The Mechanical Properties of Al_3Ti/6061 Al Composite Materials under the Magnetic Field

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Abstract. Reactants are the fluorine potassium titanate (K_2TiF_6), in situ synthesis of the melt reaction method and magnetic field is applied in the reaction ,under the same conditions, with no external field, under the magnetic field obtained Al_3Ti/6061 composite materials for mechanical properties of contrast ;Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis showed that: under the magnetic fields generated particles Al_3Ti, smaller particles, the size is about 1-3 μ m diffuse evenly distributed in the aluminum matrix; Mechanical properties of composites research shows that tensile strength σ_b and elongation rate are improved with the magnetic field, Al_3Ti/6061 composite materials tensile fracture surface shows that the fracture is a plastic fracture.

Introduction

Nowadays, composite materials are widely used in aviation, aerospace, marine and other fields. This required to be tensile, compressive strength, wear resistance, good dimensional stability and thermal conductivity. Particle reinforced aluminum matrix composite materials with high specific strength and specific stiffness, excellent mechanical and physical properties, especially the in situ reaction of raw particles reinforced aluminum matrix composites, compared with the traditional plus method, with a small particle size, particle surface without pollution, clean interface, the interface combined with good and a series of advantages, and thus praised as breakthrough new technology and highly valued [1-3]. Al-K_2TiF_6 new system is studied in magnetic field in situ by the reaction of Al_3Ti particle reinforced aluminum matrix composites.the magnetic field in the metal solidification process for the development of new materials, optimize the material preparation process, improve the comprehensive quality of the metal material products and solve the technical problems of metal materials in the preparation process to provide new means and methods of its solidification process in materials the application will become the new direction of materials research [4-6]. Be used in the reaction and found to respond more fully, more uniform particle size distribution, and the reaction without stirring, to avoid the "skin effect" due to uneven force, simple process.

Testing method

The raw materials for industrial pure aluminum (purity 99 95%), fluoride potassium titanate (K_2TiF_6) powder (purity greater than 99.0%), after pure Al is melt, add the Al-10% Mn middle alloy, crystalline silicon, after alloying, heated to 750℃, 10% of the melt mass to join K_2TiF_6. Bell pressed it into the melt internal, combination of magnetic field applied during the reaction, after the role, to join Al-60% Mg, after the melting, processing, slag melted, remove the impurities into three same crucible in a resistance furnace in situ reaction,the other two moved to the equipment Fig. 1 shows the magnetic field generating device,and single magnetic field effect the aluminum melt.we get Al_3Ti / 6061 composite materials. The samples obtained in Japanese electronics JXA-840 type scanning electron microscopy (SEM) on the micro structure analysis, in Japan's neo-confucianism D/max2500VB3 + / PC type X ray diffraction on phase analysis, in ESH-50 type universal material testing machine tensile tests。

