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顆粒型鋁基複合材料熔煉鑄造暨摩擦壓接研究

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顆粒型鋁基複合材料熔煉鑄造暨摩擦壓接研究

The Effect of Heat Treatment on Tensile and Friction Welding Properties of Particulate Reinforced 7005 Al

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一、英文摘要

The effect of heat treatment on tensile and friction welding properties of 7005 Al/10wt% 15μm and 6μm $SiC_{(p)}$ composites and 7005 Al/10wt% 15μm $Al_2O_{3(p)}$ composites have been studied. If Al_2O_3 particulate were used in the strengthening phase, Al_2O_3 particulate had the same tensile strength for the solution heat treatment and artificial heat treatment, which also was higher than the matrix. After friction welding, if the heat-effected zone had strengthening particulates, especially 6μm SiC particulate, it's hardness and stress concentration increased, and the welding strength decreased.

Keywords: Particulate aluminum matrix composites; Friction welding; Heat effected zone; Welding strength

二、緣由與目的

Compared with the monolithic aluminum alloys, particulate aluminum matrix composites (PAMC) possess better Young's modulus, hardness and wear resistance [1-4], which make it useful for the transportation [5], electronic [6-7], and sporting goods [8] industries.

Friction welding often used for joining PAMC [9-10] is a solid-state welding process, in which heat is generated by friction from the relative motion of the parts to be welded. The application of an axial force maintains intimate contact of the parts and causes plastic deformation of the material near the weld interface. Ellis et al. [11] showed that the joint strength of 2618Al / 14%SiC particulate composites is about 380N / mm^2 with friction welding. In addition, if the work piece goes through solid solution, quenching and aging treatments after friction welding, the joint strength can rise to 431 N / mm^2, which is close to the previous 2618Al joint strength of about 455 N / mm^2.

三 、 研究方法及結果與討論

3.1 研究方法

3.1.1 Materials Preparation

SiC_p(β phase) and Al_2O_{3p}(α phase) whose shapes are irregular are employed as the reinforcements. This paper was employed to add 10wt% 15μm and 6μm SiC particulate and 10wt% 15μm Al_2O_3 particulate in 7005 aluminum alloy uniformly. After 7005Al is melted at 700℃, and then the molten slag were removed. The added system and agitator were settled in a proper position in the crucible, the agitator was turned on and slowly sped up to 400 rpm. Then, the upper impeller and the lower impeller were slowly sped up to 2000 rpm and 4000 rpm. After adding certain amounts of particulate, the impellers were turned off. The billets were put into a holding furnace at 490 ℃ of a 350 ton indirect extrusion machine and then using an extrusion rate of 12 l/s, the billets were extruded into rods of 18 mm in diameter.

3.1.2 Friction Welding

The welding work pieces were turned and then put into a 200℃±3℃ air furnace to anneal for two hours in order to eliminate residual stress of turning. The welding point surface Ra was 2.5 μm before welding. The work piece was fixed at a rotation speed of 730 rpm, 3.4 N/mm^2, friction pressure and 7secs friction timing were applied. Finally a forging pressure was used for 10 seconds after friction process. After the welded flashes on the friction welded specimens were machined, they were tensile tested using an Instron machine with a crosshead speed of 5mm/min at room temperature.

3.1.3 Heat Treatment

Tensile specimens were cut from extruded 7005Al and the composites with a gauge length of 60mm. The heat treatment included (I) Holding at 400℃ for 90 min and then quenching in 22℃ water;(II) Holding at 400℃ for 90 min, quenching in 22℃ water, and then a two-step artificial aging process was used, aging at 110℃ for 8 hours, followed by 16 hours at 145℃, and, air cooling at 22℃ . After the welded flashes were machined on the friction-welded specimens.

3.1.4 Microstructure Observation

Then the microstructure was observed through an OPTIPHOT-100 Nikon optical microscope.

3. 2 結果與討論

3.2.1 Particulate in matrix distribution

The distribution of strengthening particulate in 7005 aluminum alloy is shown in Fig.1, where we can see that SiC and Al_2O_3 particulate are well distributed in the matrix. In this paper, by using the process of molten casting, particulate of 15μm and 6 μm were uniformly added to the matrix successfully.

