In situ Synthesis of Al-Cr/Al Composites and Bending Property

Qiu-lin WANG1,*, Jin-bo ZHU1, Ru-tao XU1, Bin LI2 and Tian ZHANG3
1Engineering Training Center, Chengdu Aeronautic Polytechnic, Chengdu 610100, China
2Department of Aeronautical Engineering, Chengdu Aeronautic Polytechnic, Chengdu 610100, China
3Engineering Training Center, Chengdu Aeronautic Polytechnic, Chengdu 610100, China
*Corresponding author

Keywords: Aluminum matrix composites, In situ synthesis, Microstructure, Bending property.

Abstract: Al-Cr/Al composites were fabricated by ultrasonic vibration assisted. Then the reinforced phase were characterized by XRD and EDS, and the reinforcement particle size, morphology and distribution were observed by the use of SEM, and studied on the bending property of the composite material. The result shows that, Al and Cr generate inter-metallic compounds of $\text{Al}_{0.983}\text{Cr}_{0.017}$, $\text{Al}_{5}\text{Cr}$, $\varepsilon$-$\text{Al}_{8}\text{Cr}_{5}$, $\eta$-$\text{AlCr}_{2}$, etc. The enhance particles, appear irregular polygonal shape, smaller particles diameter, distribute in the matrix uniformly. And the enhance particles and the matrix get good bond, clean interface, non-pollution. The bending strength $\sigma_{bb}$ of the composites is decline as increasing Cr content. It is easy to form stress concentration at the interface. Inter-metallic compounds grain are not easy to slip under external load force, reinforcing particles and the matrix are easy to suddenly fall off, so, composites have a greater brittle.

Introduction

Particle reinforced aluminum composite material get more attention in the aerospace, automotive and other fields, because it has many outstanding features, such as high specific strength and specific stiffness, corrosion resistance, low price, etc [1-3]. Among them, in situ particle reinforced aluminum composite material has many unique advantages. Such as reinforcement nucleated from the aluminum matrix inside and grow up, surface contamination could be avoided during reinforcement processing, the problem of poor wettability with aluminum could be solved, simplified preparation process, saving costs, etc [4-6].

Al and Cr could be synthesized inter-metallic compound at high temperatures [7,8], but it was easy to form the size of a thick strip, fragmented the continuity of matrix composites severely, degraded the performance of the composite. In this paper, the ultrasonic vibration was used for grain refinement and distributing reinforcement particles uniformly during fabricating the Al-Cr/Al composite, and researched the phase composition and bending performance of the composites.

Experimental Methods

Composite Materials Preparation

Used industrial pure aluminum as the matrix of composites, metallic chromium powder (average particle size of 75µm) as reinforcing material. Wrapped Cr powder in aluminum foil firstly, pretreatment at 250°C for 2h in SX-6-13-type box-type laboratory furnace, used to enhance the activity of Cr powder. Put the pure industrial aluminum into SQ2-4-13 type resistance furnace crucible when heated to 720°C. Then overheated the molten aluminum to 915°C, added the pretreated Cr powder; Put the probe of the KJ-1000 type ultrasonic treatment instrument into the molten aluminum, cooling water, open circulating cooling water and sonication instrument. The experimental parameters: frequency ultrasonic vibrations was 20KHz, power was 1KW. Ultrasonic vibration was completed after 10min, casting immediately.
Properties Test Experiments

Used D8-ADVANCE type X-ray diffraction to qualitative analysis phase of Al-Cr/Al composites; Used JSM-6360LA type scanning electron microscope to observed size, shape and distribution of reinforcement phase of the composites; Processed the composite material into rectangular of 7×7×70mm by cutting machine, and polished surface of the specimen by sandpaper smoothly. Mounted the specimen on SHIMADZU SFL-250KNAG type universal testing machine for three-point bending test, the span L is 50mm, head downward movement speed of 1mm/min. Measured the bending strength $\delta_{bb}$ composites, and observed fracture morphology.

Results and Discuss

Phase Analysis

Fig.1 shows the XRD pattern of Al-Cr/Al composites which were fabricated at 915\(\square\). At this temperature, Al and Cr generated inter-metallic compound of $\text{Al}_{0.983}\text{Cr}_{0.017}$, $\text{Al}_5\text{Cr}$, $\varepsilon$-$\text{Al}_3\text{Cr}_5$, $\eta$-$\text{AlCr}_2$, etc. These compounds constitute reinforcement phase of composite together. And a small amount of Cr dissolved in the Al matrix.