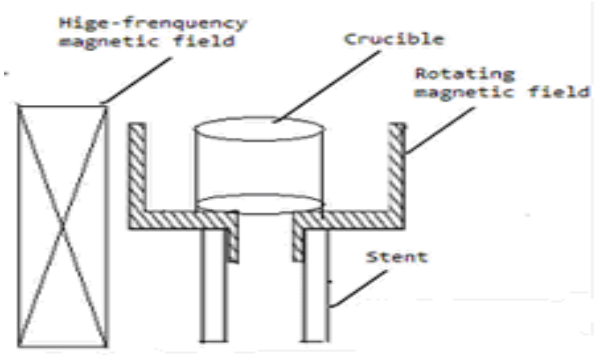


Fig. 1 The magnetic field generating device

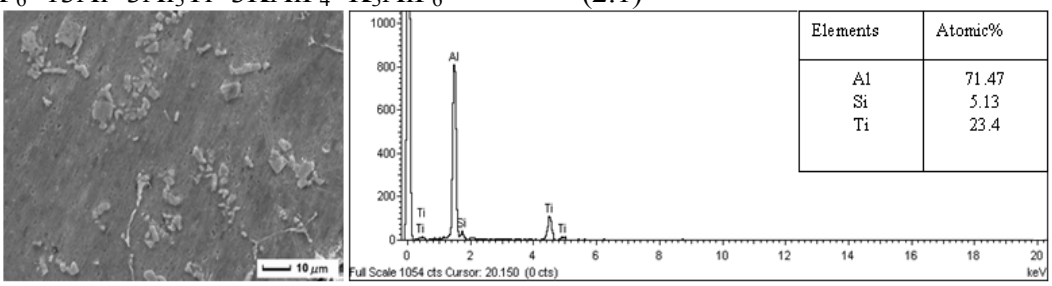
Test results and discussions

In the magnetic field Al3Ti/6061Al composite materials the composition, distribution and morphology of the reinforcing particles.

Fig. 2 shows the 6061Al-K_2TiF_6 group in the no external field in the initial reaction temperature of 1023 K, the amount of powder was added 10 percent of the melt mass of the composite microstructure of water quenched style analysis from the SEM image and its EDS analysis chart. The figure shows, response of the generation of micro particles regional exist together, combined with EDS analysis shows that Al_3Ti morphology mainly for rectangular or short clavite, and have a small amount of granular. The software analysis, we can conclude that particle size for 2 ~ 4 μm.

Fig. 3 is the in situ synthesis Al_3Ti/6061 composite materials X-ray diffraction pattern. It can be seen from the figure, in addition to Al with Mg_2Si peak, there Al_3Ti peak, which suggests that the reactions that produce Al_3Ti.Therefore, we deduce the main chemical reaction in the melt is:

$$3K_2TiF_6+13Al=3Al_3Ti+3KAlF_4+K_3AlF_6 \qquad (2.1)$$



Elements	Atomic%
Al	71.47
Si	5.13
Ti	23.4

Fig. 2 Microstructure of the composites and EDS of the Al_3Ti/6061 composites in combination of magnetic field

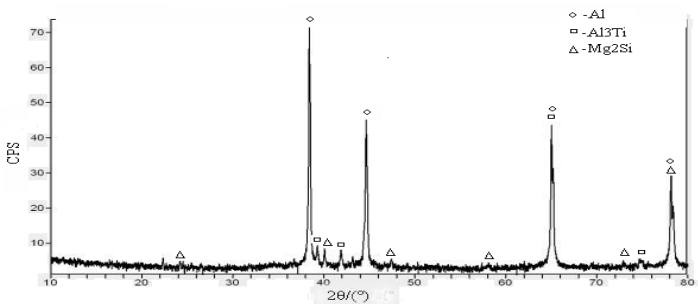


Fig. 3 XRD atlas of Al_3Ti/6061 compound materials

Use of literature data [3] standard conditions calculating the reaction Gibbs free energy:

$$\Delta G^0(Al_3Ti) = -335925.8046 + 168.326T \ .$$

when T in 1003 ~ 1023 K, the Gibbs free energy of Al_3Ti is always negative, therefore, the use of Al-K_2TiF_6 response element was prepared in 1003 ~ 1023 K temperature range Al_3Ti particle reinforced aluminum matrix composites are thermodynamically feasible.

Mechanical properties

Shown in Table 1 for no field, a single magnetic field and the combination of magnetic field 10vol% Al_3Ti/6061Al composite cast and T6 treated at room temperature tensile properties. It can be seen from Table 1 , Al_3Ti/6061Al composites cast performance and T6 state performances are improved to some extent with the introduction of combined magnetic field. Improved by 16.25% T6 treated composites under the combination of magnetic field tensile strength than no field, the elongation rate of 22.34%; the tensile strength increased by 4.98% compared with a single magnetic field, the elongation increases 7.48%.

