

# KSTAR

# Bellows

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## Development of the Welded Bellows for KSTAR Vacuum Vessel

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**Key Words :** Tokamak( ), Welded Bellows( ), Fatigue Life( )

### Abstract

Vacuum vessel of the KSTAR(Korea Superconducting Tokamak Advanced Research) tokamak is a fully welded structure with D-shaped cross-section. According to the requirements of the physics design, sixteen horizontal ports, sixteen slanted ports, sixteen baking and cooling ports, and twenty-four top and bottom vertical ports are designed for the diagnostics, plasma heating, vacuum pumping, and baking and cooling. Bellows on these ports are used for flexible components to absorb the relative displacement due to the vacuum vessel thermal expansion and the electromagnetic force between the vacuum vessel and the cryostat ports. Fatigue strength evaluation was performed to decide the dimension of the bellows. In order to assure the quality of the bellows, a prototype bellows for the neutral beam injection port has been fabricated and tested prior to main fabrication. It was conformed that the prototype bellows has sufficient fatigue strength and vacuum reliability in the expected load conditions.

가 , (1)-(2) 가  
 C : Convolution number of the bellows  
 L : Total length of the bellows  
 U : Cumulative usage factor  
 W : Span of the convolution (Base Pressure)  $1 \times 10^{-8}$  Torr  
 t : Bellows thickness (Baking) 130  
 $l_{CR}$  : Length of the center ring (Plasma Disruption) (3)

### 1.

KSTAR 4.5 K

Bellows

Bellows

(Plasma)

, Figure 1

가 가

(Race Track)

Bellows

Bellows

(4)-(5)

KSTAR

Bellows

NBI

Bellows

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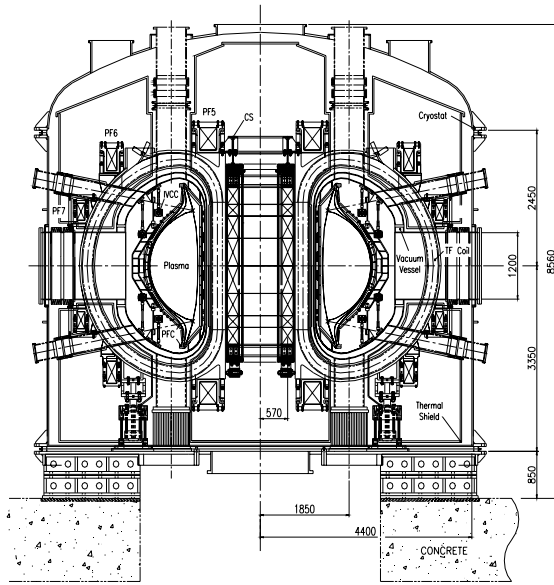


Fig. 1 Cross-section view of the KSTAR tokamak

2. Bellows

2.1

Table 1 NBI, RF, EH  
SP, TV, BV, BC

가 , Bellows (Helium Leak Rate) , (Outgassing Rate)

1) Bellows : 1 x 10<sup>-9</sup> Torr l/sec

2) Bellows (Center Ring), Bellows : 1 x 10<sup>-11</sup> Torr l/sec

Bellows (Stainless Steel)

316L GTAW Bellows Mill Sheet

3) Bellows : 가

Table 1 VV port penetration on the cryostat wall

VV Port Penetration	Quantity	Bellows Shape	Service
Lid	TV	Race Track	Diagnostics, PFC Cooling
	NBI	Rectangular	NBI, VV Pumping, Diagnostics, IVCC
	RF	Rectangular	ECH, ICRH, LHCD
Cylinder	EH	Rectangular	Diagnostics, IVCC
	SP	Circular	Diagnostics, PFC Cooling
Base	BC	Circular	VV Baking & Cooling
	BV	Race Track	Diagnostics, etc.
Total	72		

Table 2 Displacement requirements for the bellows design

Load (Repetition)	Baking (750)	Plasma Disruption (30,000)	Seismic + Baking (750)
B_NBI	X	± 4	± 5
	Y	± 11	± 11
	Z	-13	-14
B_RF	X	± 4	± 5
	Y	± 11	± 11
	Z	-13	-14
B_EH	X	± 4	± 5
	Y	± 11	± 11
	Z	-13	-14
B_TV	X	± 4	± 5
	Y	± 8	± 9
	Z	-15	-16
B_BV	X	± 4	± 5
	Y	± 8	± 9
	Z	+8	+8
B_SP	X	± 4	± 5
	Y	± 13	± 14
	Z	-13	-13
B_BC	X	± 6	± 7
	Y	± 15	± 16
	Z	+15	+15

가 , Bellows

130 , 150 , 4 가

가 , Table 2 Bellows ± 3 mm

10

1 3  
25  
50,000  
15% Eddy Current Disruption  
5% Halo Current Disruption  
10 5 ( )  
가 =0.12 g, 가 =0.08 g) 10  
1 가 25  
Hz  
4) : Bellows  
가 가 NBI Bellows

