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Different Metals Joining Method Reinforced by Carbon Fiber

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ABSTRACT

Airplanes and racing cars are dream worthy power-driven machineries. Al has been a light structural metal to save their energy. Since Cu exhibits the spark free as well as thermal conductivity and heat sink, it has been often utilized for spark free wheel for oil in the pipe of tanker. In addition, titanium and aluminum, which are used for the seat side and aluminum use for the body frame in airplanes, exhibit the high resistance to corrosion with light weight. When the Al/Cu and Al/Ti joining with high strength can be developed, the high reliability, which corresponds to safety for airplanes and racing cars, can be expected. In order to enhance the joining strength, a new joining method reinforced by carbon fiber has been suggested. The joint reinforced by Ni-coated carbon fiber exhibits the high tensile strength, which was higher than that with conventional adhesion.

1. INTRODUCTION

Airplanes and racing cars are dream worthy power-driven machineries. Aluminum (Al) already applied for engine parts, has been a light structural metal to save their energy. On the other hand, copper (Cu) exhibited the spark free as well as thermal conductivity and heat sink and then was often utilized for spark free wheel for oil in the pipe of tanker. Thus, the Cu-Al welded joint was expected to be applied to fill opening edges of fuel system to be safety without spark of a Formula racing car, which is dream worthy mover machines. However, the welding part mostly exhibits the brittleness. In addition, joint of titanium (Ti) and Al is expected to save the weight of an airplane. Elements of Ti and Al, which are used for the seat side and Al use for the body frame, exhibit the high resistance to corrosion with light weight, as well as specific proof stress. The joint is currently required in a frame lounge under the seat of A380 type airplane.

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On the other hand, strengthening of fiber-reinforced metals has been studied [1]. When the Al/Cu and Al/Ti joining with high strength can be developed, the high reliability, which corresponds to safety for airplanes and racing cars, can be expected. The purpose of the present work is to evaluate the effects of the carbon fiber reinforced Ti/Al and Cu/Al joints on the tensile strength.

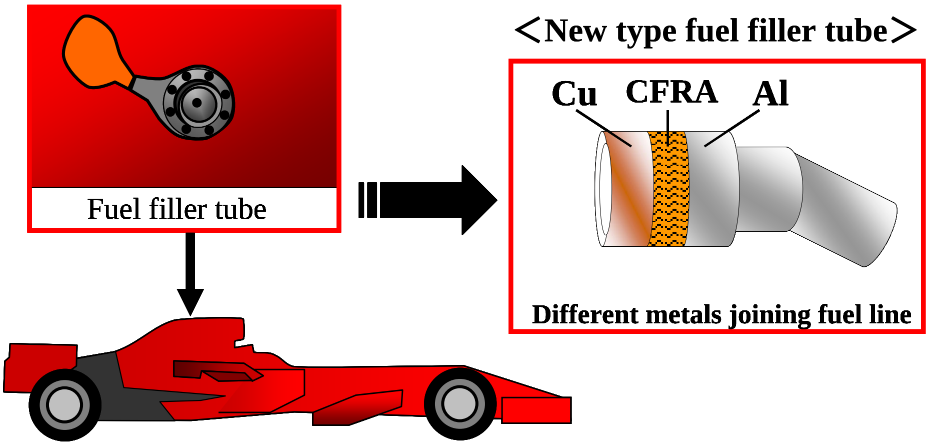

Fig. 1 Schematic diagram of Al/Cu joint new type engines parts.

2. EXPERIMENTAL

2.1 Preparation of Ni coated carbon fiber

By using a nickel (Ni) coated carbon fiber, both Cu/Al and Ti/Al joint samples with carbon fiber reinforced joint were developed. Fig. 2 shows DC magnetron sputtering process. The leak rate, residual gas pressure, argon gas sputtering pressure, sputtering potential and deposition rate were from 8 × 10-6 to 1 × 10-4 Pa･ m3/s, below 1.0×10^{-3} Pa, 5.0×10^{-1} Pa, 200 V and 2 µm/h, respectively. The Ni films were coated by DC-magnetron spattering device, as shown in Fig. 4. The carbon fiber surface was covered with the nickel film. [2-3]

