

# Joining of C/C composites and GH3128 Ni-based superalloy by Ni-Ti mixed powder as an interlayer

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## Introduction

C/C composites and GH3128 nickel-based high temperature alloys (GH3128 for short) are excellent high-performance materials. They have been widely used in the fields of aviation, aerospace, military and in other high-tech fields [1-4]. However, compared with high-temperature alloys, the strength of C/C composites is low at room temperature, and the preparation period is long and cost. When C/C composites are connected with nickel-based superalloys, not only the carrying capacity and life of the high temperature composite structures are enhanced, but the weight is reduced.

But it is very difficult to connect the two materials. This is because: (1) C/C composites and GH3128 is not wetting [5, 6] and (2) the thermal expansion coefficients of the two materials are quite different. For example, the thermal expansion coefficient of GH3128 is about 8.15-fold that of the two-dimensional C/C composites at 1000 °C [7, 8]. To solve this problem, a modified SiC coating was first prepared on the C/C composites surface by a pack cementation process in this work. Ni-Ti powder was then used as an interlayer to join successfully SiC coating modified C/C composites and GH3128 by a vacuum hot-pressing diffusion process. The mechanical properties and microstructure of the joint head between C/C composites and GH3128 were investigated.

## Experimental

The C/C composite samples used in this work were two-dimensional needle-pricked C/C composites that were developed in our own laboratory. The bulk density was 1.65 ~ 1.70 g/cm<sup>3</sup>. The GH3128 sample was provided by the Xi'an Aero-Engine Factory. The original sizes of the two connecting sample materials were 20 mm × 10 mm × 5 mm.

The purities of C powder and Si powder for SiC coating were 98.0 % and 99.8 %, respectively. The particle sizes were 75 μm and 48 μm. The purities of Ni and Ti were 99.8 % and 99.9 % in the middle layer. The particle sizes were 75 μm and 48 μm.

Prior to test, the samples to be used for connection were first polished with fine sandpaper. They were then cleaned in ethanol under ultrasonic vibration for several minutes, and finally dried in an oven for subsequent use. Ni, Ti, Si, and C powders were grinded in a mortar for 30 min, respectively, after weighing. They were dried in an oven for next use.

A SiC modified coating on the C/C composites sample surface was prepared in a ZGS-400 graphite furnace at high temperature. The pack cementation temperature was controlled between 1700~2400 °C. The heating rate was 5~30

°C / min and the holding time 1 ~ 3h. In the process, argon gas was used for the protection of the furnace wall and the sample.

Ni-Ti powder was used as an interlayer connection material. The C/C composites and GH3128 samples were connected in a ZRY-55 vacuum hot pressing furnace. By comparison test, a better connection process was achieved. The bonding temperature was 1050~1250 °C, the connection time 15~60 min, the connect pressure 8 ~ 20MPa, and the vacuum degree in the furnace less than 1×10<sup>-2</sup> Pa.

The shear strength of the materials was tested in a CMT5304 material universal testing machine. The element distributions on the SiC modified coating was characterized by Pert PRO X-ray diffractometry (XRD). The fracture morphology of the SiC modified coating and the fracture of the middle connection layer was observed under ZEISS-SUPRA55 field emission scanning electron microscopy (SEM) with an energy-dispersive spectrometry (EDS).

## Results and Discussion

### 3.1 Microstructure of SiC modified coatings on the C/C composite surface

Fig.1 shows the XRD patterns of the SiC modified coating on the C/C composite surface prepared by pack cementation. The coating consists of three phases of α-SiC, β-SiC and Si compositions. It can be inferred from the intensity of the diffraction peaks and the half width that the dominant component is the α-SiC phase with a small amount of β-SiC and free Si.

Fig.2 gives the SEM images of the SiC coating, in which (a) stands for the coating surface photo, and (b) the cross section photo. Fig.2 (a) indicates that the prepared SiC coating is more compact, and no obvious penetrated cracks and pores exist. Meanwhile, there are larger size SiC particles that fill the continuous phase among them and smaller particles that adhere to larger ones and to the continuous phase surface. The presence of SiC particles plays an effective role in relaxation of the stress in the coating. The existence of the continuous phase not only enhances further the density of the coating and increases the combination between the coating and the C/C composites, but also relaxes the thermal stress in the coating in the heat pressure connection process.

