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Influence Some Elements on Aluminium Alloys

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Abstract: The creation of new materials of high resistance and low density is one of the main important concerns of metallurgists, in view of the aeronautic evolution. The aluminium alloys, with lithium, present a particular interest because they represent a gain of weight of 10-15% and offer a good rigidity and ameliorated characteristics. In different cases, the use of these alloys is better than composite materials or other alloys of other systems. Unfortunately, they gain technologic casting properties and consequently, they complicate their putting into form. In the first step, this work is a study of the influence of the addition of elements (Cu, Mg, Li), the modification agents (Ti, Zr, Sc) and impurities(Fe, Si, Ca, Na and other) on linear shrinkage, on the aptitude at the hot and the cold creek formation and the alloy structure of Al-Li-Mg and Al-Li-Cu systems. Then, the study optimizes the chemical composition of the alloys of the examined systems in the aim to increase the strength at the creek formation and the homogeneous wheat obtaining. The influence of the principal allied elements on the susceptibility at the creek formation and the linear shrinkage of the alloys of the Al-Li-Mg and Al-Li-Cu systems. The modification of the alloys of Al-Li-Mg by the addition of Zr and Sc is an efficient mean against the shrinkage on grain. Practically, a recommendation had been proposed on the optimization of the chemical composition of the alloys, according to their principal addition elements, modified by the additives and the impurities in the aim to diminish their fragility by the heat susceptible to the formation of the cold creek and the obtaining of fine grains of homogeneous structure. The application of this recommendation allows diminish or to eliminate totally the scandium grade uncertain alloys.

Key words: Alloys, casting, modification, creek formation, linear shrinkage

INTRODUCTION

The materials with high resistance and low density are one of the most important problems of the metallurgists and the physicians conditioned by the development in the air fleet and aeronautic technology. Here, the interest is focused on the aluminium alloys, with lithium. The latter allows to diminish the weight ten times and to increase their rigidities and to ameliorate the exploitation characteristics. The use of these alloys is more efficient than the use of the alloys of the other systems.

However the alloys related to lithium have weak properties; they oxidize in intense manner and are saturated in hydrogen at the flowing moment; have weak thermic conduction and great elasticity modulus which by consequence leads to the formation of hot creek and cold during the flowing of the ingots. They have a high susceptibility to the heterogeneous structure formation and faculty on the surface of the floats castings.

Of the cited negative Al-Li alloys qualities is also the insufficient information of their properties which complicates the work with these alloys at the elaboration step and also in the production domain and evokes the necessity of the complementary research realisation.

The aim of the present work is to study the influence of the additional elements (Cu, Mg, Li) on the linear shrinkage of the alloy system Al-Li-Mg and Al-Li-Cu.

MATERIALS AND METHODS

For preparation of alloys aluminium with a high purity (Al-99.95%; Mg-99.96%; Li-99.5% and the alloys mothers: Al-50%Cu; Al-5.0%Be, Al-5.0% Zr, Al-3.5% Ti and Al-2.0% Sc have been used. The casting has been unfolded in graphite-grog crucible in the temperature is measured by a chromel-alumel thermocouple of precision±10°C. The lithium is introduced in the alloy liquidates in pure state out of the oven with 10% of loss on fire in excess. At 720-730°C lithium has mixed with the alloy liquidates and after 20-30 sec the metal is flowed in the mould's imprint. The temperature of the casting is in the order of 700-710°C. For protection of the metal from oxidation in all alloys 0.15% beryllium was introduced. The content of

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additional elements in alloys is determined by a spectrochemical method and by a photometric method. The quadratic average gap of the concentration of the given additional elements composition constitutes: Mg-5, Li-4, Cu-3, -99 and Sc-6%.