3.2.2 The Effect of Heat Treatment on Tensile Properties

The tensile properties of the specimen, which have been solution heat-treated are shown in Table 1. It was found that the tensile properties of 7005Al/15P/Al_2O_3 composite were larger than 7005Al/6P/SiC and 7005Al/15P/SiC. The tensile properties of 7005Al/6P/SiC and 7005Al/15P/SiC were quite similar. Compared with the matrix, the composites possessed better tensile strength, and the elongation was reduced from 15% to10.3%.

The tensile properties of the specimens after artificial heat treatment are shown in Table 1. It was found that the tensile properties of 7005Al/6p/SiC and 7005Al/15p/SiC were quite similar.

3.2.3 The microstructure of the particulate in the heat affected zone

In Fig.2(a), we can see that there is an obvious plastic field in the Zpd zone of the 7005Al.

Fig.2(b) is the 7005Al/15μm Al_2O_3

particulate composites in the heat-affected zone. The plastic flow is less obvious than in 7005Al, because the Al_2O_3 particulate can effectively prevent the plastic flow. We see that in the Zpl zone, the Al_2O_3 particulate are distributed evenly in the matrix, which is different from the orientation of Al_2O_3 particulate in the Zud zone.

Fig.2(c) is the microstructure of 7005Al/15μm SiC particulate composites in the heat-affected zone. We can see that there is more of an obvious plastic field in the Zpd zone than the 7005Al/15p/Al_2O_3. This is because when spinning was employed, the softer matrix was ploughed by the SiC_p, and most of the heat was produced by friction of "the really contact point and then the flash temperature of the SiC_p transferred to the matrix. Heat formed per SiC_p(q) is obtained through the formula, $q=\tau v=\mu dH_v$, (τ : shear per particulate, d : sliding distance, μ: coefficient of friction at constant spinning velocity, sliding distance and plastic contact pressure ,and contact temperature 25℃–700℃.For polycrystalline SiC is 0.4-1.1, for polycrystalline Al_2O_3 is 0.5-1.0, H_v : average Vicker's hardness, for polycrystalline SiC is 3100, for polycrystalline Al_2O_3 is 2000. The amount of friction heat is produced in the process of friction 7005Al/SiC composites were larger, the thermal conductivity of SiC(0.06-0.1cal/cm.s.℃) is larger than Al_2O_3(0.06cal/cm.s.℃) ,and was helpful in producing greater plastic flow in the matrix.

Fig.2(d) is the microstructure of 7005Al/6μm SiC particulate composites in the heat-affected zone. We can see that there is an obvious plastic field in the Zpd zone, because the 6μm SiC particulate moves more easily than 15μm SiC and Al_2O_3 particulate in the plastic flow.

四、 計畫成果自評

The effects of heat treatment on tensile and friction welding properties of extruded rods are discussed, and the conclusions are as follows:

1.The solution heat treatment can achieve larger tensile strength in the composites than the parent material. For the 7005Al/SiC $_{(p)}$ composites, higher stress concentration formed than in the 7005Al/Al_2O_3 $_{(p)}$ composite, so that a poorer tensile strength is obtained; through the artificial heat treatment, precipitate formed easily at the matrix-particulate interface, higher stress concentration was produced, and tensile strength was poorer than in the parent material. For the 7005Al/ $Al_2O_{3\,(p)}$ composite, the tensile strength obtained by the solution heat treatment and the artificial aging treatment were similar.

2.The strengthening phase in the Zpl increased stress concentration and reduced it's welding strength, and 7005Al/6p/SiC had the poorest welding properties. Breaks occurred in the higher density of particulate of the Zpl zone, and 7005Al have dimple ductile fractures and the composite had low ductile fractures surface morphology.

五、參考文獻

[1] T. Mochida, M. Taya and D. J. Lloyd, Mater. Trans. Japan Inst. Metals 1991; 32:931-942.

[2] T. J. A. Doel and P. Bowen, Composites

Part A 1996; 27A:655-665.

[3] A. L. Geiger and J. A. Walker, JOM 1991; 43(8): 8-15.

[4] B. Venkaraman and G. Sunderarajan, Acta Mater 1996;44(2):461-473.

[5] Honda Motor Co. 1991. Brochure. Tokyo, Japan.

[6] P. K. Rohatgi, F. M. Yarandi and Y. Liu, Materials Science and Engineering 1991; A147: L1-L6.

[7] J. T. Lin, D. Bhattacharyya and C. Lane, Wear Proceedings of the 10th International Conference on Wear of Materials 1995: 883-888.

