.28 % AlSi7 and 0.2–0.2 % AlSi12.

When the share of Al was kept constant at 0.2%, and when the remaining two factors also had a 0.2% the abrasiwe wear of AlSi12Mg alloy was reported *zs* = 0.312 (Fig. 3). When the share of AlSi7 was increased (0.3% of the mass of the processed alloy), abrasive wear increased to reach 0.316 g. The more intensive growth of abrasiwe wear (*zs* = 0.339 g) was received after analogous increased participation of AlSi12 to the level 0.3%. There is the highest abrasive wear of AlSi12Mg alloy in analysed plan of investigations. When the share of Al was kept constant at 0.2% and about 0.265% AlSi12, the variations in the level AlSi7 does not influence on change of abrasive wear. After decrease quantity AlSi12 component AlSi7 affects on abrasive wear directly in proportion to changes its content in mixture, however after increased quantity AlSi12 inversely in proportion to its quantity. The AlSi12 is the main reason of change of analysed parameter for showed at Fig. 3 weight in weight concentration.

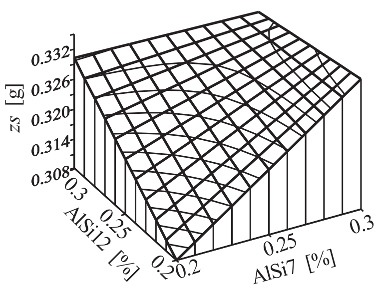

Fig. 2. Abrasive wear (*zs*) AlSi12Mg alloy with AlSi7∈<0.2, 0.3> [%], AlSi12∈<0.2, 0.3> [%], Al = 0.3%

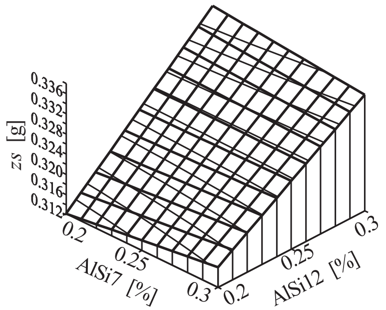

Fig. 3. Abrasive wear (*zs*) AlSi12Mg alloy with AlSi7$\in$<0.2, 0.3> [%], AlSi12$\in$<0.2, 0.3> [%], Al = 0.2%

When the share of AlSi7 was kept constant at 0.3% and when the remaining two factors had a 0.2% share of the mixture, abrasive wear reached *zs* = 0.316 g (Fig. 4). When the share of AlSi12 was increased from 0.2% to 0.3%, abrasive wear increased by 6% to reach 0.335 g. Increased abrasive wear was received after analogous increased in modifier contents of Al , too. For 0.3% Al abrasive wear was *zs* = 0.330 g. For 0.3% AlSi7 i 0.3% AlSi12 and when the share of Al was increased from 0.2 to 0.3%, abrasive wear was reduced to reach 0.329 g. When the share of AlSi7 was kept at 0.3%, changes of Al i AlSi12 in range <0.265, 0.29> [%] was not change of wear (Fig. 4). When the share of both significant factors (Al or AlSi12) was kept at range about 0.28%, the resulting abrasive wear was stabilized on unchanging level.

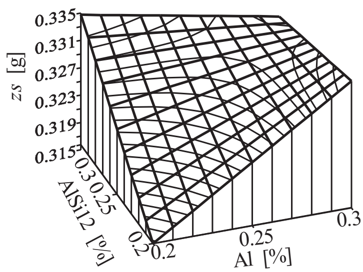

Fig. 4. Abrasive wear (*zs*) AlSi12Mg alloy with Al$\in$<0.2, 0.3> [%], AlSi12$\in$<0.2, 0.3> [%], AlSi7 = 0.3%

The abrasive wear of AlSi12Mg alloy with constant 0.2% AlSi7 and when the remaining two factors of modifier on range 0.2–0.3 % was showed on Fig. 5. When the share all of components of modifier was kept constant at 0.2%, abrasive wear reached *zs* = 0.312 g. When the share of Al was increased, abrasive wear reduced to reach 0.308 g. After analogous introduction 0.3% AlSi12, was received opposite direction of influence. For it the change of wear is directly proportional to its content. The distribution of contour lines indicates that AlSi12 had a more intensive effect on the analyzed parameter then Al. When the share of AlSi12 was kept constant at 0.3%, the lowest wear was reported for also a higher share of the remaining factors (0.3%), reaching *zs* = 0.329 (Fig. 5). When the share of Al and AlSi12 was reduced to 0.2% and with 0.2% AlSi7, abrasive wear increased to reach 0.339 g. For the contents of modifier abrasive wear is the higher in this plan of investigation. Increasing content the AlSi7 in mixture strengthens influence the Al.