Table 1 The mechanical properties of 10vol%Al_3Ti/6061Al composites under different outfield condition

	Cast		T6 treated	
Field types	σ_b [M Pa]	δ [%]	σ_b [M Pa]	δ [%]
No field	190	15.4	220	9.4
Single magnetic field	208	16.4	251	10.7
Combination of magnetic field	223	17.9	262	11.5

Analysis of strengthening mechanisms of Al_3Ti/6061Al composite consists mainly of three kinds: Orowan strengthen + fine-grain strengthening + solid solution strengthening. Orowan [7-9] strengthening is by get close hard particles through the obstacles when wrong registration and cause the strengthening function,which is inversely proportional to the particle spacing,particle spacing is small, the dislocation line bypassing the particles when the curvature is more large, resulting in increased resistance of dislocation movement leaving the material exhibits high strength. Fig. 8 shows the 6061Al alloy and 10vol% Al_3Ti/6061Al composite of OM pictures. By the software analysis, composite grain size d1 = 97 μm, 6061Al alloy grain size d2 = 350 μm. Al_3Ti with the existence of α-Al, the following relationship (001) Al / / (001) Al3Ti, [001] Al / / [100] Al_3Ti, Al_3Ti with α-Al lattice constant mismatch of 5.2%, can easily become α-Al nucleation core to meet the total cell corresponds to the conditions, which indicates that Al_3Ti can be used as a substrate of α-Al phase heterogeneous nucleation, and the experimental results also confirmed that due to the generation of Al_3Ti, α branches in matrix crystal divided into small equiaxial crystal. It is the reflection of fine-grain strengthening mechanism in metal matrix composites the importance of the field.

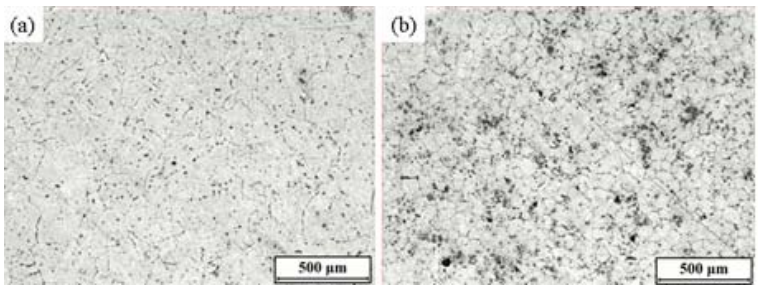


Fig. 4 OM pictures of (a) 6061Al and (b) Al_3Ti/6061Al composite materials

Solid solution strengthening [10,11] is the external atomic solid soluble in matrix, on one hand it can hinder the dislocation motion, and on the other hand because foreign atom and the base metal atoms have different size, will produce the mismatch strain field, and with a wrong strain field produce interaction. Foreign atomic and the base diameter of the greater the difference between atoms rate (the bigger the ε) and foreign atoms in the higher concentration of matrix, the solid solution strengthening the stronger ability. Solid solution strengthening the strength to solut produced expression σ solut= G ε(xf/4) 1/2, for Al_3Ti / 6061 Al composite materials, Ti atomic solid soluble in α(Al), Ti atomic radius of 2 A, and the Al atom radius of 1.82 A, because Ti and Al

atomic radius of different grid work inevitably be an aberration, produce the strain field, thus it can be seen, the melt in response Al_3Ti endogenous particles reinforced aluminum matrix composites, solid solution strengthening caused by Ti has a strength greater contribution to Al_3Ti/6061 Al composite material .

Conclusions

Al-K_2TiF_6 system response in the magnetic field synthesis Al_3Ti small particles, the size of about 1-3um sharp corners occur significantly passivation and dispersion evenly distributed in the aluminum matrix. Al_3Ti / 6061 Al composite material has good tensile strength and good plasticity, along with the introduction of the magnetic field, Al_3Ti/6061 composite materials of as-cast performance and T6 state performance all have certain degree of improvement. the composite material magnetic field introducing T6 state tensile strength are not when the outfield increased by 16.25%, the elongation increased by 22.34%; Compared with no magnetic field, composite materials tensile strength increased by 4.98%, the elongation increased 7.48%; It combined magnetic field the Al_3Ti/6061 Al the mechanical properties of composite is on greatly improved. By Al_3Ti/6061 Al composite materials tensile fracture of SEM photos, we can conclude that when join electromagnetic field, the tensile fracture visible from composite materials, materials and brittleness flat area has basically disappeared, greatly increasing the number toughness nest, toughening nest tiny size, morphology uniform.

Acknowledgments

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