The susceptibility of alloys at creeks'formation is studied with thee hl f special shell. The value of the linear is determined by the linear shrinkage dimension variation of the test-tubes, poured in two moulds in bras of dimensions 200×16×15 and 250×14×12 mm. After solidification at room temperature, the length of samples is measured with a precision of 0.05 mm and the value of the linear shrinkage is calculated according to the formula:

$$\epsilon = l_{\phi} - l_{sample} / l_{\phi}$$

Where l_{ϕ} is the length of the mould's print, l_{sample} is the length of the print at the ambient temperature. The temperature at beginning of the linear shrinkage (T_{bls}) is determined by means of device of Bolchakov. Alloys are flowed in the mould's print in absothermosilicate which assures a liquid cooling speed of 1K/s.

The aptitude of alloys to the evolution of shrinkage deformations is determined according to the value of the sample's bending, flowed in pigs for the linear shrinkage study.

The study of the alloy structures is realized by samples, obtained by different speeds of cooling of the to the liquid state (1.5 and 30 K/s).

Influence of principal elements: We have studied the influence of the principal elements on the Aptitude at the Hot Creek Formation and Cooling Creek (AHCF and CC), the Linear Creek (LC) Fig. 1, 2 and the warping. The grade f thee elements varies within wide limits: Cu (0.9-6.3%), Mg (1.0-10%), Li (0.5-4.5%). These limits are near the industrial alloys composition, which have an AHCF and CC. The study of LC shows that the alloys of the system Al-Li-Mg have creek values more weak than the alloys Al-Li-Cu Table 1, 2 this is linked to the temperature limits[1] in which develop (Tslc-Tam), where (Tslc) temperature of state of the linear creek, (Tam) is the ambient temperature the LC states in the case of the Al-Li-Mg (445°C) is less considerable than the alloys of the Al-Li-Cu (528°C) system Fig. 1. Examining the influence of the alloys compositions on LC, we can notice that the introduction of lithium in the studied alloys has a considerable increase of the coefficient values of the linear compression and the values of the LC alloys, this is linked to the coefficient values of the thermic compression of lithium (56.10^{-6}/K) which is twice superior than of aluminium (26.10^{-6}/K). Then we have seeker the aptitude

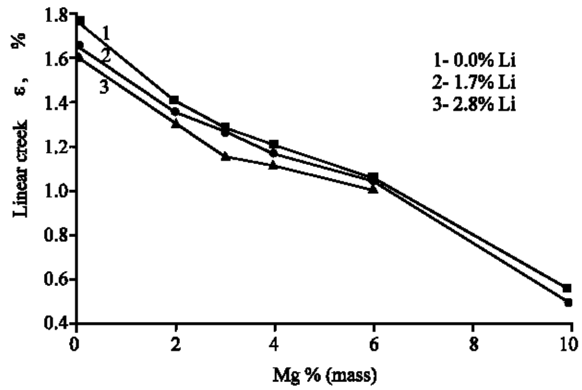

Fig. 1: Linear creek of alloys Al-Li-Mg

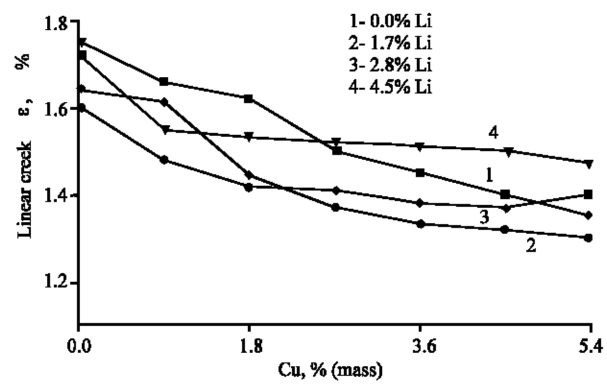

Fig. 2: Linear creek of alloys Al-Li-Cu

Table 1: Aptitude of alloy Al-Li-Cu at creek's formation, (L_{crit},cm)

