ULTRASONIC VIBRATION LIQUID CAST SiC_W / Al AND SiC_P / Al COMPOSITES [1]

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ABSTRACT

SiC_W / Al and SiC_P / Al composites have been produced by an ultrasonic vibration casting technique. Ultrasound irradiation promoted the wetting of reinforcements in aluminum liquid, improved the reinforcement distribution in the metal matrix, and reduced porosity. The composites can be remelted. Initial studies of the preparation procedures, microstructure, fracture surface morphology and remelting properties of SiC_W / Al and SiC_P / Al composites fabricated by ultrasonic vibration liquid are presented in this work.

Key Words: Ultrasonic vibration liquid casting SiC_W / Al SiC_P / Al

1 INTRODUCTION

Discontinously reinforced aluminum matrix composites possess special characteristics including high specific modulus and strength, good high temperature properties, good wear resistance, and modifiable thermal expansion coefficients and they can be obtained by using conventional fabrication techniques. Various techniques such as powder metallurgy, squeeze casting, compocasting, liquid casting and spray deposition have been developed, but most of them have not been employed in industry because of their high cost. Liquid casting produces ingot by uniform mixing and casting of the aluminum melt which is directly added with dispersoids during melting.

There have been many papers about liquid cast particle reinforced aluminum matrix composites[1-3], but little work about the preparation SiC_W / Al composites has been reported, because the very fine SiC whiskers are difficult to wet and blend into aluminum liquid. Using ultrasonic irradiation during casting can improve the distribution and reduce porosity. In an earlier work, Rohatgi[1] reported that ultrasonic vibration can improve wetting of reinforcement and matrix but didn't give details. Recently, there appeared a paper[4] about the application of ultrasound in casting. As an initial study, this work paid attention to the preparation procedure, microstructure, fracture surface morphology and remeltability.

2 EXPERIMENTAL

2024Al, LF11(Al, 4.8 ~ 5.5 wt.-% Mg, 0.3 ~ 0.6 wt.-% Mn, 0.02 ~ 0.1 wt.-% Ti) and Al-6 wt.-% Si aluminum alloys were employed as matrix materials reinforced with α-SiC particles(average size of 10 μm) or TW-200 β-SiC whiskers(from Japan). A 1 kW ultrasound device with modifiable resonance frequencies was used as the ultrasound source.

The aluminum alloy was molten in a crucible and degassed. Then pre-treated SiC whiskers or SiC particles were added in and mixed for some time . The molten mixture was casted

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into ingots after ultrasonic stirring. Slicing slab were prepared for an optical microscope and TEM; SEM was used to examine the microstructure and fracture surfaces. A differential thermal analytical device and optical microscope were used to evaluate the composite properties.

3 RESULTS AND DISCUSSIONS

The energy wave is focused by an amplitude modulation shaft and travels with moduated amplitude to form strong ultrasound vibrations. "Hollow bubble" caused by the high pressure of ultrasound can fully agitate dispersoids and aluminum liquid to clean the surface of dispersoids by crushing the oxide film to improve wettability. It is well known that fine SiC whiskers or particle are difficult to mingle into aluminum liquid because of their poor wettability. Although strong stirring is used, dispersoids will float on the surface of aluminum liquid when stirring is suspended. Some complicated techniques such as squeeze casting and compocasting were developed to cast composite materials, even coating reinforcement surfaces pre-heat treatment have been used to improve wettability. However, the amount of dispersoids which can be added is limited by using these techniques. Using ultrasonic vibrations during squeeze casting can greatly improve the wetting of SiC and Al liquid. The added amount may exceed 20% volume fraction. SiC reinforcement can be uniformly distributed by ultrasounic stirring(Fig. 1).

Fig.1(a)and 1(b) are optical micrographs of the as-cast 7vol.-%SiC_p / 2024Al and 15vol.-%SiC_p / 2024Al composites.Fig.1(c) gives an optical micrograph of 20vol.-%-SiC_p / 2024Al composite(P / M) for comparision. Fig.2 gives optical micrographs of 10vol.-%SiC_p / Al-Si and 20vol.-%SiC_p / -LF11 cast composites. It is obvious that reinforcements were well distributed when the composites were obtained by ultrasound vibration liquid casting(UVLC). But SiC particles in composites with lower volume fractions tend to segregate along grain boundaries because of the pushing of the solidification frontage. The distributions are more uniform with increasing SiC_p content, which may be the reason that the increasing number of SiC particles distributed uniformly in Al melt by ultrasound vibration offered more nucleating sites to produce smaller grains. Although the reinforcements in P / M composites are well distributed, the uniformity is restricted by the size of the Al alloy powders.

