

KSR-III

*, **, ***, ****

Thermo-Elastic Analysis and Test of the KSR-III Kick Motor Nozzle

In-Hyun Cho*, Seung-Hyub Oh**, Jae-Suk Yu***, Tae-Ho Rho****

Abstract

This paper predicted the engineering constants of spatially reinforced carbon/carbon composites and analyzed the mechanical behaviour of the kick motor nozzle. Those equivalent engineering constants are used to analyze the mechanical behaviour of the kick motor nozzle. Because the distribution of equivalent engineering constants is varying as change its structure, we made a program to predict engineering constants of spatially reinforced composites. The kick motor nozzle consists of graphite or spatially reinforced carbon/carbon composites for the nozzle throat, carbon/phenol for the nozzle entrance and the expansion part, and steel for the outer surface of the expansion part. The 4-D carbon/carbon composite shows the smallest deformed shape of the nozzle throat, which has a favorable effect on the rocket thrust, and the most uniform deformation of all nozzle throat materials. In addition to analysis, ground firing tests of 4D C/C nozzle throat and graphite nozzle throat were performed.

가
3
가
graphite
carbon/phenol,
4-D /
4D /
가
: / (carbon/carbon composite), (graphite), (nozzle throat), (thermo-elastic analysis), (ground firing test)

* / ihcho@kari.re.kr

** / shoh@kari.re.kr

**** ()

1.

가

1.1

(secondary structure)
, (rocket)
(beam) (primary structure)
가

3
가
Joon-Hyung Byun Plain weave 8-harness
satin weave
Plain weave 8-harness satin weave
(unit cell)

Rajiv
yarn slice

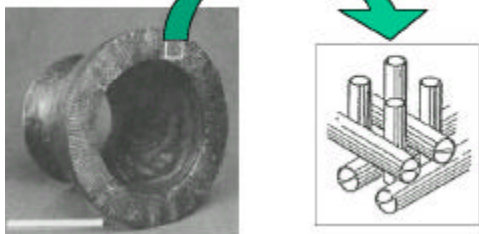
Blacktetter
plain weave

PATRAN plain

weave 3

3 /

1.1



1.1. Spatially reinforced composite nozzle.

2. 3

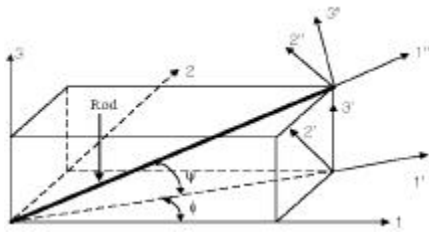
1.1 (rod) (matrix)가

2.1

3

가

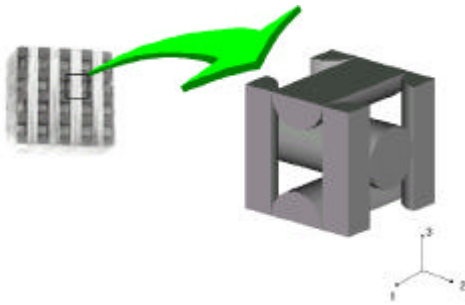
$$[C] = [K]^T [C'] [K] \quad (2.1)$$



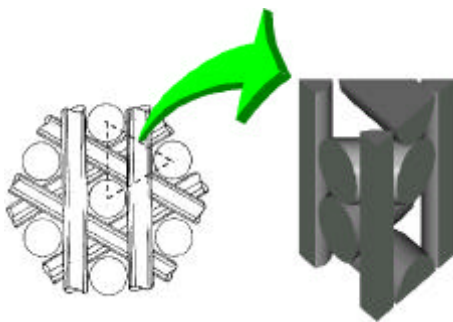
2.1. Local and global coordinate system for the rod.

$$[K] = [C] [S]^{-1} \quad (2.2)$$

$$[S] = [T]^T [S'] [T] \quad (2.2)$$



2.2. Unit cell of the 3-D SRC.



2.3. Unit cell of the 4-D SRC.

2.2.

