

THE FABRICATION TECHNIQUE OF A NEW AXIAL ROD 4D FLEXIBLE-RIGID MIXTURED WOVEN C/C COMPOSITE

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Introduction

The preform of carbon/carbon (C/C) composite, which is the carbonaceous matrix reinforced with carbon preform, determines the properties of C/C composite to a great extent. With regard to C/C composite material used on solid rocket motor throat, 4D multidirectional weave technique is the most effective method to fabricate the preform of C/C composite. Its major advantage is optimizing the characteristics for the structure and satisfying the design load of the component by varied freedomly the fiber amount and the weaving orientation. As the throat material, it must have good ablation resistance. In this paper, the preform fabrication as well as densification process of the new axial rod 4D flexible-rigid mixtured woven C/C composite (4D mixtured C/C) is introduced. Comparison of the material with axial rod 4D rigid woven C/C composite and radial rod 4D C/C composite is also present. Results indicate that the material with a final density of 1.95g/cm³ has excellent ablation resistance.

Experimental

1 Manufacture process of the preform

1.1 Machining of tooling

Mandrels are machined to two $\Phi 200 \times 10$ mm plates from high density high strength graphite. Using numerical control driller, 3500 holes with predetermined location and diameter are drilled in each plate.

The weaving tooling is assembled by the two plates. The distance between the upper and lower plate is determined by the height of preform.

1.2 Fabrication of the preform

The 4D preform is made of dry carbon fibers and rigid carbon rods. Carbon rods are pultruded from 6K high

strength carbon fibers impregnated with unsaturated polyester resin. The diameter of carbon rod is 1.15mm. The rods inserted into the corresponding holes of upper and lower plates are aligned in equilateral triangle form axial array and provide the Z direction reinforcement. The spacing between axial rod form channels in three directions. Each direction has an angle of 120° with each of the two others. Dry carbon fibers are arranged in these channels in succession and three layers are one cycle. The bulk density of the preform is about 0.6g/cm³. Figure 1 shows schematic of the 4D preform.

2. Densification process

The 4D preform is heat treated at the temperature of 2000-2200°C to char the resin and remove the sizing on the fibers, also the preform is stabilized. Following heat treatment, the preform is compressed and its density reaches over 0.60g/cm³. Following a cycle of vacuum impregnation/atmospheric carbonization, the preform is fixed. After removing mandrels from the preform and several cycles of HPIC with coal tar pitch, the final density of C/C material reaches to 1.90-1.95 g/cm³.

Results and Discussion

1 Advantages of axial rod 4D mixtured woven preform

- (1) Due to the high efficiency and low difficulty of the weaving process, it is easy to realize mechanization of weaving.
- (2) No continuous fibers in circumferential direction of the preform can reduce processing stress produced by fiber shrinkage in graphitization process.
- (3) About 70% fibers are present in the direction perpendicular to axial direction, Thermal conductivity increases and thermal-gradient decreases in radial direction of the material, thus can lower thermal stress

of C/C throat at operation time.

2 Properties of the 4D mixed C/C material

Compressive strength, flexible strength as well as arc stagnation point ablation rate of the 4D material is shown in table 1.

Table 1. Properties of the 4D C/C material

Item		axial rod 4D mixed C/C	axial rod 4D rigid C/C	radial rod 4D C/C
Compressive strength, MPa	Axial	94.1	156.6	121.6
	Radial	60.6	93	86.5
Flexible strength, MPa		91.9	101.8	63
Ablation rate, g/s	Axial	0.564	0.294	1.335
	Radial	0.403	0.372	0.786

Table 1 indicates that both mechanical and ablation resistance of the axial rod 4D material are superior to those of axial rod 4D rigid woven material and radial rod 4D material. The important reason is that axial rod 4D rigid texture is formed by all rigid rod thus produce larger porosity. While in 4D mixed woven, radial fibers are dry carbon fibers and can be compressed to obtain a higher fiber volume fraction. The density after heat treatment can reach to 0.60g/cm^3 , which is higher than that of 4D rigid preform (0.52g/cm^3). Compared with radial rod 4D material, with the same fiber volume fraction, its ablation

rate is much lower and more suited for low erosion C/C throat material. The result is due to the difference between their woven structure and a more finer reinforcing network of axial rod 4D mixed woven.

Conclusions

Two conclusions can be drawn from the study:

- 1 The manufacture technique of the axial rod preform combines the advantages of international advanced preform weaving techniques of low erosion, low cost C/C throat material. It improves fiber volume fraction effectively and obtains a finer grain preform.
- 2 Mechanical properties of the axial rod 4D material are obviously superior to that of axial rod 4D rigid woven material and radial rod 4D material. Its ablation resistance is the best in the three materials.

References

- [1] Li Ruizhen, Li Yadi, Su Junming, Cui Hong, Su Zhe'an, Zhou Shaojian. Study of the Properties of Axial Rod 4D Woven C/C Composite. Extended abstracts, Eurocarbon'98. Strasbourg, France: Science and Technology of Carbon, 1998;

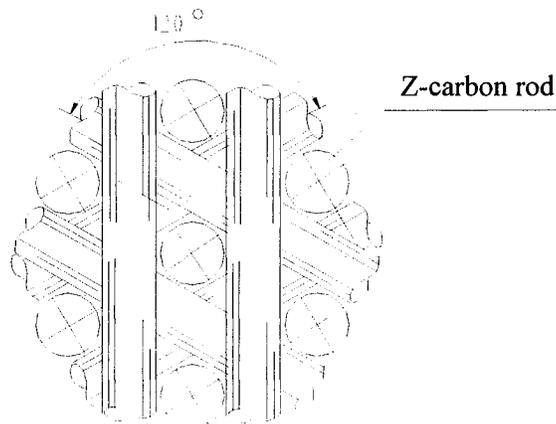


Figure 1. Schematic of the 4D preform