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Polymer-Metal Joining Method with carbon fiber

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ABSTRACT

Titanium (Ti), aluminum (Al) and carbon fiber reinforced polymer (CFRP), which are typical light structural materials not only to save the energy, but also to enhance the mobility of aircraft, have been already utilized for dream worthy mover machines as well as airplanes. CFRP is recently applied to not only wing, but also fan blades of turbo fan engines. To prevent impact force, leading edge of titanium is often mounted on the CFRP fan blades by adhesive force. Although welding, blazing, rivet connecting and glue are popular joint methods, they mostly reduced the materials strength. In order to prevent the fracture at joint interface, a joining method using impregnated Nickel (Ni) -coated carbon fiber has been successfully developed in joining CFRP and CFRM to prevent damage for impact force such as bird strike. The CFRM/CFRP joint method using impregnated Ni-coated carbon fiber improved the mechanical properties.

1. INTRODUCTION

Carbon fiber reinforced polymer (CFRP), aluminum (Al) and titanium (Ti) are typical light structural materials with high strength to save their energy and to enhance the mobility of airplane. Ti and Al were often jointed to CFRP by adhesion or bolts and rivets. Bolts and rivets are useful joining method, although they often reduce the materials strength. The glue has been useful tool to joint the Al parts to CFRP, its strength is not enough. As shown in Fig.1, carbon fiber reinforced polymer (CFRP) with Ti sheath has been recently utilized for fan blades of turbo fan engines of airplane. To prevent the impact damage, the leading edge of Ti is often mounted on the CFRP fan blades by adhesive force. Al and CFRP are also utilized for airplane's wings. If the Ti/CFRP and Al/CFRP joining with high strength can be developed, the high reliability,

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which corresponds to safety for airplanes, can be expected. In order to prevent the fracture at joint interface between different materials, the joining method by using impregnated Ni-coated carbon fiber has been suggested. The purpose is to evaluate the effects of the joint method of Ti/CFRP and Al/CFRP by using impregnated Ni-coated carbon fiber on the mechanical properties.

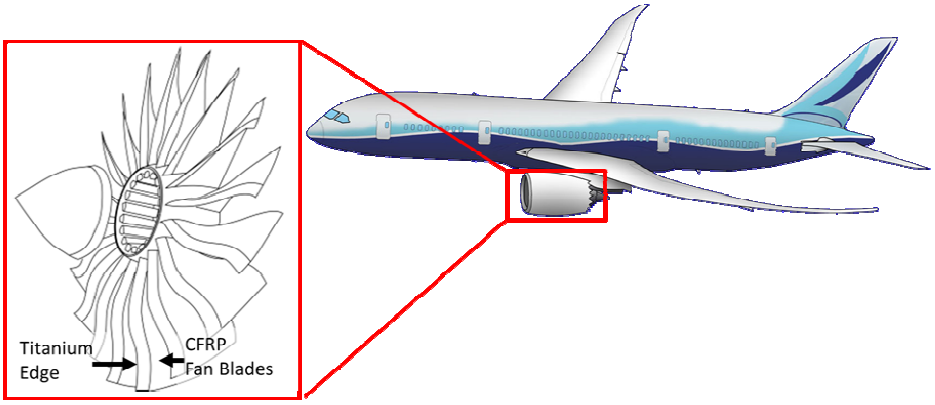

Fig.1 Application of carbon fiber reinforced polymer (CFRP) with Ti sheath has been recently utilized for fan blades of turbo fan engines of airplane.

2. EXPERIMENTAL

2.1 Preparation of Ni coated carbon fiber

By using a Ni coated carbon fiber, both Ti/CFRP and Al/CFRP joint samples with carbon fiber reinforced interface were developed. Fig.2 shows DC magnetron sputtering apparatus. The leak rate, residual gas pressure, argon gas sputtering pressure, sputtering potential and deposition rate were from 6.0×10^{-6} to 8.0×10^{-4} Pa・m^3/s, below 1.0×10^{-3} Pa, 5.0×10^{-1} Pa, 100 W and 2 μm/h, respectively.