(superposition of stiffness matrix)

2.2 2.3

(unit cell) 3

가

(spatially reinforced composite : SRC)

SRC 가

2.2

SRC

가

SRC 가

SRC

2.2

(volume fraction)

가 (volume

$$VF_i = \frac{\text{ith rod volume}}{\text{unit cell volume}} \quad (2.3)$$

i = 1, 2, 3, 4

(2.3)

i-

i-

3

가

(iso-strain)

[1,2,3,4]

가

가

가

가

SRC

가

가

가

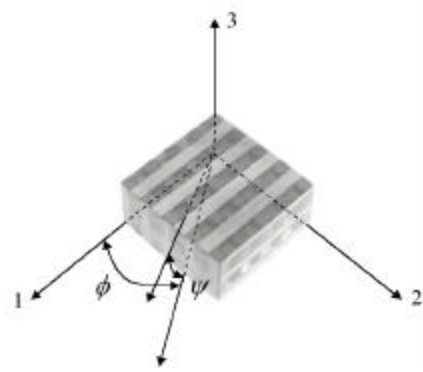
가

가

가

$$[C]_c = \sum_{i=1}^n VF_i [K]_i^T [C'] [K]_i + \left(1 - \sum_{i=1}^n VF_i\right) C_{iso} \quad (2.4)$$

n 3-D SRC 3 4-D SRC
 47} . [C]iso
 (2.4)
 가 SRC
 (2.4) SRC
 (composite stiffness matrix)
 SRC
 3
 3



2.4. Arbitrary direction of the SRC.

2.1. Material properties of the rod.

Symbol	Rod
d(mm)	1
E1r(GPa)	166
E2r, E3r(GPa)	6.83
G12r, G13r(GPa)	2.99
G23r(GPa)	2.39
ν12r, ν13r	0.304

2.3.

([S]_c) (2.1) ([C]_c)
 ([S]_c = [C]_c⁻¹)

$$E_{11c} = 1/S_{11c}, E_{22c} = 1/S_{22c}$$

$$E_{33c} = 1/S_{33c}, G_{23c} = 1/S_{44c}$$

$$G_{31c} = 1/S_{55c}, G_{12c} = 1/S_{66c} \quad (2.5)$$

$$\nu_{12c} = -S_{21c}/S_{11c}, \nu_{31c} = -S_{13c}/S_{33c}$$

$$\nu_{23c} = -S_{32c}/S_{22c}$$

(2.5) SRC 2.1
 1-2-3 2.4

$$[S'']_c = [K][S]_c[K]^T \quad (2.6)$$

(2.6) 3 4
 1 2.4 0°
 90 3° 0° 90
 3° [S'']_c

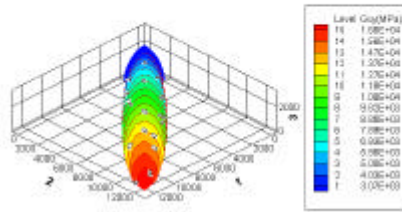
2.1 2.2 2.1
 T300 Carbon fiber Carbon matrix
 Chamis(1983) 7)가

2.2. Material properties of the carbon matrix.

Symbol	Carbon matrix
Em(GPa)	3
νm	0.35

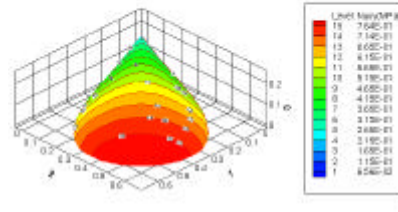
Carbon matrix

2.5 3-D SRC Exx
가 24 가 45°
가
가



Carbon matrix

2.6 3-D SRC Gxy
가 45°
가
가 45°
가 45°



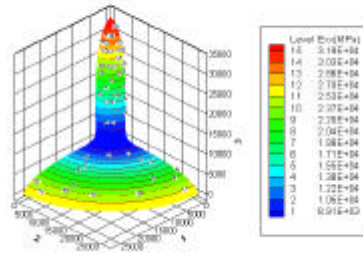
2.7 3-D SRC

가 45°
가

2.7. Poisson's ratio distribution of the 3-D SRC.

가

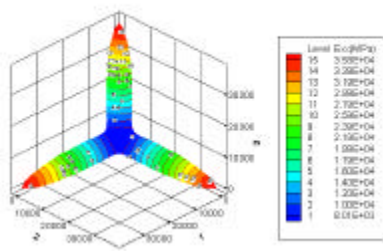
Carbon matrix가
가



2.8. tensile modulus distribution of the 4-D SRC.