![Figure 1. XRD patterns of the composites.](image)

Microstructure

Fig.2 shows microstructure of Al-Cr/Al composite with different Cr content. The reinforcing particles, which were synthesized by in situ reaction of Al and Cr, appear irregular polygonal shape, smaller particles diameter, distributed in the matrix uniformly. And the enhance particles and the matrix get good bond, clean interface, non-pollution. The reason is ultrasonic would bring in cavitation bubbles when it effect in aluminum - chromium melt. These cavitation bubbles could produce instant high temperatures up to 104K and 105MPa high pressure when they collapsed [9,10]. The instantaneous high temperatures promote the compounds generated, instantaneous high pressure could crush the nascent compound grains and grains are grown, the crushed grain has become the new nucleation sites, which greatly increases the nucleation of the melt, so the grain composites has been refined.
**Bending Properties**

Fig. 3 shows the bending strength $\sigma_{bb}$ of the composites with different chromium content. As could be seen, with increasing Cr content, the flexural strength of the composite declined. This is because, Al and Cr generate inter-metallic compound at high temperatures, wherein $\varepsilon_1$-Al$_8$Cr$_5$ has a complex cubic structure, $\varepsilon_2$-Al$_8$Cr$_5$ has rhombohedral structure, $\eta$-AlCr$_2$ has body-centered cubic structure, these compounds are mutual diffusion form uniform mixing reinforcement, evenly distributed in the composites. However, it is easy to form stress concentration at the interface. Inter-metallic compounds grain is not easy to slip under external load force, reinforcing particles and the matrix is easy to suddenly fall off, so, composites have a greater brittle, making the composite bending strength $\sigma_{bb}$ reduced[11-13].

![Figure 3. The bending strength $\sigma_{bb}$ of the composite with different Cr content.](image)
Fig. 4 shows bending fracture morphology of the composites and its enlargement. In the figure, "bright and dark field" distinction is clear, and fracture morphology is uneven. The height of the "bright field" are very sharp, was lacerated, apparently under an applied load undergo plastic deformation, fracture after being stretched; the lower the "dark field", could clearly be seen as a reinforcement of traces, relatively smooth surface, below brittle fracture, almost no plastic deformation. In the junction of "light and dark field" is mostly sugar-shaped fracture, is brittle fracture mostly. Fracture morphology of figure 4a is bump ups and downs, lacerated more, less sugar-like, indicating that the composite showed plastic. Cr content is lower at this time, the Al-Cr inter-metallic compound brought brittle is not enough to change the overall nature of the material. Fracture morphology of figure 4b is flat relatively, more sugar-like. More Cr content made the composite materials brittle fracture, bending strength also fell badly at this time. Figure 4c apparent the traces of reinforcing particles stripped from the matrix, the bending strength of the composite material is greatly reduced. The reason is a larger Al-Cr inter-metallic compound fragmented the continuity of the matrix severely, so, the brittle composite material increases.

Conclusions

(1) Al-Cr/Al composites were successful fabricated by ultrasonic vibration assisted. The enhance particles, appear irregular polygonal shape, smaller particles diameter, distributed in the matrix uniformly. And the enhance particles and the matrix get good bond, clean interface, non-pollution.
(2) The bending strength $\sigma_{bb}$ of the composites declined as increasing Cr content. It was easy to form stress concentration at the interface. Inter-metallic compounds grain was not easy to slip under external load force, reinforcing particles and the matrix was easy to suddenly fall off, so, composites have a greater brittle.

Acknowledgements

This work was financially supported by Chengdu Aeronautic Polytechnic Science Foundation (061623Y,161613,2015-1); Department of Education of Sichuan Province(17ZB0037).

References

[1] X.Q. Zhou, D.Y. Yu, X.Y. Shao: Composite Structures, 154(2016)10:616.
[2] J.A.K. Gladston, N.M. Sheriff, I. Dinaharan: Trans. Nonferrous Met. Soc., 25(2015):683.
[3] S.M. Hao, J.P. Xie and A.Q. Wang: Trans. Nonferrous Met. Soc., (2014)8:2467-2473.
[4] H.M. Wang, G.R. Li, Y.T. Zhao: Materials Science and Engineering A, 527(2010)12:2881.
[5] H.P. Li, J.W. Fan and J.L. Kang: Trans. Nonferrous Met. Soc., 24(2014)7:2331.
[6] F. Chen, T.M. Wang and Z.N. Chen: Trans. Nonferrous Met. Soc., (2015)1:103.
[7] Q.L. Wang, J.B. Zhu, R.T. Xu: Journal of Aeronautical Materials, 36(2016)2:21. (In Chinese)
[8] J. Zhang, Q.L. Wang and Y.Hu: Foundry Technology, 33(2012)7:759. (In Chinese)
[9] L.Z. Zhao, Y. Jiao, Q.L. Wang: Functional Materials, 45 (2014) 08:08042.(In Chinese)
[10] A. Puskar: The use of high-intensity ultrasonic (Elsevier, Amsterdam 1982).
[11] M. Zhang, C.J. Chen and Q.M. Chang: Rare Metal Materials and Engineering, 38(2009)z3:119.
[12] T. Zhang, M.J. Fu and X.Q. Han: Journal of Materials Engineering, 43(2015)7:68. (In Chinese)
[13] Y. Zhong and H.B Zhou: Journal of Functional Materials, 45(2014)z2:59. (In Chinese)