S E N S ' 2 0 0 6
Second Scientific Conference with International Participation
SPACE, ECOLOGY, NANOTECHNOLOGY, SAFETY
14 – 16 June 2006, Varna, Bulgaria

АЛУМИНИЕВИ СПЛАВИ С КОМПОЗИЦИОННА СТРУКТУРА ЗА ПРИЛОЖЕНИЕ ПРИ ПОВИШЕНИ РАБОТНИ ТЕМПЕРАТУРИ

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Ключови думи: алуминиеви сплави, композити с метална матрица, високи работни температури

Резюме. *Изследвани са сплави от четворната система Al-Fe-V-Si с цел получаване на in-situ композиционни структури с метална матрица. Установена е възможността за влагане на керамични пълнители за допълнително дисперсно уякчаване на сплавта. Определени са механичните показатели при повишени температури и е установена граница за приложение на изследваната сплав. Изследвана е стабилността на изходната бързозатвърдяла структура при термомеханични обработки до 500^{o}C.*

Установено е пренебрежимо изменение на размерите на интерметалидната фаза, диспергирана в пластичната матрица. Изследваната структура показва добра устойчивост на окисление във въздушна атмосфера при температури до 500^{o}C.

ALUMINIUM COMPOSITE FOR APPLICATION AT ELEVATED TEMPERATURE

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Key words: aluminium alloys; composite material; high temperature application

Abstract. *Alloys of the quaternary system Al-Fe-V-Si were studied in order to prepare composite structures with metal matrix. Feasibility was found out to incorporate ceramic additives for additional strengthening of alloys. Mechanical properties at elevated temperature were tested and boundaries for application established. Stability of the rapidly solidified precursor structure was studied up to 400^{o}C. Minor size changes of the intermetallic phase particles, dispersed in the metal matrix, were found. Substantial resistance to oxidation in air at 500^{o}C was observed.*

Introduction

Composite materials (CM) were developed in order to ensure high mechanical properties at various thermal and radioactive conditions. Aluminium based CM with ceramic particles have been developed recently for application in automotive and airspace industry. Ceramic particles of SiC, Al_2O_3, TiB_2, B_4C, TiC are being tested [1] for this purpose. Two main methods for preparation of composite materials are used – mechanical mixing of powders and introduction of ceramic particles in the melt preceding its solidification. 'In-situ' preparation of CM have been developed recently [1].

The purpose of this presentation is to study the influence of TiC additions in Al-Fe-V-Si alloys on their mechanical and corrosion properties.

Experimental

CM were prepared using powder metallurgy methods. The microstructure of alloys was studied by optical microscopy (Reichert MeF2). Phase transitions were monitored with the aid of differential scanning calorimeter DSC-2 (Perkin Elmer). The apparatus curves were digitalized and presented showing the positive exo-effects. Micro hardness measurements were carried out on a microscope NEOFOT with micro hardness accessory HANEMAN.

Microcrystalline powders were prepared by gas atomization in horizontal equipment (gas flow under pressure of 5 atm). The melt is dispersed by the gas ejection though a nozzle. Atomization chamber (8x2x3 m) allows solidification to end before droplet precipitation. Different sizes of powder particles were taken for different experiments after fractional sieve analysis of the powders.

With an hour mechanical milling for homogenization in planetary mill, Al-Fe-V-Si powders with different quantities of TiC were prepared for compacting. The latter was performed in two stages [2]:

a) Pre-compacting by static pressing at 600-650 PA into an ingot 40 mm in diameter and 70-75% density compared to a cast specimen.

b) Final compacting into bulk ingot by hot extrusion. A press form was used with local heating allowing changeable reduction ratio. Extrusion was performed in temperature interval 450-480ºC at reduction 1/12.

Mechanical testing of tensile strength and ductility was performed by a tester Amsler.

Results

Powders of Al-Mg-V-Si with two different concentrations of Mg with and without additions of TiC (Table 1) were studied. As seen on Table 1 this addition causes micro-hardness increase measured in both compositions.