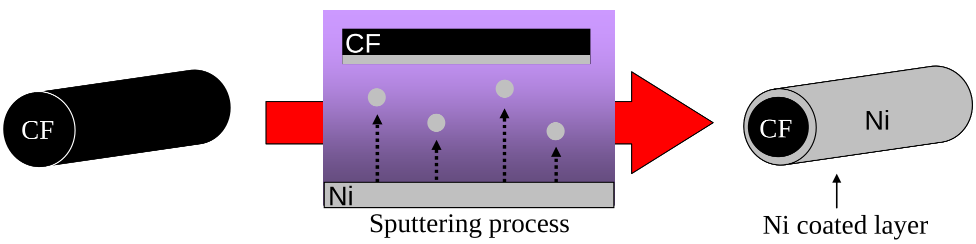

Fig. 2 Schematic drawing of Ni-coating on carbon fiber with DC-magnetron sputtering apparatus.

2.2 Preparation of joint of Cu/Al

The making Ti coated carbon fiber joint part is pre-process before the first step. The first step of the welding method was that the fiber was contacted and soaked up by capillary action with molten Ti, which was melted by electron beam irradiation with high potential at one side of the carbon fiber bundle (see Fig. 3). The second step of the welding method was that the Ti coated carbon fiber junction was contacted and wrapped with molten Cu, which was solidified under gravity and pressure. The third step was that the aluminum junction fiber was contacted and wrapped with a molten aluminum, which was solidified under gravity pressure. The carbon fiber junction was a fiber-reinforced alloy and probably acted as one of ideal joint parts of Cu/Al.

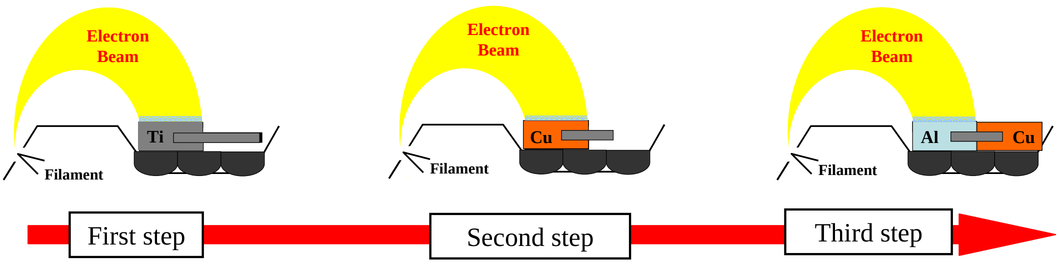

Fig. 3 Schematic diagram of preparation of Cu/Al junction with carbon fiber.

2.3 Preparation of joint of Ti/Al

As shown in Fig. 4, the first step of the welding method was that the fiber was contacted and wrapped with molten Ti, which was solidified under gravity and pressure. The second step was that the Al welded fiber was contacted and wrapped with a molten Al, which was solidified under gravity pressure. The carbon fiber junction device was a fiber-reinforced alloy and probably acted as one of ideal joint parts of Ti/Al.

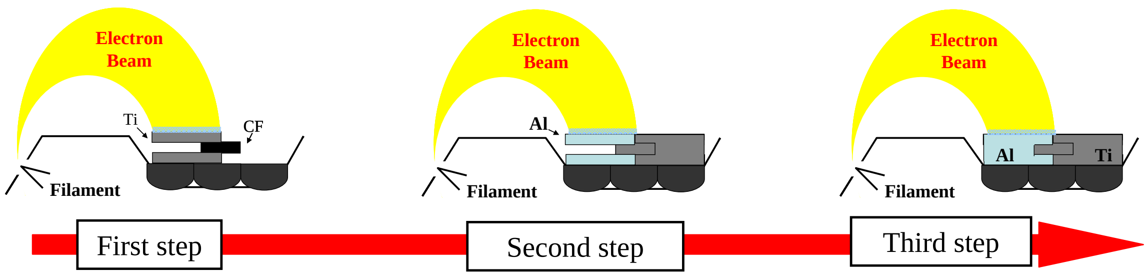

Fig. 4 Schematic diagram of preparation of Ti/Al junction with carbon fiber.

