DEVELOPMENT OF C/C COMPOSITE THRUSTER

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Introduction

Advanced material technology is an essential foundation for aerospace development. Future aerospace demands even lighter and thermal resistance material to reduce the inert weight of motor. The current generation of attitude control thrusters used on commercial and military satellites is generally metal structure. Even using high temperature metal component, additional cooling technique is required to maintain metal below its yield temperature, which greatly reduce efficiency and increase complexity of the system. C/C composite can keep excellent comprehensive properties even at very high temperature (>3000℃). Its density is less than 1.90g/cm^3, while the density of high temperature metal, such as columbium, can reach to 9g/cm^3. Using a C/C component, the weight can reduce to 50% even with a thickness twice of that of high temperature metal. Although with inherent oxidation in an oxidizing atmosphere at high temperature, by means of appropriate treatment, C/C composites still offer attractive advantages for thruster operation time is less than 60 seconds. In this paper, the preform fabrication, densification process as well as the hydrostatic test are present.

Experimental

1. Preform fabrication

Mandrels were precisely machined from fine grain graphite and the preform was braided over the mandrel using T300 carbon fiber. The fiber volume fraction of the preform is controlled in the range of 30-55%.

2. Densification process

The preform was high temperature treated to 2000℃ to remove the sizing on the fiber and make it stabilized. Using isothermal CVI technique, with propylene as reactant gas, the preform was densified to a density of 1.65-1.70g/cm^3. Then with an cycle of HPIC, the final density reaches over 1.80g/cm^3.

3. Hydrostatic test

The thruster was machined to a cylindrical ring with a length of 40mm. According to hydrostatic test result, the hoop strength can be calculated.

Results and Discussion

1. Opportunity of removing the mandrel

The preform was stiffened by CVI process. Only it reaches to a certain density, can the mandrel be removed. If the density is too low, there will be too many barbs on the thruster to machine. On the other hand, the mandrel was removed earlier contributes to increase densification efficiency. The relationship between the opportunity of removing mandrel and outward appearance of the component is shown in table 1.

Table 1 indicates that it is better to remove the mandrel when the density is 1.40-1.50g/cm^3.

2. Relationship between material density and densification time

Relationship between material density and densification time is shown in figure 1 and table 2.

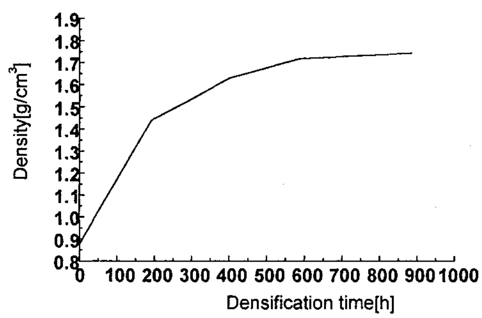

Figure 1. Relationship between material density and densification time

Figure 1 shows that the density increases with densification time and the trend of increase by degree reduce gradually. Up to a density of 1.70g/cm^3, densifing the material further by isothermal CVI become difficult. Using HPIC, pressure forces thermoplastic pitch into very small fissure and cracks, the density increases greatly. After a cycle of HPIC, the density of C/C composite can reach over 1.80g/cm^3.

3. Hydrostatic test

Hydrostatic test is a common method for pressure vessel to measure the material properties. From the results of hydrostatic test, the hoop tensile strength can be calculated. The data are shown in table 3.Table 3 indicates that the material can meet the design, but the hoop tensile strength is quite low. In order to increase the material strength further, works can be done from two aspects:

Firstly, the preform is braided using high module carbon fiber to reduce the strength loss in high temperature process.

Secondly, the braid structure should be improved to increase the fiber volume fraction in hoop direction.

Conclusions

Several conclusions can be drawn from the study:

1. For the thruster developed in this paper, it is better to remove the mandrel when the material density is 1.40-1.50g/cm^3.
2. The combination densification process of isothermal CVI and HPIC can increase the densification efficiency.
3. Using high module carbon fiber and improving the braid structure may further reduce the weight of the component.

References

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Table 1 The relationship between opportunity of removing mandrel and outward appearance of the component

Material density, g/cm^3	Densification time	Outward appearance of the component
1.33	920℃/102h+940℃/150h	Too many barbs on the thruster to machine
1.33	920℃/102h+940℃/150h	Many barbs on the thruster
1.37	920℃/178h+940℃/78h	Appearance is coarse
1.40	920℃/178h+940℃/78h	Fairly well
1.50	940℃/263h	Excellent

Table 2 Comparison of isothermal CVI with HPIC

Densification process		CVI	HPIC
Densification time, h		294.5	About 100
Initial density, g/cm^3	ave	1.70	1.70
	S	0.020	0.021
	Cv,%	1.23	1.24
Final density, g/cm^3	ave	1.74	1.81
	S	0.004	0.006
	Cv,%	0.22	0.32

Table 3 Result of hydrostatic test

Items					ave
	1	2	3	4	
Burst pressure, MPa	4.5	5.5	6.3	5.0	5.32
Hoop tensile strength, MPa	30.0	29.2	33.4	31.1	28.9
Burst appearance	Burst in hoop direction				