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炭化ホウ素を用いた C/C コンポジットの溶接接合

Welded joint of C/C composites with boron carbide

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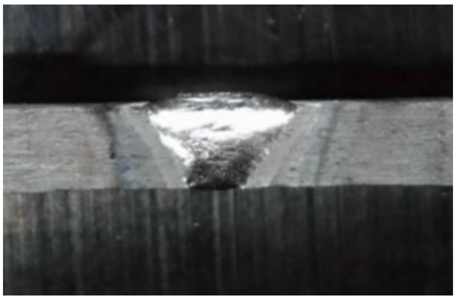
Abstract: In this study, arc welding of C/C composite test pieces using boron carbide as a filler material was performed to investigate the possibility of welding, and tensile strength was measured by tensile testing. In addition, changes in strength were investigated when B_2O_3 was mixed with the filler material. After welding, observation of the welded area confirmed that the boron carbide had descended, indicating that welding was possible. Furthermore, tensile testing revealed that the tensile strength of the specimens using boron carbide mixed with B_2O_3 had improved, and cross-sectional observation showed that boron carbide had melted into the central area. This is thought to be due to B_2O_3 decreasing the melting point of the filler.



1. Introduction

Carbon-based materials are used for crucibles in materials experiments conducted in microgravity environments in space, but these cannot be completely sealed. Therefore, they are triple-sealed using quartz glass, tantalum capsules, and other materials. If welding of carbon-based materials becomes possible, sealing will become simpler, which is expected to accelerate materials development.

Previous studies have focused on the decrease in melting point at the eutectic point of the B-C binary phase diagram and have performed arc welding. Using graphite as the base material and boron carbide as the filler, a maximum tensile strength of 12.13 [MPa] was achieved. In this study, the base material was changed from graphite to C/C composite material, and the possibility of welding and tensile strength were evaluated. The effect of B_2O_3-based flux was also investigated. C/C composite, made from carbon and carbon fiber, offers heat resistance and thermal conductivity comparable to graphite but with higher elastic modulus and strength, retaining these properties at high temperatures.

2. Methods

Experiments were conducted in an argon-filled glove box (Fig. 1). Two base materials were fixed parallel to each other in a jig, 0.1 [g] of granular B_4C was placed at the center, and arc discharge was performed above it.

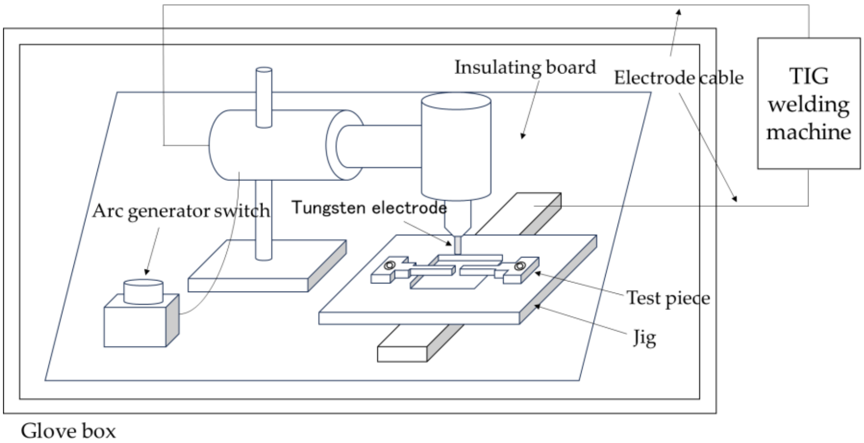


Figure 1. Schematic diagram of the glove box interior

An arc discharge was performed using a TIG welding machine (RILAND/TIG 200P) and φ1.6 YWCe-2 electrodes, with direct current and positive polarity. Tack welding was done at 70 [A], followed by turning over the piece, adding the same amount of B_4C, and full welding at 180 [A]. The piece was then turned over again for another 180 [A] arc discharge on the provisional weld. Using the same welding method, two types of test pieces were fabricated in addition to those using only boron carbide. First, a 0.025 [g] sample of B_4C and B_2O_3 (mass ratio 9:1) bonded with a semiconductor laser was placed between the pieces. Second, we used a test piece coated with boric acid–petroleum jelly flux on the surface and placed 0.010 [g] of boron carbide between the pieces. After preparing the test pieces, tensile strength was measured by tensile testing.

3. Result and Discussion

Figure 2 shows the welded area of a test piece. This shows that the filler descended to the bottom and welding was possible.

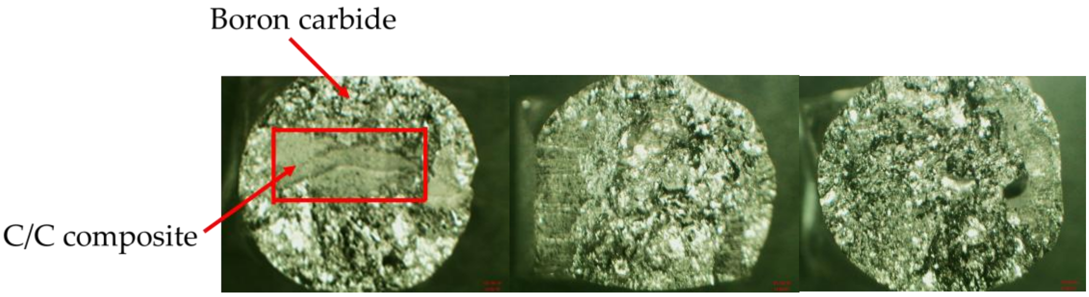
Figure 2. Welded area after welding

Table 1 shows tensile test results; graphite values are from previous work.

Table 1. Tensile test results

Filler	Mass ratio (B$_4$C:Additive)	Tensile strength [MPa]	
		C/C composite	Graphite
Pure B$_4$C	10:0	2.02	8.31
With B$_2$O$_3$	9:1	2.86	
	4:1(Flux)	10.20	
With Aluminum	12:1		12.14
	9:1		10.39
	7:1		9.423
	6:1		7.815
	3:1		5.024

C/C composite materials using a filler mixed with boron carbide and B_2O_3 exhibited higher tensile strength than those using pure B_4C. Figure 3 shows fracture cross sections.



(a) (b) (c)

Figure 3. Cross section of each test piece after fracture: (a) Pure B_4C ; (b) B_2O_3 acid added ; (c) Flux applied

Test piece (a) was welded using pure B_4C. Since there was no B_4C in the center and the base material was exposed, it is thought that the tensile strength decreased. In contrast, test piece (b), which B_2O_3 mixed into the filler, contained B_4C throughout the central area, resulting in higher strength. Test piece (c) was joined by applying flux. The melting point was decreased by the flux, and fine boron carbide particles were present in the center, which significantly improved the strength.

4. Conclusion

C/C composites could be joined by TIG welding using B_4C as a filler. The addition of B_2O_3 to B_4C resulted in higher tensile strength than that obtained using only boron carbide.

References

1) A Masahiko Iyoda: Encyclopedia of Carbon . Asakura Shoten(2007)

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