Table 1 Composition and Micro-hardness of the alloys studied

Alloy	Composition, wt.%	Micro-hardness, Hv
1. AlFeVSi alloy with high Mg content	Al-8.1% Fe-2.1%V-7тегл.%Si-1.1%Mg	153
2. Composite material - alloy №1 with TiC	Al-8.1% Fe-2.1%V-7тегл.%Si-1.1%Mg + 10% TiC	161
3. AlFeVSi alloy with low Mg content	Al-9.5% Fe-1.5%V-7тегл.%Si-0.2%Mg	123
4. Composite material - alloy №3 with TiC	Al-9.5% Fe-1.5%V-7тегл.%Si-0.2%Mg + 10 тегл.%TiC	134

It is shown in Ref. [2] that the structure of microcrystalline ribbons, prepared from a similar composition with up to 3 wt.%Si, is two-phased, consisting of super-saturated Al matrix and a quaternary intermetallic phase. An exothermic DSC peak in experiments with constant heating rate was observed [2] (Fig.1), which corresponds to decomposition of the Al supersaturated solution and growth of intermetallic particles.

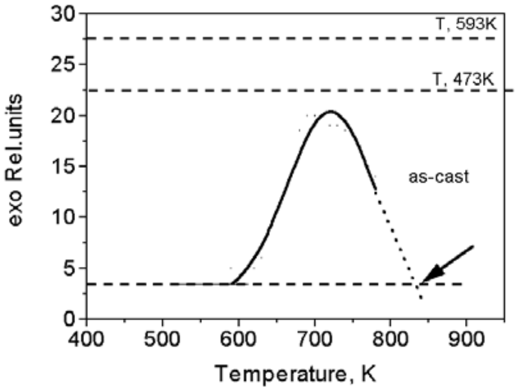

Fig 1. DSC curve [2] shows heat release between 580-830 K from a ribbon specimen with composition Al-8.5%Fe-1.06%V-2.75%Si.

DSC measurement of ribbons from alloy №1 (Table 1), in increased heating mode, exhibited two exothermic peaks (Fig.2). First of the peaks corresponds to Si precipitation during decomposition of the Al matrix and second – to quaternary intermetallic phase forming. Similar results were obtained from micro-crystalline ribbons with the same content without Mg additions [3].

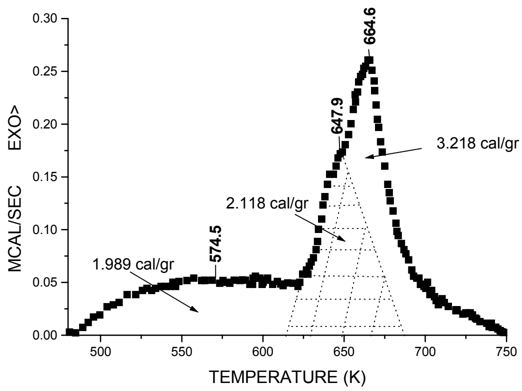

Fig 2. DSC curve shows heat evolvement in partially overlapping temperature intervals from a ribbon with composition - alloy №1.[3]

The hot extrusion processing of microcrystalline powders with and without TiC causes decomposition of supersaturated solutions similar to the one, mentioned above (Fig.1 and 2). As a result, the extruded samples didn’t show substantial DSC heat release (Fig.3). Small temperature effects observed can be attributed to relaxation of residual stresses in compacted ingots. Introduced deformation energy during compacting is released during the hot extrusion, as found in alloys with 3%Si [4]. Inert TiC particles diminished these heat releases even more.

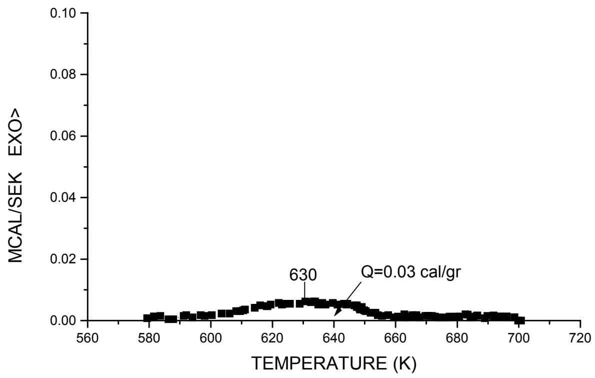

Fig 3. DSC curve of extruded composite sample from alloy №2 (10 wt.% TiC).

As is seen from Table 1 the composite specimens show higher micro-hardness than the extruded ingots without addition of TiC. The composites have higher density, which is in line with a successful extrusion.

Strength increase due to ceramic addition was reported in earlier studies [5]. Rupture strength increases and ductility drops with TiC concentration increase (Figs. 5 and 6). Even after isothermal annealing at temperature close to hot extrusion conditions the ingots exhibit relevant mechanical properties.

As the studied materials are intended for elevated temperature applications their oxidation resistance is of particular importance. It was found that all Al-Fe-V-Si alloys show substantial stability in air up to 500°C. The alloys with high Mg content didn't oxidize up to this temperature as well.