3. RESULTS AND DISCUSSION

3.1 Evaluation of strength at Cu/Al joint sample with CFRI

Fig. 5 shows schematic diagram of joint sample of Cu/Al with carbon fiber. Fig. 6 shows stress-strain curves of Cu/Al junction with Ni coated carbon fiber bundle (CF-Cu/Al) and welding Cu/Al junction without carbon fiber. The CF-Cu/Al exhibits the high strength (15.2 MPa) which is higher than that of welding Cu/Al. The CF-Cu/Al also enhances the maximum hardening modulus and the tensile strength, as well as its strain.

Based on the micrograph in the CF-Cu/Al, [3] the holes after pullout of carbon fibers are simultaneously observed. Based on the EDS results of atoms distributions, the large amounts of atoms have not been migrated. By using Ni coating, the diffusion layer and carbides, which enhances the friction force to prevent the pullout of carbon fiber and also raises the resistant stress to cut the carbon fiber, cannot be observed. Since volume fractions of carbides and diffusion layer are too small, carbon fibers don't tremendously decay.

As shown in Fig. 6, the fracture occurs at Al part in the Cu / Al junction with carbon fiber bundle. However, the tensile strength of the Cu / Al junction with carbon fiber bundle is higher than that of the welding Cu / Al junction. When the joint sample is heated and solidified, the process reduces the grain size, resulting in tensile strength improvement. Strain of the CF-Cu/Al is higher than that of a Cu/Al, because the carbon fiber acts as a deformation resistance by fiber-reinforcement.

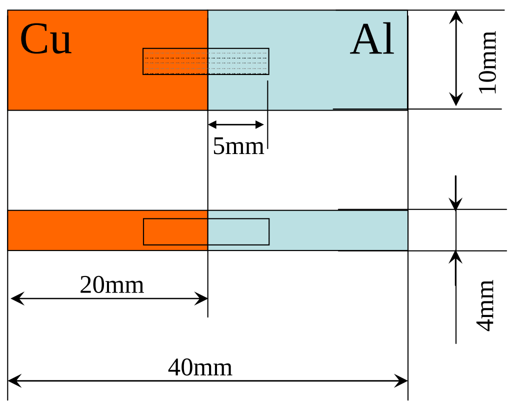

Fig. 5 Schematic diagram of joint sample of Cu/Al with carbon fiber.

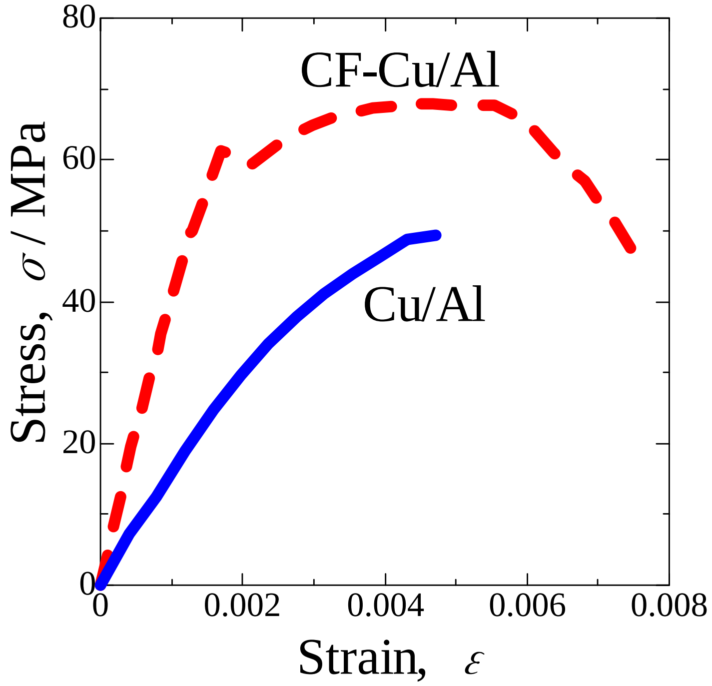

Fig. 6 Stress-strain curves of Cu/Al junctions with and without carbon fiber.