At present, national rapidly solidified Al alloy powders are sized between 50～100 μm,

(a) × 170 (b) × 170 (c) × 340

Fig. 1 Optical graphs of UVLC SiC_p / 2024Al composites

(a)—7vol.-%SiC_p / 2024Al; (b)—15vol%SiC_p / 2024Al; (c)—P / M 20vol.-%SiC / 2024Al

(a) × 800 (b) × 200

Fig. 2 Optical graphs of UVLC composites

(a)—SiC_P / Al–Si; (b)—SiC_P / LF11

Fig. 3 Optical micrograph of UVLC SiC_W / Al composite (× 900)

and the average size of reinforcement free zones in P / M 20vol.–%SiC_P / Al is about 20 μm(Fig.1), while that of UVLC 15vol.–%-SiC_P / Al composite is about 35 μm. So it is possible to obtain desired reinforcement distribution by using this new technique. Fig.3 is an optical graph of UVLC SiC_W / Al showing whisker with a high aspect radio and suitable dispersion.The interfaces showing good combination between particles and matrix are clear(Fig. 3 and 4).

Compared with compocasting which brings gasses into the metal melt by strong stirring, the UVLC process provided dense SiC_P / Al composites and strongly impeded the formation of hollow microballoons during casting. In this work, ultrasonic irradiation, mechanical stirring and degassing treatment were employed to avoid bringing in gas and promote the removal of gas absorbed by aluminum alloy to obtain dense cast composites.

Fig. 4 TEM of UVLC SiC_p / 2024Al composite (× 90,000)

Fig. 5 is the fracture morphology of cast SiC_p / 2024Al composite. Although it is rather flat in low resolution, the fracture surface consists of the dimple teraring ridge and second crack, and micropores can be observed(Fig. 5).

Reinforcements in UVLC composites still had suitable distribution after remelting (Fig.6).

According to Eq.(1), aluminum liquid

Fig. 5 Fracture morphology of UVLC SiC_p / Al composite

may react with SiC to form Al_4C_3 which will diminish the strength and the chemical stability of composite.

$$4Al+3SiC \rightarrow Al_4C_3+3Si$$

Fig. 6 gives optical micrographs of UVLC composites of different matrices after remelting. SiC particles in SiC_p / Al–Cu–Mg composite with low Si content reacted with Al(Fig. 6 (a)). However, there no obvious reaction in SiC_p / Al–Si composite with higher Si content. A differential thermal analytical technique was also used to evaluate the remelting properties. It is possible to determine the reaction intensity by measuring changes in the melting point of the composite. According to Eq.(1), the reaction between SiC_p and Al results in the formation of the element Si which decreases the melting point of Al alloy from the view of the Al–Si phase diagram. In this work, the melting point of UVLC SiC_p / 2024Al composite was 637℃ , and it decreased to 624℃ after remelting, so there was little Si formed. It was reported by Lloyd[6] that the melting point of squeeze cast SiC_p / 6061Al decreased from 633℃ to 577℃ after 1 h of remelt treatment at 900℃ . So, it should be concluded that UVLC composites can be remelted well with suitable SiC_p distribution and no obvious reaction.

Fig. 6 Micrographs of UVLC composites after remelting (× 400)

(a)—SiC_p Al–Cu–Mg; (b)—SiC_p Al–Si(× 400)

4 CONCLUSIONS

(1)SiC_W / Al, SiC_P / Al composites were obtained successfully by using ultrasound vibration liquid casting technique;

(2)Using ultrasonic vibrations can improve the wettability and distribution of SiC reinforcement in Al matrix and reduce porosity;

(3)UVLC composites possess good remeltability.

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chanical-chemical activity is minimal where the residual stress equals zero, but with the increase of residual stress, the mechanical-chemical activity becomes greater.

Because the change in the residual stress of H68A tubes(corroded seriously in seawater) was great across the depth profile, the cracks of the tubes propagated in the following ways.

(1) In a region of large residual stress, the fracture of metals between tunnels was liable to happen due to the great mechanical-chemical activity, so that cracks went through the region quickly producing a sharp morphology;

(2) In a region of small residual stress, since the mechanical-chemical activity was low, cracks propagated slowly by crevice corrosion. In addition, dissolved copper ions obtained electrons for reduction due to the low concentrations of oxygen and hydrogen ions in the cracks. This led to the deposition of red corrosion products. Therefore the cracks developed a dull morphology;

(3) In the regions where the residual stress changed at great speed, cracks arose with both sharp and dull morphologies;

The part near the top of the crack was protected by the anodic current of the top, but the protective effect decreased as the distance from the top of the crack increased. Therefore the region near the top of crack retained its original corrosion morphology while the open part of the crack, as an anode, became wide by dissolution. This is the reason for the unique morphology of H68A tubes which corroded seriously in seawater.

H68A tubes experiencing slight corrosion in seawater had residual stress similar to sample №. 2. It is necessary to mention that annealed H68A planes immersed in seawater for 4 years had a low corrosion rate 10μm / y and the maximum depth of local corrosion was less than 0.35 mm, which shows that the H68A alloy has good corrosion resistance in quiet seawater.

5 CONCLUSION

(1) Sample №. 1 had large residual stress and great change in the residual stress through the wall of tube, while the residual stress of sample №. 2 is small and remainss steady through the wall;

(2) The great residual stress in the depth profile of the wall results in stress-corrosion cracking of H68A brass tubes;

(3) The unique morphology of cracks in H68A tubes results from the uneven distribution of residual stress in the depth profile. The cracks are sharp in region of large residual stress. In contrast, the morphology of the cracks in regions of small residual stress is dull.

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