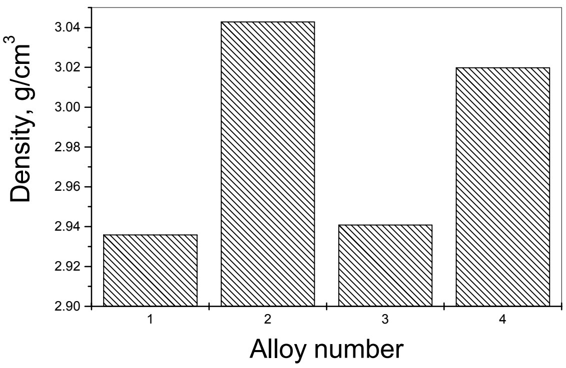

Fig. 4 Density of the extruded alloys (Table 1).

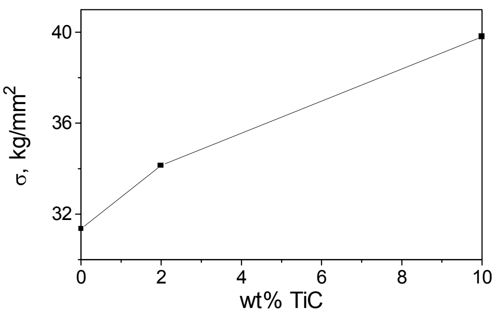

Fig. 5 Influence of addition of TiC on the rapture strength of prepared composites.

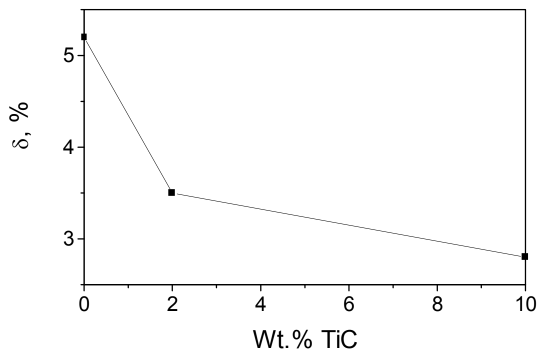

Fig. 6 Influence of addition of TiC on the ductility of prepared composites.

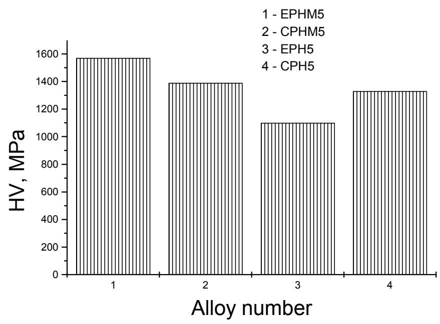

Fig. 7 Micro-hardness of the studied alloys after isothermal heating at 400^{o}C.

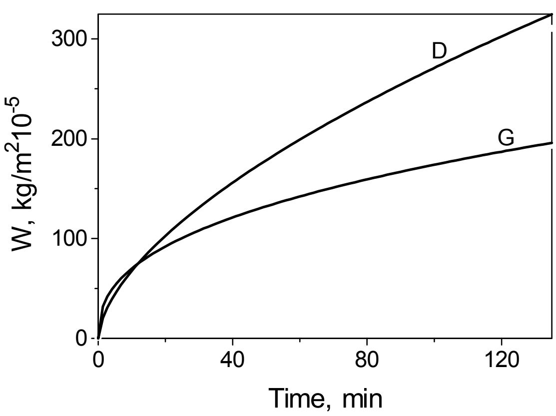

Fig. 8 Growth of oxidation layer after isothermal heating at 500^{o}C, D – alloy №1, G – alloy №2.

Fig, 8 shows comparative oxidation curves of alloy №1 and the composite (alloy №2) at temperature – 500°C, which is substantially higher than the application temperature for these alloys.

Conclusions

Bulk ingots with substantial density, elevated micro-hardness and mechanical properties were prepared by hot extrusion of powders of Al-Fe-V-Si alloys and TiC. Better mechanical properties were observed at concentrations of TiC≥10 wt.%.

It was found out that decomposition of the supersaturated Al solid solution takes place at temperatures suitable for hot extrusion. The precipitated nano-sized phases partially enlarge, though, causing better strength features of the composites. No substantial coarsening of the microstructure of the extruded samples is observed up to 400°C. The resistance to oxidation in air of materials studied was excellent up to 500 °C.

Acknowledgement: Financial support by Bulgarian National Science Fund - Contract TN 1401/04 is gratefully acknowledged.

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