[8] Alcan 1991 Product Brochure. San Diego, CA.

[9] K. K. Wang and P. Nagappan, Welding Journal Research Supplement 1970; 49(9): 419-425.

[10] K. K. Wang and Wen. Lin, Welding Journal Research Supplenment 1974; 53(6): 233-241.

[11] M. B. D. Ellis, M. E. Gittos and P. P. I. Threadgill, Materials World 1994; 12(8): 415-417.

Table 1 The tensile properties of particulate metal matrix composite

Specimen	$\sigma_{y0.2\%}$ (Kgf/mm^2)	UTS (Kgf/mm^2)	σ_f (Kgf/mm^2)	ε_1 (%)
7005Al	29.6^{+} 28.1^{*}	35.17^{+} 34.5^{*}	35.3^{+} 34.0^{*}	14.0^{+} 15.0^{*}
7005Al/15P/SiC	26.2^{+} 30.9^{*}	23.9^{+} 38.7^{*}	30.8^{+} 38.5^{*}	12.0^{+} 10.3^{*}
7005Al/6P/SiC	26.5^{+} 30.9^{*}	33.1^{+} 38.6^{*}	31.18^{+} 37.4^{*}	11.1^{+} 10.9^{*}
7005Al/15P/Al_2O_3	31.9^{+} 31.8^{*}	39.8^{+} 39.7^{*}	38.7^{+} 38.4^{*}	14.3^{+} 11.0^{*}

+ : the artificial aging heat treated

* : the solution heat treated

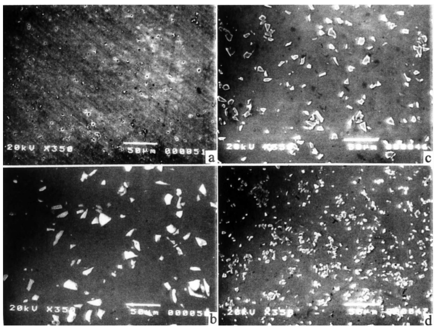

Fig 1 Microstructure of (a)7005 Al base material; (b)7005 Al/15μm Al_2O_3; (c) 7005 Al/15μm SiC; (d) 7005 Al/6μm SiC particulate composites.

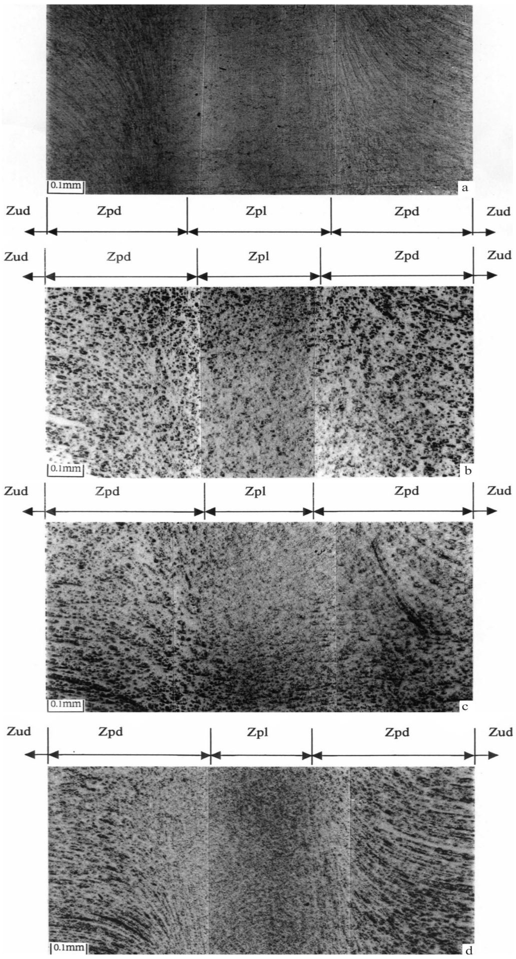

Fig 2 Microstructure of (a) 7005 Al-7005 Al ; (b)7005 Al/15μm $Al_2O_{3(p)}$-7005 Al/15μm $Al_2O_{3(p)}$ composites ; (c)7005 Al/15μm $SiC_{(p)}$-7005 Al/15μm $SiC_{(p)}$ composites ; (d)7005 Al/6μm $SiC_{(p)}$-7005 Al/6μm $SiC_{(p)}$ composites.