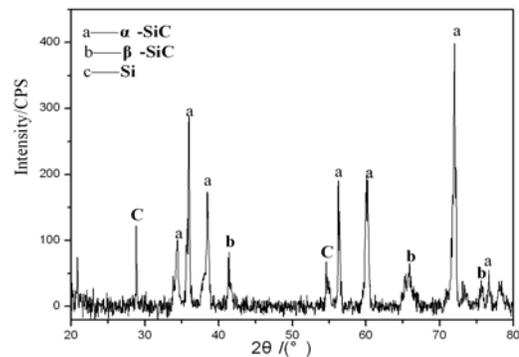
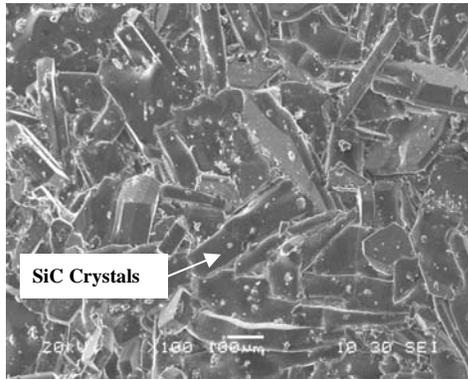
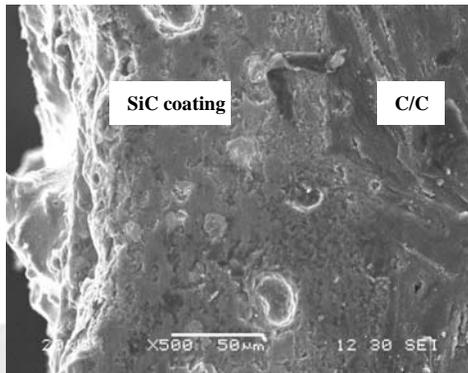


Fig.1 XRD pattern of modified SiC coating on the surface of C/C composites



(a) Surface



(b) Cross section

**Fig.2** SEM images of the SiC coating of C/C composites: (a) surface, and (b) cross section

### 3.2 Influence of the modified SiC coating on the performance of the joint heads

Table 1 indicates the influences of the SiC modified coating of C/C composites on the shear strength of the joint heads between C/C composites and GH3128. When the connection process remains the same, the existence of the modified SiC coating exerts remarkably impacts over the joint strength. After the C/C composites are modified by the SiC coating, it connected well with GH3128 at the temperature of 1170 °C. The shear strength of the joint heads reaches 22.5 MPa. When the C/C composites are not modified by the SiC coating, it fails to connect with GH3128. That is, the shear strength is almost equal to 0 MPa.

**Table 1 Influence of the modified SiC coating on the shear strength of the joint**

No.	Existence of modified SiC coating	Connection temperature / °C	Shear strength/ MPa
1	Without SiC coating	1170	0
2	With SiC coating	1170	22.5
3	With SiC coating	1150	1.4
4	With SiC coating	1130	0.9

It can also be seen from Table 1 that when the connection temperature lies between 1150 °C and 1130 °C even there exists the SiC modified coating on the surface of the C/C composites, the shear strength of the joint heads is almost equal to 0.

### Conclusion

(1) A modified SiC coating was prepared by a pack cementation method on the surface of C/C composites. The coating was closely integrated with the C/C composites. It not only enhanced the wetting of C/C composites to Ni, Ti and other elements, but also relieved fully the thermal stress caused by the mismatch of thermal expansion of the joints between the C/C composites and GH3128.

(2) At the temperature of 1170 °C, the shear strength of the joint head between the SiC coating modified C/C composites and GH3128 reached 22.5 MPa. The connection was very poor when the C/C composites were not modified by the SiC coating.

(3) The connection temperature exerted significant impacts on the connectivity between the SiC coated C/C composites and GH3128 nickel-based high-temperature alloy. When the bonding temperature was 1130 °C and 1150 °C, respectively, obvious crack defects existed in the joint, resulting in the shear strength of the joint being almost equal to 0. When the bonding temperature was 1700 °C, the shear strength was higher, approximately 22.5 MPa.

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