Carbon/ phenol

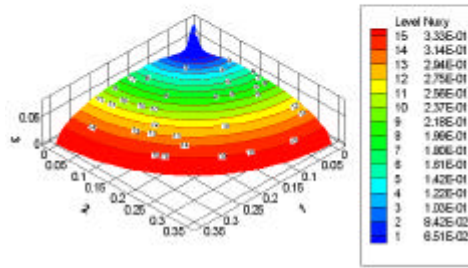
0/90 가 0.1 가 45°
0.72



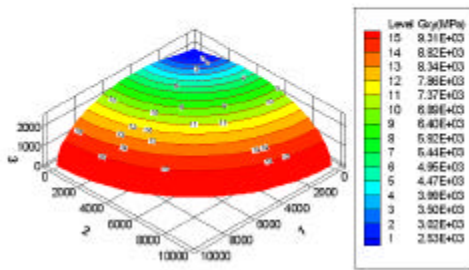
2.9. tensile modulus distribution of the 3-D SRC.

2.8 4-D SRC Exx
4-D SRC 3-D 1-2
가 60° Quasi-
isotropic 1-2
가 4-D SRC
가 (1-3 2-3 4
5°) 가
가
2.9 4-D SRC Gxy

1-2
60°
가 3 가
가 90° 3-D SRC 가
가 2.10 4-D SRC
1-2 가
3 가 가



2.10. Poisson's ratio distribution of the 4-D SRC.



2.9. Shear modulus distribution of the 4-D SRC.

3.

3.1

PATRAN

MSC
ABAQUS

3.1
(graphite)

3-D/ 4-D SRC,
Carbon/ phenol,

3.1. Material properties of kick motor nozzle(I).

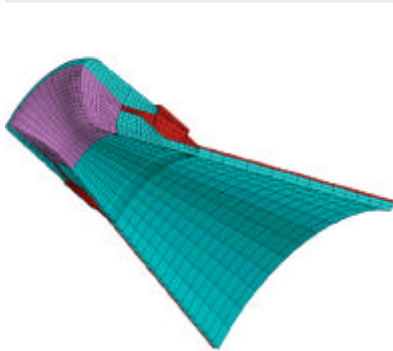
Symbol	3-D SRC	4-D SRC	Symbol	Carbon/Phenol
1d,2d,3d,4d (mm)	1,1,1	1,1,1,1		
E _{xx} (GPa)	37.8	33.5	E _{zz} (GPa)	73.7
E _{yy} (GPa)	37.8	26.5	E _{qq} (GPa)	73.7
E _{zz} (GPa)	37.8	26.5	E _{rr} (GPa)	5*
G _{yz} (GPa)	2.1	9.8	G _{r_q} (GPa)	2.5*
G _{zx} (GPa)	2.1	2.1	G _{qz} (GPa)	5.0
G _{xy} (GPa)	2.1	2.1	G _{zr} (GPa)	2.5*
v _{xy}	0.078	0.077	v _{r_q}	0.03*
v _{zx}	0.078	0.061	v _{rz}	0.03*
v _{yz}	0.078	0.35	v _{qz}	0.1

steel 4130
4-D SRC

3-D
3 Carbon/ phenol

(Tape Rapping)

Phenol



3.1. Mesh generation for the nozzle.

Carbon/ Phenol

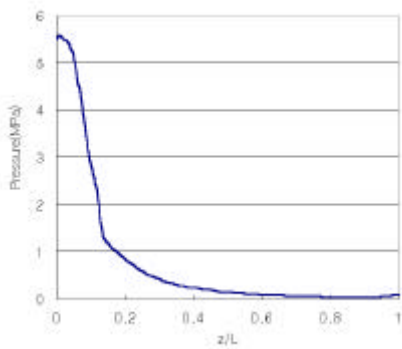
45 °

3-D/ 4-D SRC

가

4-D SRC

3.1 x-



3.2. Pressure distribution on the wall along the axis.

Carbon/

3.1 *

1 1

3.2

3.2

5.516(MPa)