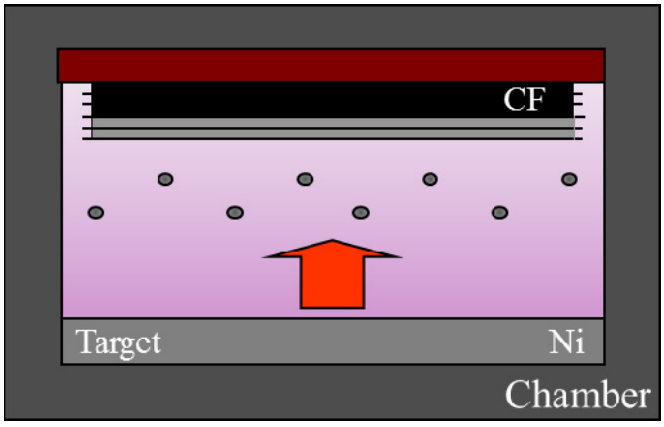

Fig. 2 Schematic diagram of Ni-coating on carbon fiber with DC-magnetron sputtering apparatus.

2.2 Preparation of joint sample of CFRP/CFRM with CFRI

A carbon fiber reinforced interface (CFRI) has been successfully developed to joint the carbon fiber reinforced metal (CFRM) of Ti and Al to the CFRP. The first step of the welding method was that the fiber was contacted and soaked up by capillary action with molten Al and Ti , which were melted by electron beam irradiation with high potential, at one side of the carbon fiber bundle (see Fig.3). After solidification, the second step was that another side of the bundle was dipped in the polymer resin, as shown in Fig.4.

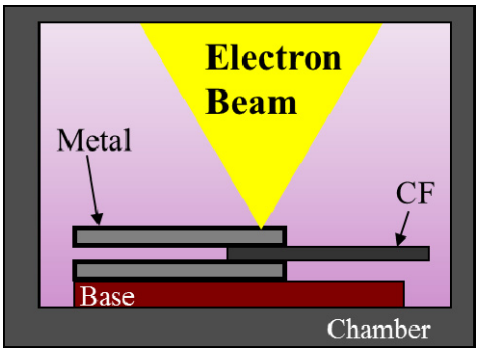

Fig. 3 Schematic diagram of joining process between CF and molten metal.

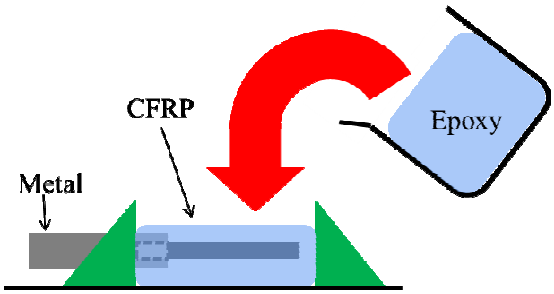

Fig. 4 Schematic diagram of joining process between CFRP.

3. RESULTS AND DISCUSSION

3.1 Evaluation of Al/CFRP

Fig.5 shows tensile stress-strain curves of joint samples of Al/CFRP and Al/Glue/Epoxy. The strength of the Al/CFRP (33.4MPa) is 7.8 times higher than that of Al/Glue/Epoxy (4.3MPa). Fig.6 shows changes in Charpy impact value of the joint samples with Al/CFRP and Al/Glue/Epoxy against fracture probability (P_f). The impact value of the Al/CFRP (14.8kJ/m^2) is 11.4 times higher than that of Al/Glue/CFRP (1.30kJ/m^2) at mid P_f of 0.5.

3.2 Evaluation of Ti/CFRP

Fig.7 shows tensile stress-strain curves of joint samples of Ti/CFRP and Ti/Glue/Epoxy. The strength of the Ti/CFRP (11.4MPa) is 7.8 times higher than that of Ti/Glue/Epoxy (1.86MPa). Fig.8 shows changes in Charpy impact value of the joint

samples with Ti/CFRP, Ti/Epoxy and Ti/Glue/Epoxy against fracture probability (P_f). The impact value of the Ti/CFRP (2.68kJ/m^2) is 1.6 times higher than that of Ti/Glue/CFRP (1.66kJ/m^2) at mid P_f of 0.5.

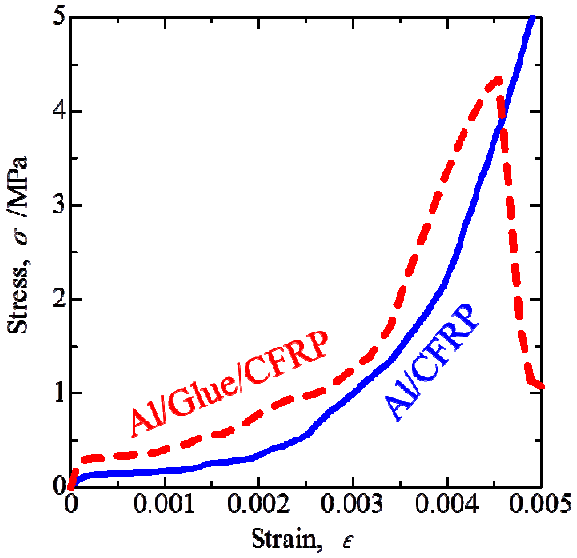

Fig. 5 Stress-strain curve of Al/CFRP with and without carbon fiber.