3.2 Evaluation of strength at Ti/Al joint sample with CFRI

Fig. 7 shows schematic diagram of joint sample of Ti/Al with carbon fiber. Fig. 8 shows photograph of fractured sample Ti/Al junction with Ni coated carbon fiber bundle (CF-Ti/Al). Ductile fracture of CF-Ti/Al is observed in aluminum rod.

Fig. 9 shows stress-strain curves of Ti/Al junction with Ni coated carbon fiber bundle (CF-Ti/Al) and welding Ti/Al junction without carbon fiber. The CF-Ti/Al decreases the tensile strength of the welding Ti/Al junction sample from 122 to 108. CF-Ti/Al enhances the strain (0.038) at tensile strength. Although it is lower than that (0.059) for pure Al sample, it is higher than that (0.023) for welding Ti/Al junction sample.

As shown in Fig.8, the fracture occurs at aluminum part in the joint Ti / Al sample with CFRI. Although the tensile strength (108 MPa) of the joint CF-Ti/Al is slightly smaller than those (122 MPa) of the welding Ti/Al junction without carbon fiber, the strain of the CF-Ti/Al is about two times higher than that of a Ti/Al.

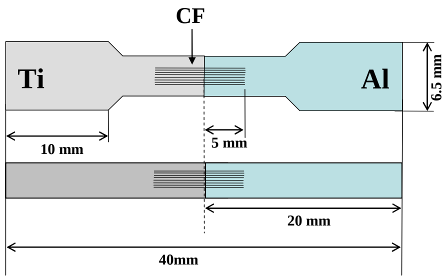

Fig. 7 Schematic diagram of joint sample of Ti/Al with carbon fiber.

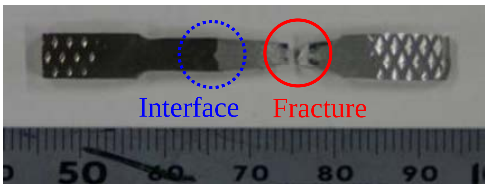

Fig. 8 Photograph of fractured sample of Ti/Al junctions with carbon fiber.

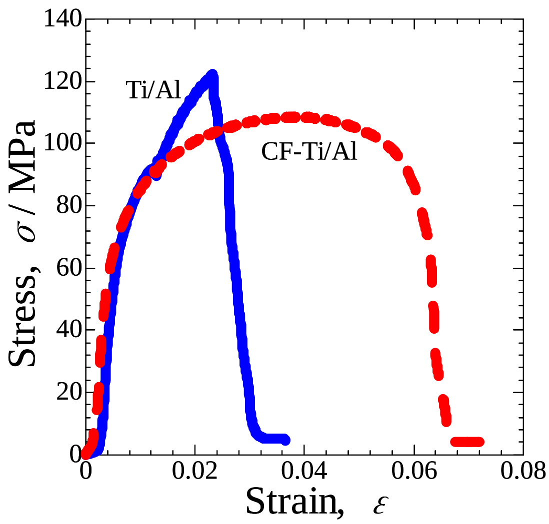

Fig. 9 Stress-strain curves of Ti/Al junctions with and without carbon fiber.

4. CONCLUSION

In order to prevent the fracture at joint interface, a joining method using impregnated nickel-coated carbon fiber was successfully developed in joining Cu and Al to improve the joint strength. Tensile properties of Cu/Al junction sample with Ni coated carbon fiber bundle (CF-Cu/Al) and welding Cu/Al junction sample were investigated. The CF-Cu/Al exhibited the high strength, which was higher than that of welding Cu/Al joint sample. The CF-Cu/Al also enhanced the maximum hardening modulus and the strain at tensile strength.

On the other hand, Ti/Al junction sample with Ni coated carbon fiber bundle (CF-Ti/Al) enhanced the strain (0.038) at tensile strength. Although it was lower than that (0.059) for pure Al sample, it was higher than that (0.023) for welding Ti/Al junction sample without carbon fiber.

Especially, by using Ni coated carbon fibers, the diffusion layer and carbides cannot be observed. Therefore, the carbon fiber joint reinforcement is the one of safety methods to join the structural materials.

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