Analysis of the Relationship Between the Interface Structure and the Strength of Carbon-Aluminum Composites

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Abstract: Analysis of the relationship between the interface structure and the strength of carbon – aluminum has been studied. Al_4C_3 phase was formed at the fiber-matrix interface when the copper content in the matrix is low whereas Al_4C_3 and $CuAl_2$ phases were resulted at the fiber-matrix interface, as the copper content is high in the matrix. Two phases promote too strong bonding in the composites. The tensile strength would deteriorate with too strong interfacial bonding.

Keywords: carbon, aluminum, interface, strength, rod-phase, lumped phase

1. Introduction

Carbon reinforced aluminum (C-AL) composites have found wide uses for the structural designs in the aeronautic applications. The preference of C-Al composites is the attractive combination of properties: light weight, high strength, and manufacture possibilities [1]. The carbon has a very low surface energy; therefore it is difficult to be wetted by the molten aluminum. A successful coating Ti-B was suggested [2]. The interfacial reaction between the fiber and the matrix is a very important factor affecting the strength of C-Al composites. The chemical composition of matrix influences the mechanical properties. Al-alloy matrix reacts thermodynamically with fibers at its melting point [3]. The reaction product is Al_4C_3.

The objective of this paper is to develop the relationship between the interface structure and the mechanical property (i.e; tensile strength) of the C-Al composites.

2. Experimental Procedure

Two commercial Al-alloys (chemical compositions are given in the Table-1) were used for the matrix. Carbon fiber blends of 3000 filaments were employed as the reinforcing fibers. The C-Al composite wires were manufactured by the infiltration (Ti-B) method.

Table-1: Chemical composition of the matrix

Alloy	%Cu	%Si	%Mg	%Mn
$Alloy_1$	0.40	1.00	0.60	0.25
$Alloy_2$	4.20	1.20	0.60	0.60

Transmission electron microscopy (TEM) specimens were taken along the longitudinal axis of the composite wires [4]. The specimens were thinned to 25μm and then milled to perforation. The tensile test was carried out for the analysis of the strengths of composites [5, 6]. Scanning electron microscopy (SEM) was employed for the fracture analysis of the composite specimens.

3. Results and Discussion

The average observation over three samples of the same type was followed for each test procedure.

3.1 *TEM analysis of composites*

TEM micrographs of C-Al composites are shown in Fig.1. In the Carbon- $Alloy_1$ composites, a rod shaped phase is noticed at the fiber matrix interface. The rods were probably growing individually from the carbon fibers into the Al-alloy matrix. The fiber – matrix interface reaction product is Al_4C_3. TEM analysis reveals that each Al_4C_3 rod is a single crystal and its [001] orientation is normal to the longitudinal axis of the rod. The advanced angle of the Al_4C_3 rod during growing in the matrix is randomly oriented as there is no definite crystallographic orientation relationship between the Al_4C_3 rod and the matrix. In the Carbon-$Alloy_2$ composites, a lump shaped phase is observed at the fiber matrix interface. The fiber – matrix interface reaction products are Al_4C_3 and $CuAl_2$. TEM analysis identifies that $CuAl_2$ has a body centered tetragonal (BCT) crystal structure. The $CuAl_2$ phase might be either solidified from the melt by a eutectic reaction due to rapid cooling or precipitated from the Al alloy solid solution.

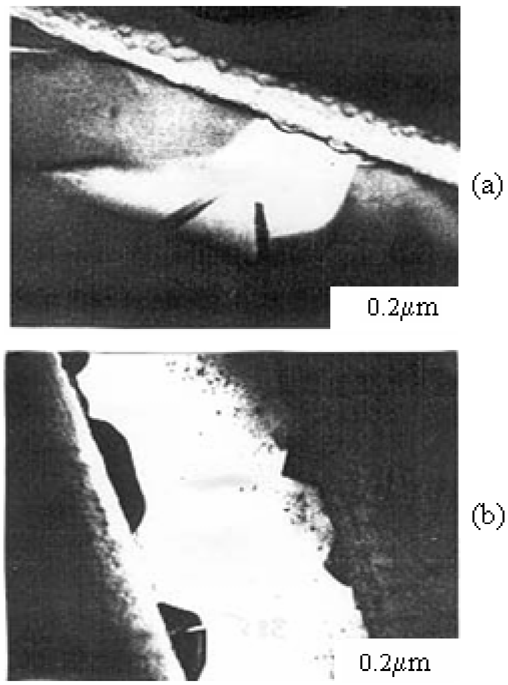

Fig.1 TEM micrographs of (a) Carbon-Alloy$_1$ and (b) Carbon-Alloy$_2$ composites

3.2 *Strength of composites*

Tensile test results of Carbon-Alooy$_1$ and Carbon-Alloy$_2$ are respectively 552.4 and 368.6 MPa. The tensile strength of Carbon- Alloy$_1$ composite is greater than that of Carbon-Alloy$_2$ composite. This is owing to larger amount of Cu content in the matrix of Carbon- Alloy$_2$ composite. The fracture morphologies of the tensile tested specimens as shown in Fig.2 justify this phenomena. The fracture surface of the carbon-Alloy$_2$ composites is characterized by the flat surface, which reflects the strong interfacial bonding. The fracture surface of the Carbon-Alloy$_1$ is distinguished by the pullout surface that is symptom of less strong interfacial bonding.

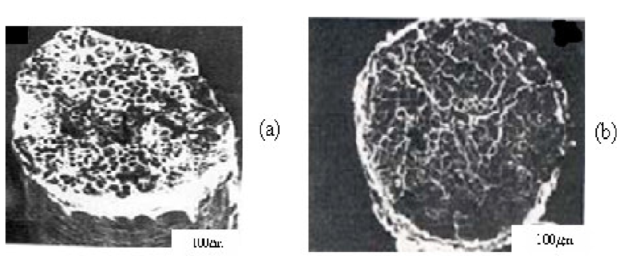

Fig.2 SEM micrographs of the fractured surfaces of tensile specimens (a) Carbon-Alloy$_1$ and (b) Crabon-Alloy$_2$

3.3 *Interface structure and strength relationship*

The results in this study show that the fall of tensile strength by copper addition is related to the increasing of the interfacial bonding between the fibers and the matrix and the type of interfacial phase formation and its orientation. The Al_4C_3 phase was nucleated from the carbon fiber and advanced into the alloy matrix of Carbon-Alloy$_1$ composite. This would result chemically interacting and mechanically interlocking bonds. These adhesive and cohesive bonds provide strong fiber – matrix interface bonding. In the case of Carbon-Alloy$_2$ composite, both Al_4C_3 and $CuAl_2$ phases were formed. Thus the addition of copper enhances the interface bonding qualitatively and quantitatively. The result is very strong interface bonding between the fibers and the matrix. The very strong interface bonding in Carbon-Alloy$_2$ composites governs the flat fracture surface. Therefore, the decreased tensile strength is in Carbon-Alloy$_2$ composites. The fractured surface in the Carbo-Alloy$_1$ composites is pulled out and subsequently the consequence is the increased tensile strength.

4. Conclusions

The rod – shaped Al_4C_3 phase was formed at the fiber – matrix interface in the carbon-aluminum composites. With increased content of copper in the matrix, two phases Al_4C_3 and $CuAl_2$ were resulted at the fiber – matrix interface. If the interface is too strong the tensile strength is too less.

5. References

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