3.1

3.1

가

3-D SRC

90 °

3-D SRC가

90 °

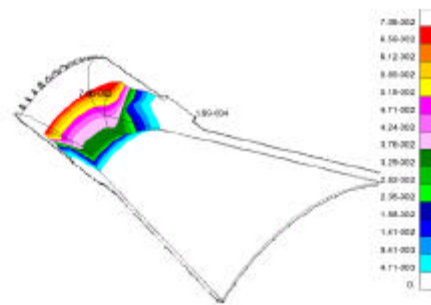
90 °

(cyclic

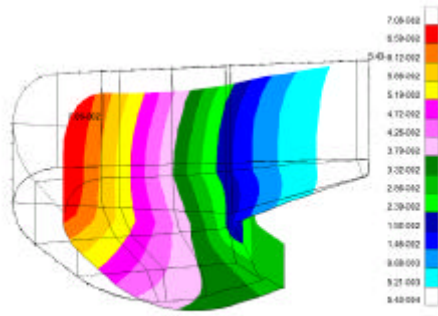
symmetric)

3.2. Material properties of the kick motor nozzle(II).

Symbol	Graphite	S-4130
Em(GPa)	7.0	200
vm	0.071	0.28



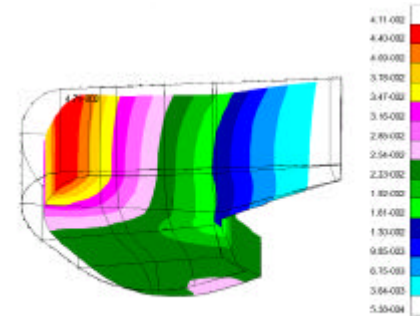
nozzle.



nozzle.

graphite
3.3

200

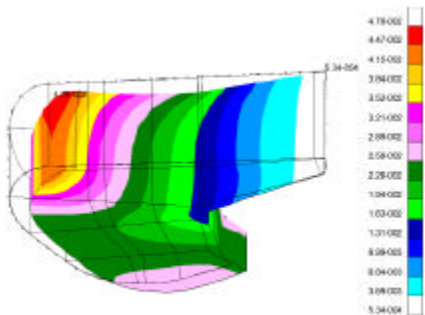


nozzle.

3.2 KM

3.2.1

1 ,
2 ,
3.4, 3.5, 3.6
graphite, 3-D SRC 4-D SRC
graphite 3-D/4-D SRC
3-D 4-D SRC
3-D SRC 4-D SRC가
가
4D C/C graphite
3.7 3.8
4D C/C
graphite



nozzle.

graphite

가 11

가 11

가

3.2.2

2

가

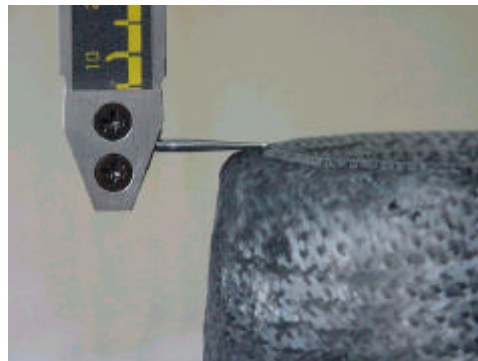
2

가

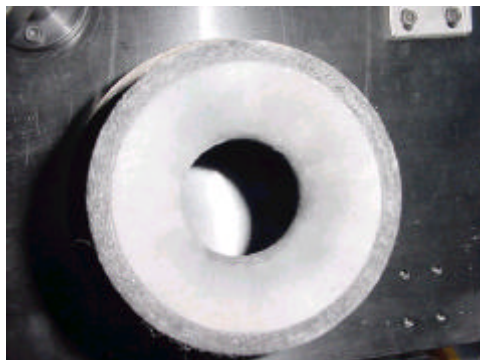
가



3.7. 4D C/C



3.9. 4D C/C



3.8. graphite

4.

graphite
4-D SRC

3-D

3-D SRC

4-D

SRC 60°

가

가

C/C

4D C/C

4D

graphite

3.9

0.5 1mm

4-D SRC가 가
 , 3-D SRC
 . 4-D

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2. Rajiv, A., Naik, Pratt and Whitney, "Multiaxial Stiffness and Strength Analysis of Woven and Braided Composites," AIAA, 1997, pp. 1148-1158.
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