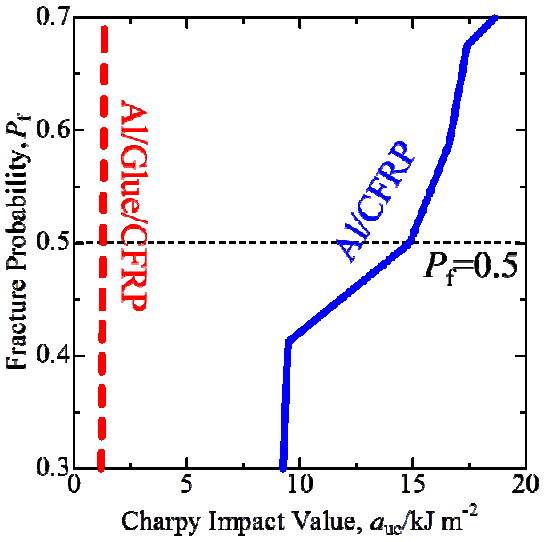

Fig. 6 Changes in Charpy impact value of Al/CFRP with and without carbon fibe against probability.

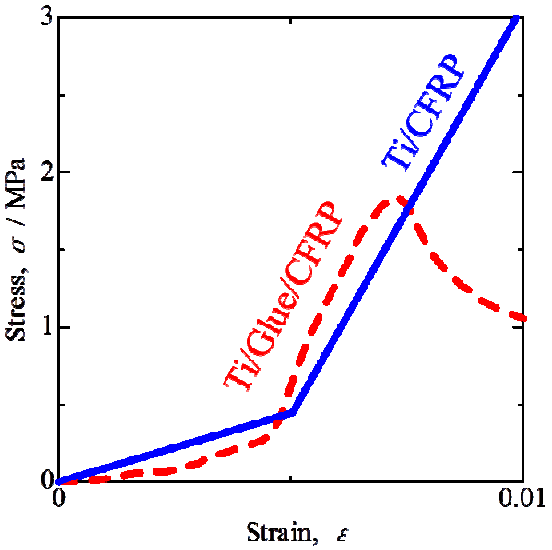

Fig. 7 Stress-strain curve of e Ti/CFRP with and without carbon fiber.

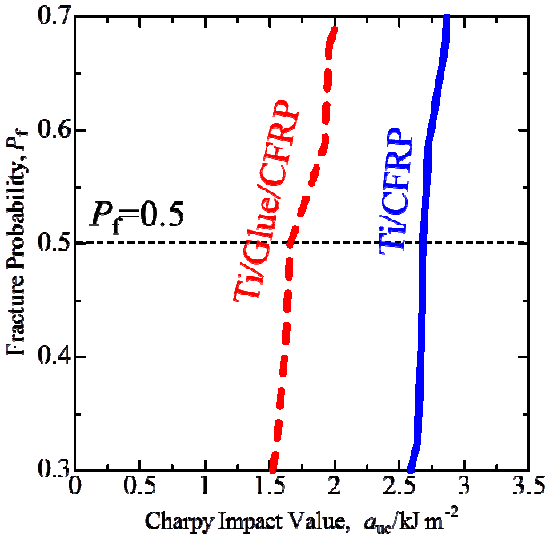

Fig. 8 Changes in Charpy impact value of Al/CFRP with and without carbon fiber. against probability.

3.3 Effect of carbon fiber on joining reinforcement

When the joint samples with CFRI are fractured by tensile and impact test, the fractured crack propagation should break the carbon fiber in the samples. As a result, the joint with carbon fiber enhances the tensile strength and impact value of Ti /CFRP and Al/CFRP.

4. CONCLUSION

In order to prevent the fracture at joint interface, a joining method using impregnated Ni-coated carbon fiber has been successfully developed in joining CFRP and CFRM. The carbon fiber reinforced interface probably acts as one of ideal joining methods to produce the safety structure materials of aircraft with an energy saving.

REFERENCES

N. Miwa, M. Hirano, K. Tanaka and Y. Nishi (2008), “Tensile Test of Joining Sample with Carbon Fiber-Reinforced Interface between CFRP and CFRM”, J. Japan Inst. Metals, Vol. **72**, 146-151.