	Cu % (mass)							
Li,% (mass)	0	0.9	1.8	2.7	3.6	4.5	5.4	6.3
0	10.3	4.3	3.5	3.0	4.0	4.5	4.7	5.7
0.55	12	3.0	2.5	2.5	2.5	3.0	3.0	3.0
1.1	11	2.5	2.0	2.0	2.5	3.0	3.6	5.0
1.7	5.8	2.5	2.5	3.0	3.0	3.5	4.3	6.3
2.25	3.0	2.5	3.0	4.0	5.0	6.0	7.0	8.3*
2.8	3.7	3.5	3.0	3.2*	6.0*	8.3*	9.2*	10*
3.4	7.7*	4.0*	3.0	3.0*	3.0*	3.5*	3.5*	3.5*

(*) Aptitude of alloys at the cooling formation

Table 2: Aptitude of alloy Al-Li-Mg at creek's formation ($L_{crit.}$. cm)

	Mg % (mass)								
Li % (mass)	0	1	2	3	4	5	6	8	10
0	10.3	3.0	4.0	4.0	5.5	7.3	6.3	9.8	10.8
0.55	12	3.5	3.5	4.0	4.0	4.0	4.0	4.5	6.0*
1.1	11	3.0	3.5	4.0	3.5	4.0	4.0	4.3	6.0*
1.7	5.8	3.5	3.5	4.0	4.0	4.0	4.0	4.0*	4.3*
2.25	3.0	2.5	4.0	3.7	4.0	4.0	4.3	4.5*	5.0*
2.8	3.7	3.5	3.5	3.5*	3.0*	4.0*	3.7*	4.0*	3.5*
3.5	7.7*	3.5*	4.0*	4.0*	4.0*	4.0*	3.5*	4.0*	3.0*

(*)Aptitude of alloys at the cooling formation of the alloys Al-Li-Mg, Al-Li-Cu to the warping development, which is caused by irregular cooling Fig. 2. The of warping value in the alloys increases in sensible manner due to the higher grade of the allied elements and the restraint[2] causes the break of the pig contrary to the alloys which do not contain lithium

MODIFIERS AND IMPURITY EFFECT

Influence of modifiers: The modificaation of alloys of the system Al-Li-Mg and Al-Li-Cu by Zr and also Zr-Sc leds to an important finess of the grain of lithium and the diminution of the hot fragility of alloys Table 3. This behaviouurr is linked t the diminution of the initial temperature of the linear shrinkage naarrowing of the effective crystallization interval and also to the possibility of the increase of the value of the elastic and plastic deformation in alloys at high temperatures.

The effect of the modification attaineed is due to release of a great quantity of dispersed particles of intermetallic compounds which in presence of Zr and Sc form a complex compound

$$(Zr_x,Sc_{1-x})Al_3, \text{ or } x<1$$

and represent a good centers crystallization. This will be cleer by the change of the dimension and the form of the lithium grain, provoking a structure non dendritique of dimension approaching to concentrations of elements modifiants at the distribution of the deformation and the tension to the long of the piece's casting on 10-15%, decreases the global value of the linear shrinking, narrows the effective crystallization interval.

It is clear that, it is linked by the kinetic growth of centers of crystallization which do not have time to be released the metal liquidates to weak content of Zr and Sc and do not render the action of the modification correspondant, if the cooling is rapid. At important content of elements modifiants centers of crystallization form in exceeding it and the receipt structure a center of character not-dendritique independent of the speed of cooling. The dimension of the grain in this case becomes comparable with that of the dendritic screen and defined by the relation: $d = A/V_{cool}^{1/3}$. Where A is a constant, V_{cool} is a speed of cooling.

That is why to a content of elements modifiants alloys that cool slowly have larger grains.

Researches have proved that the optimal proportion between the content of Zr and Sc in alloys is 1:2 (1 part of Zr on 2 part of Sc according to the mass). However, according to concentrations determined, these elements are interchangeable and the indicated proportion can not to maintain.