The changes of abrasive wear AlSi12Mg alloy with constant range at 0.2% AlSi12 was showed at Fig. 6. The above suggests that changes in the AlSi7 from 0.2 to0.3% share of the mixture affect with less effect on the abrasive wear of

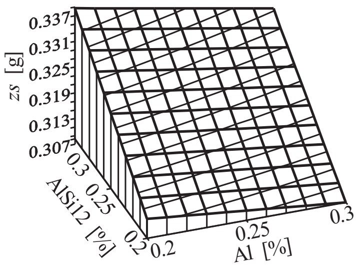

Fig. 5. Abrasive wear (*zs*) AlSi12Mg alloy with Al∈<0.2, 0.3> [%], AlSi12∈<0.2, 0.3> [%], AlSi7 = 0.2%

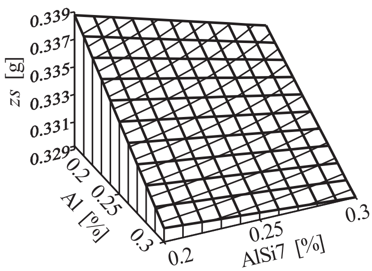

Fig. 6. Abrasive wear (*zs*) AlSi12Mg alloy with AlSi7∈<0.2, 0.3> [%], Al∈<0.2, 0.3> [%], AlSi12 = 0.3%

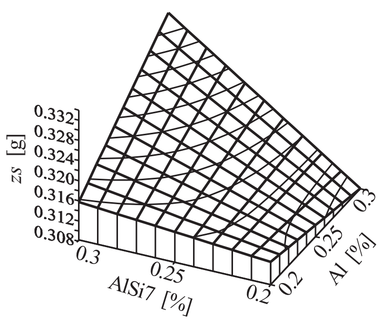

Fig. 7. Abrasive wear (*zs*) AlSi12Mg alloy with AlSi7∈<0.2, 0.3> [%], Al∈<0.2, 0.3> [%], AlSi12 = 0.2%

the AlSi12Mg alloy then analogous change of Al. The intensity of abrasive wear, in this arrangement, dynamically increases with concurrent increased in modifier quantity of Al and AlSi7.

A comparison of the effect of Al and AlSi7 and with AlSi12 on constant range 0.3% on the abrasive wear of the AlSi12Mg alloy indicates that Al is capable of inducing more intensive changes (Fig. 6). However, for 0.2% AlSi12 more intensive changes was affirmed for AlSi7 (Fig. 7). Then, the effect of mixture components on the range of abrasive wear in AlSi12Mg alloy depends of their percentage. This facts speaks about co-operation of analysed factors.

Conclusions

The largest gradient of changes was received for 0.3% Al and AlSi7∈<0.2, 0.3 > [%]. For participation 0.2 % Al, similarly how for 0.2 % AlSi7, change suitably AlSi7 or Al does not cause the large change of abrasive wear.

Summing up analyze influence the applied to processing of alloy AlSi12Mg of components on base of Al with variable of content Si, the growth of abrasive wear was affirmed for AlSi12Mg alloy treatment with growth of part of silicon in homogenous modifier.

Minimal abrasive wear zs = 0.308 g may be achieved by using 0.3% Al, 0.2% AlSi7 and 0.2% AlSi12.

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References

BORKOWSKI S. 1999. *Quality controll of cast constructional materiale for example cast iron*. WNT, Warsaw.

ELMADAGLI M., PERRY T., ALPAS A.T. 2007. *A parametric study of the relationship between microstructure and wear resistance of Al-Si alloys*. Wear, 262: 79–92.

GUZIK E., KOPYCIŃSKI D. 2006. *Modeling Structure Parameters of Irregular Eutectic Growth: Modification of Magnin-Kurz Theory*. Metallurgical and Transactions 37A: 3057–3067.

KRUPIŃSKI M., DOBRZYŃSKI L.A., SOKOŁOWSKI J.H. 2008. *Microstructure analysis of the automotive Al-Si-Cu casting*. Archives of Foundry Enginieering, 8: 71–74.

LIPIŃSKI T. 2000. *Analysis of influence exothermical mixtures on AlSi7Mg alloy*. Mińsk, pp. 87–89.

LIPIŃSKI T. 2006. *Ekological modification AlSi7Mg alloy*. Archives of Foundry Engineering, 6/18: 91–96.

LIPIŃSKI T. 2008. *Improvement of mechanical properties of AlSi7Mg alloy with fast cooling homogenous modifier*. Archives of Foundry Enginieering, 8: 85–88.

LIPIŃSKI T. 2008. *Modification of the Al-Si Alloys with the use of a Homogenous Modifiers*. Archives of Metallurgy and Materials, 53(1): 193–197.

LJUTOVA O.V., VOLCHOK I.P. 2008. *Increase of foundry properties of secondary silumins*. Archives of Foundry Enginieering, 8: 89–91.

NOVA I., EXNER J., HOSEK Z., NOVAKOVA I. 2004. *Crystallization of Al-Si alloys in the course of high pressure die-casting*. Archives of Foundry, 4(14): 325–332.

Orłowicz A.W., Tupaj M., Mróz M. 2008. *Mechanical properties of AlSi7Mg with sodium*. Archives of Foundry Engineering, 8.

Pezda J. 2007. *Continous modification of AK11 silumin with multicomponent salt on base of NaCl*. Archives of Metallurgy and Materials, 4: 151–154.

Pietrowski S. 2001. *Silumins*, University of Łódź.

Romankiewicz F., Romankiewicz R. 2006. *The influence of modification for structure and morphology fractures of alloy AlSi132*. Archives of Foundry Enginieering, 6(22): 436–440.

Wołczyński W., Cypruś R. 1999. *The analisis of the influence of the gibbs free energy onto the lamella-rod transition in Al-Si alloy.* Archives of Metallurgy, 44(3): 339–353.

Yasmin T., Khalid A.A.,. Haque M.M. 2004. *Tribological (wear) properties of aluminum-silicon eutectic base alloy under dry sliding condition*. Journal of Materials Processing Technology, 153–154: 833–838.