Carbon-Carbon Pins

Chongjun Li, Wanji Cui ,and Xiaoxu Huo
Shaanxi Non-Metal Materials and Technologies Institute
P.O. Box 101 Xi'an,Shaanxi 710025 P.R.CHINA

Introduction

Carbon-Carbon composites are the unique structural and functional materials. The mechanical properties of C/C increase with increasing measurement temperature;the thermal conductivity of graphitized C/C decrease as the temporature raises[1].These special performances make C/C important in the field of super-high temporature application,especially in solid rocket motor(SRM); C/C composite nozzle is one example[1,2,3].Aimming at the demands of the future aerospace technology to C/C nozzle,the joint structural parts in C/C nozzle,C/C pins,are studied.On basis of double side shear strength,the influence factors on carbon-carbon pins such as braiding(weaving) methods, densification technology and interface are discussed as follows.

Experimental

The PAN based carbon fiber preforms are formed by four methods[3,4]:radial carbon rods — carbon fibers 3D mixed weaving(I), axial carbon rods — carbon fibers 4D mixed weaving(II),four-step 4D braiding(III),four-step 4D braiding laid in warp(IV).The bulk density and fiber volumne fraction(V_f) of preforms are listed in table 1.The densification technology is depicted in figure 1,in which preforms I, III, IV are the same process of technology 1,preform II is densified by technology 2.The double side shear strength of C/C pins is measured similarly to metal pins, sample size is Φ 10 × 55mm,the shear section is observed by SEM.

preform→ pretreatment → CVI* → HIP* → graphitization → machining → C/C pin

technology 1

preform→ heat treatment → VIC* → HIP* → graphitization → machining → C/C pin

technology 2

* CVI:Chemical Vapour Infiltration; HIP:Heat Isostatic press(precursor:pitch);
VIC:Vacuum Impregnation pitch---Carbonization

Fig.1 the technological process of C/C pin

Table 1 experimental and properties of C/C pins

preform	forming	weaving(I)	weaving(II)	braiding(III)	braiding(IV)
preform	density(g/cm^3)	0.73	0.60	0.88	1.02
	V_f(%)	42	34	50	60
C/C pins	density(g/cm^3)	1.80	1.93	1.82	1.82
	testing direction	radial	axial	warp	warp
	axial V_f	14%	11%	25%	30%
	strength(MPa)	29.48	27.87	51.6	63.7

Results and Discussion

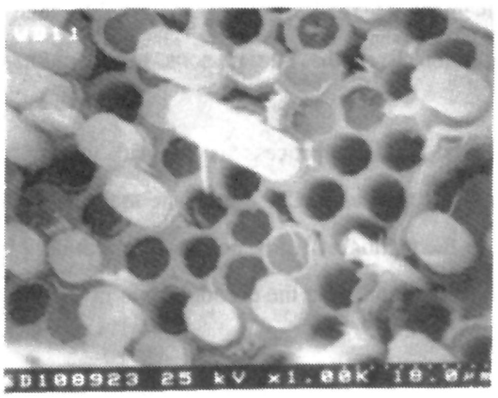
The density,shear strength and axial V_f of C/C pins are listed in table 1.

Technology and microstructure

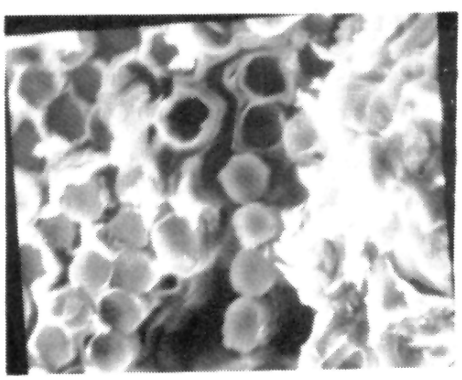
The shear fracture section SEM are shown in fig.2,2(a) is the SEM of braiding(III) C/C,which employs technology 1 to densify; 2(b) is the SEM of weaving(II) C/C,which employs technology 2.Section in (a) is irregular,where fibers are pulled out,this means that C/C of technology 1 have the weak bonding in interface.SEM (b) has the flat section,few fibers are pulled out,typical brittle fracture;this shows that interface in weaving(II) C/C is strong,which is favorable to utilizing the strength of carbon fiber,so technology 2 is more suitable for C/C pin.

The two differental microstructure originates the different matrix.Technology 1 C/C has the mixed matrix of CVI and pitch carbon,it is first densified by CVI,CVI carbon is formed during gasification,which has three distinct micostructure according to process[1,5]. CVI carbon has to re-arrange to close graphite structure and interface bonding will change and decrease during graphitization.So technology 1 C/C has the weak interface microstructure.Technology 2 C/C has pitch carbon matrix only, which is formed from liquid,it already possesses the graphite structure after the mesophase,the layer structure will maintain in the following heat treatment,so technology 2 C/C has strong and dense interface microstructure.

Meanwhile,we can see that pitch carbon matrix is grown around the carbon fiber like sheath from the SEM of 2(b).It's well known that CVI carbon has this special sheath-like growing feature,but it hasn't been reported for pitch carbon matrix,this is probobally related to the high pressure carbonization[5].



(a) four-step 4D braiding(III) C/C
(technology 1, × 1000)



(b) axial carbon rods — carbon fibers mixed weaving(II) C/C(technology 2, × 1000)

Fig.2 the SEM of C/C pin's shear fracture section

The influence of preform forming on the shear strength
From table 1,we can see that C/C pin made from weaving(I,II) C/C has the shear strength of 29.48 MPa and 27.87 MPa respectively,while the 4D braiding C/C pin's strength is improved by 70% as compared with the weaving(I) C/C,the strength of 4D braiding laid in warp is as high as 63.7 MPa,more than 2 times of weaving(I) C/C.Though there exist the differences of weaving(braiding) methods,density and process, it's the V_f ,especially the axial V_f , that causes the great changes[1].The axial V_f is listed in tab.1,it's clear that pin's shear strength is in direct proportion to the axial V_f .This shows that V_f is decisive to the C/C pin's shear strength.

Conclusions

1) For technology 1 C/C, the interface is weak between CVI carbon and carbon fiber.While for technology 2 C/C,the pitch carbon matrix is strongly bonding to carbon fiber in interface.The pitch carbon matrix is sheath-like grown around carbon fiber,just like CVI carbon.
2) V_f is decisive to the C/C pin's shear strength,the C/C pin of 4D braiding laid in warp has the highest shear strength,it's up to 63.7MPa.
3) Technology 2 and braiding preform with yarns laid in warp is favorable to making C/C pins.

References

[1] Buckley JD. Carbon-Carbon,An Overview,Ceramic Bulletin 1988;67(2):364-368.
[2] Bropuere BH.Carbon/Carbon Nozzle Exit Cones SEP's Experience and New Developments. AIAA-97-2673,1997.
[3] Baker CF,Dunn DR,Mills ER. Low Cost, Low Erosion Throat Material for Solid Rocket Motors.AIAA-94-3187,1994.
[4] Ko FK.Textile Preforms for Carbon-Carbon Composites. In:Buckley JD and Edie DD editor.Carbon-Carbon Materials and Composites, Noyes Publications,1993:71-104.
[5] Peebles LH, Meyer RA,and Jortner J. Interfaces in Carbon-Carbon Composites.In:Ishide M editor.Interfaces in Polymer, Ceramic,and Metal Matrix Composites,Elsevier Science Publishing Co.Inc.,1988:1-14.