Table 3: Influence of the modification of the Zr and Sc on the hot fragility of the alloy B (Table 4)

	Sc. %		
Zr. %	0	0.15	0.3
0	3.7/3.8	3.3/3.7	3.3/4.0
0.1	3.0/5.0	5.3/3.7	11.3/12.0
0.2	7.3/10.3	9.8/12.0	11.3/12.0

N.B.: The numerators are values of L_{cryst}.cm flowed in a cold mould. The denominators are values of L_{cryst}. cm. flowed in a mould heated until 200°C

Table 4: Recommendation for the chemical alloy composition

Type of alloy	Content in addition elements. % mass: Li	Cu	Mg	Zr	Sc	Ti
A	1.9-202	0.04	4.6-5.4	0.06-0.1	0.12-0.17	0.05
				0.08-0.12	0.16-0.21	0.02
B	2.3-2.8	0.04	2.3-2.	0.08-0.2	—	—
	2.2-2.5			0.1-0.15		
C	2.3-2.8	0.05	3.2-4.2	0.06-0.1	0.1-0.2	0.05
	2.2-2.5			0.08-0.12	0.12-0.17	0.02
D	1.4-1.7	2.7-3.3	0.1	0.09-0.14	—	0.02-0.06
			0.05	0.12-0.17		0.02
E	1.-2.3	2.6-3.3	0.1	0.09-0.14	—	0.02-0.06
			0.05	0.12-0.17		0.02
F	2.1-2.5	2.6-3.3	0.05	0.08-0.13	0.05-0.10	0.03-0.06
				0.12-0.18		0.02

N.B.: The numerator: used alloyd compositions. The denominator: changes recoommended numerals

A preliminary heating until 200°C for the study of the fragility at hot ends showed a sensitivity increase of the effect of the modification, which expressed by the diminution of the inclination of alloys tendency to crack formation already to the weak concentration of modifying elements. It was noticed, that the modification of system alloys studied for titanium and also titanium compounds of scandium or of zirconium is not important, because in this case the refining of alloy grain is not accompanied by the diminution of their hot fragility. The titanium of the alloays Al-Li is recommended to change the zirconium of 1-1.5 pats of the Zr on 1 part of Ti (according to the mass). The increase of the content in alloys of the main elements of addition especially the Cu, Mg and Li favours the increase of the effect of modification, can be expressed in the refining of the grain and the diminution of the susceptibility of alloys at the hot creek's formation. The increase of the action of modification of Zr and Sc is due to the diminution of their solubility in the alloy liquidates, the saturation by others elements and precipitating them of a great quantity of particles of the intermetallic compounds presenting centers of grain crystallization of the solid solution. Consequently, the variation of the rate of addition in alloy has to change the content of modifying elements.

In all, realized experiences allow to give the recommendation of the optimization of the chemical alloy composition according to the main elements of addition and additives modifiants with finest grains, the reduction of their fragility at hot and susceptible at the cooling creek formation, also the diminution of the cost of alloys Table 4.

The application of the recommendation allows to diminish the content of the Sc in the alloy (A) 0.16, 0.21% until 0.12, 0.17% and with the conservation of the technological and mechanical property levels and to decrease appreciably its cost. In the alloy (F) it is better to exclude the scandium composition, introduced in quantity 0.05, 0.10% because of its inefficiency beside these weak concentrations, which also results in substantial economy.

Influence of impurities: It was established that impurities in alloy Al-Li find a different effect on the susceptibility at the creek formation in function of the composition of alloys according to the main elements, modified by additives and other impurities.