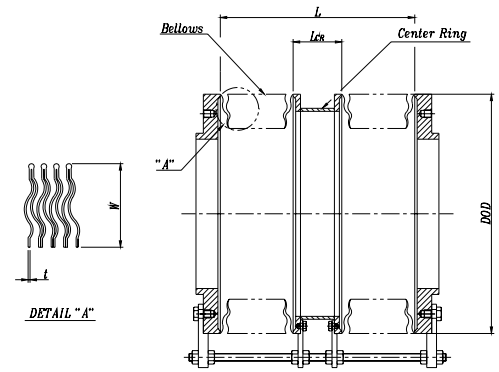


Fig. 2 Basic shape of the welded bellows for KSTAR vacuum vessel

Table 3 Welded bellows dimension & cumulative usage factor

Bellows	DOD (mm)	L (mm)	$l_{CR}$ (mm)	C	W (mm)	t (mm)	U
B_NBI	1370x1610	395	85	34	80	1	0.49
B_RF	898x1350	410	165	28	70	0.8	0.25
B_EH	476x1350	410	170	26	70	0.8	0.26
B_TV	478x798	360	126	32	62	0.8	0.19
B_BV	478x798	360	135	36	62	0.8	0.30
B_SP	OD390	340	150	30	45	0.6	0.09
B_BC	OD330	325	130	46	40	0.6	0.28

DOD : Diaphragm outer dimension

(Cumulative Usage Factor) 1

Table 3 Bellows 가

### 3. Bellows

#### 3.1

Bellows

8

SP, BC, TV

가 . 2003

NBI , NBI, RF, EH, BV

Bellows

3 Figure 4

B\_SP Bellows

Figure , B\_NBI

Bellows

(1) : Bellows

316L

JIS

Mill Sheet

(2)

: Bellows

, S Bellows

## 2.2 Bellows

Bellows Bellows 가

Bellows

가 Bellows

가 가 Bellows Figure 2

Bellows

Bellows

NBI, RF, EH, SP, TV Bellows Bellows

/ 가

Bellows

, Bellows 가

Bellows

Bellows

BV BC , Bellows

Bellows

Minor's Rule 가

가 Bellows

Diaphragm  
 BV&TV  
 SP, BC  
 (3) : Bellows  
 Chloride)  
 가 (Gaze)  
 (4) : Bellows

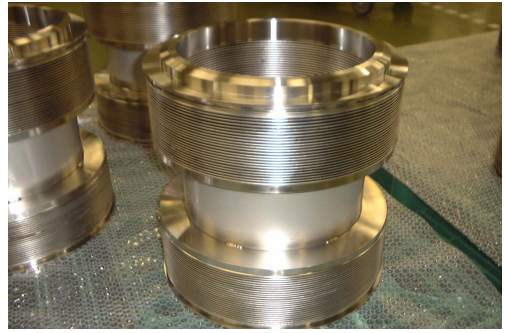


Fig. 3 B\_SP bellows

(5) :  
 (6) : 가 가  
 (Poly Sheet)

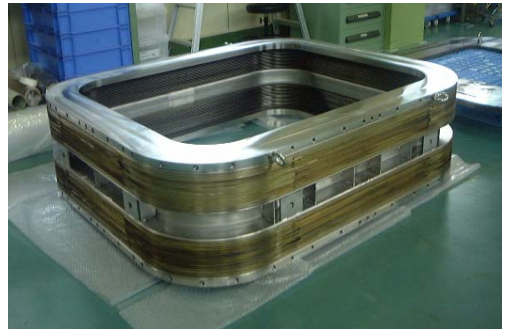


Fig. 4 B\_NBI bellows prototype

Bellows 가  
 3.2  
 Bellows  
 NBI Bellows 가

O-ring  
 Bellows 가  
 48  
 (2) B\_NBI Bellows  
 NBI Bellows 가

(1)  
 Mill Sheet Bellows  
 Bellows

200 48  
 $1 \times 10^{-11}$   
 Torr l/sec  $cm^2$   
 5 가  
 $1 \times 10^{-9}$  Torr l/sec  
 Bellows

(Spatter)  
 Bellows  
 가 (Hood)

Bellows  
 Bellows 가 0.15  
 MPa

Figure 6

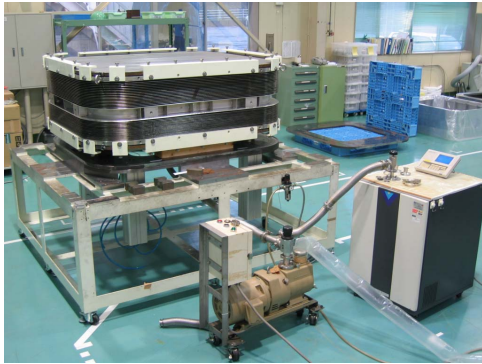


Fig. 5 Helium leak test for B\_NBI bellows prototype

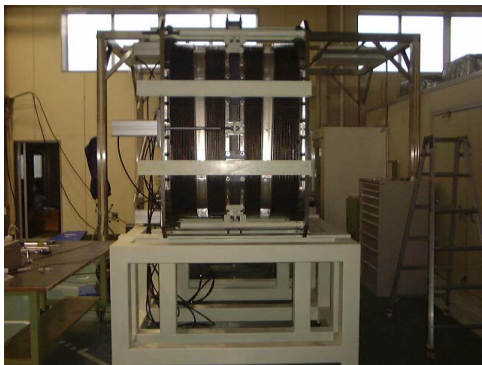


Fig. 6 Life test for B\_NBI bellows prototype

4.

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Bellows , 2004 1  
Bellows . Bellows 가

가가 ,  
Bellows  
가 .  
가  
(KSTAR Project)

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