The introduction of impurities in alloys, containing an insignificant quantity of modifiers as rule, behaves to the increase of their fragility at hot. The exception constitutes on impurities 0.07-0.1% Si in the alloy (B) and impurities 0.05-0.1%Ca in alloys A exerting a positive influence on their susceptibility at the creek formation. Researches have shown, that the addition of calcium in the alloy A favours also the fineness of the grain of lithium, that of course is more essential factor in the plan of the increase of its stability to creeks, we have established, that impurities until 0.10% of the calcium do not find a considerable influence on mechanical properties of half-product cast by compression from the alloy A. It is important to notice that impurities of sodium in a quantity up to do not practically effect the hot fragility of alloys of the system Al-Li-Mg to the binary alloy difference Al-Mg. Particularly, the nuisible influence on the susceptibility to the hot and cold creek formation are impurities of the magnesium in alloys of the system Al-Li-Cu. First is due to the diminution of the temperature of solidus and the extension of the interval of alloy crystallization and second because it is linked with the release of the rebounded phases according to boundaries of grains and the diminution of the capacity of alloys at the evolution of the deformation at low temperatures. The content of magnesium in alloys of this system must not be beyond 0.05-0.1%.

The research of the influence of hydrogen on the stability at creeks of the alloy A has shown that the variation of its content of 0.7-3.0cm^3/100g does not reflect on the susceptibility of the alloy to the creek formation allowing the properties of the hydrides of zirconium in alloys, containing the lithium, not to react and its modifying effect does not diminish.

It had been noted, that a good modification of zirconium and scandium of alloys of the system Al-Li-Mg is practically insensitive to the presence of impurities of Fe, Si, Ca, Sn, C, Pb introduced in quantities 0.5-1.0% and Na in the u t quantity 0.1%. Consequently, the modification is the mean fight against the creeks at hot, provoked by the presence of different impurities in the alloys.

CONCLUSION

The influence of the principal additional elements on the susceptibility at the creek formation and the linear creek of the alloys of the systems Al-Li-Mg and Al-Li-Cu, indicate that the alloys of the system Al-Li-Mg have a weak value of the linear creek, than the alloys Al-Li-Cu and this is due the low non-equilibrium solidus temperature of the Mg alloys.

The increase of the grade of the additional elements provoke the visible increase of the warping value, so the alloys resistibility at the hot creek formation suddenly diminishes. This is due to the role of lithium whose value must not be beyond 2.5%.

The modification of alloys of the system Al-L-Mg and Al-Li-Cu by zirconium and also Zr-Sc ends to an important refining of the grain and the diminution of the fragility which is linked with the effective crystallization interval, by diminution of the value of linear shrinking and the distribution of the more regular tension at the length of the test tube and also with the elastic and plastic deformation to high temperatures. The modification of the alloys of the examined titanium system is not needed in relation to the absence of a positive influence of this element about the susceptibility of alloys to the hot creek formation. The titanium in these alloys is recommended in order to substitute it by the zirconium 1-1.5 part of to 1 part of Ti (according to the mass).

Impurities in alloy Al-Li show a different influence on the tendency at creek formation and as a rule, they end to the increase of their hot fragility, the exception is for impurities of 0.07-0.1% of silicon in the alloy B and 0.05-0.1% of calcium in the alloy A, to the introduction at which the stability to creeks of alloys increases. The good modification by zirconium and scandium of alloys of the system Al-Li-Mg is practically insensitive to the presence of Fe, Si and other as impurities. This allows conclude that the modification is an efficient mean to fight against the hot creek, causing a presence of different impurities in the alloys.

The present research allows to give a recommendation on the optimization of the chemical composition of the alloys of the studied systems. For alloys A and C the concentration of modifying elements: 0.08-0.02 Zr and 0.12-0.17 Sc are optimal grain the structure point of view and the susceptibility at the crystallization creek formation. In the alloy F it is better to eliminate completely the scandium, introduced in quantities 0.05-0.1% due to its inefficiently according to its insignificant concentration. With this the content of zirconium is necessarily to increase up to 0.12-0.18%. The limitation of the content in iron and silicon in the studied systems recommends to maintain the values of 0.10% Si and 0.15% Fe. The content of magnesium in alloys of the system Al-Li-Cu must not go beyond 0.05-0.1%.

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