Process Development of Residual Stress Relaxation in KSTAR CICC

K. Kim[a], E. Chung[b], K. Park[a], W. Chung[a], K. Lee[a], H. Park[a], D. Lee[a], S. Ahn[a], J. Joo[a]
a Korea Basic Science Institute, Yusung-Gu, Daejeon,305-333, Korea, kpkim@kbsi.re.kr
bHanbat National University, Yusung-Gu, Daejeon, 305-719

1. Introduction

The Korea Superconducting Tokamak Advanced Research (KSTAR) magnet system consists of 16 toroidal field (TF) coils and 14 poloidal field (PF) coils. The overall tokamak configuration of the KSTAR is shown in Figure1. All of the TF and PF coil system used internal-cooled cable in conduit conductors (CICC). Incoloy 908 material is used for the conduit of TF and PF 1~5 coils. Nb_3Sn is used in TF and PF1~5 coils for superconducting cable[1].

Nb_3Sn must be heat-treated at the temperature of 660℃ about 240 hr, to have superconducting characteristics. However, the Incoloy 908 can crack by SAGBO (Stress Accumulated Grain Boundary Oxidation) in the condition of above 200MPa stress, above 0.1ppm oxygen content and at 550 – 800 ℃[2].

Vacuum heat-treatment process prevents SAGBO in CICC during heat-treatment process. We also developed the process of relaxing the residual stress in CICC in case of vacuum failure. We applied this process in the winding process of CICC.

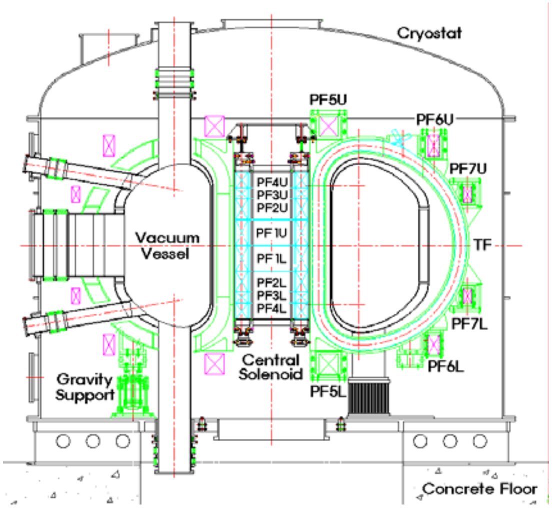

Figure. 1. KSTAR Tokamak Configuration

2. Main Parameters of PF1-4 coils

The parameters of PF1-4 coils are listed in Table I. The number of PF1-4 coils is two respectively. Material of the conductor is Nb_3Sn, and that of conduit is Incoloy 908. The mean radius of the coil is 570 mm. The length of PF1 coil is about 663 m. The three-dimensional design for the PF4 coil and manufactured PF4 coil are shown in Figure2.

TABLE I
Parameters of the PF coils

Parameters	PF1	PF2	PF3	PF4
Superconductor	Nb_3Sn			
Jacket material	Incoloy 908			
Mean radius [mm]	570			
Number of coils	2	2	2	2
CICC length [m]	663	537	283	410
Weight [ton]	2.24	1.81	0.96	1.39

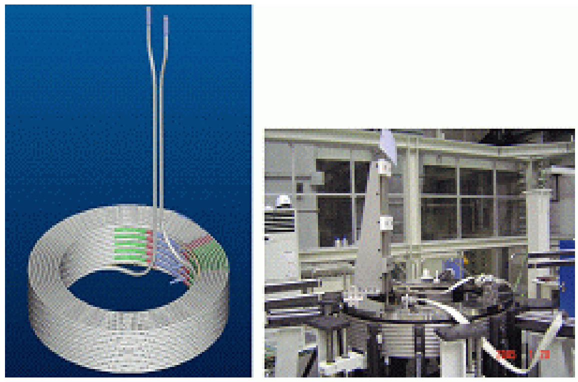

Figure. 2. The KSTAR PF4 coil

3. Process of relaxing the residual stress

The KSTAR PF1-4 coils are produced by a continuous winding process. The minimum radius of PF coil is 463mm and that of PF coil lead is 215mm. High surface residual stress in CICC grows during the bending process. Grit blasting process is adopted to relax the stress in CICC.

The grit-blasting machine uses zirconium beads instead of sand or cast steel beads. The zirconium beads have good durability and uniform surface roughness and are free of contaminants.

(a) Before winding process (b) After lead bending

Figure. 3. Grit blasting machine

We apply the grit blasting process in two positions, before winding process and after lead bending. Figure 3 shows the grit blasting machines. The first machine is used for cleaning CICC and relaxing the residual stress due to welding. Second machine is used for relaxing the residual stress after lead bending.

4. Residual stress measurement for CICC

Hole Drilling Method was used to measure the residual stress of CICC. We drilled the hole with regular depth of blind method. The procedure of this measurement followed the international standard ASTM std E-836. The strain gage used in this experiment is type of No. CEA-06-062UL-120.

Figure 4 shows the device to measure the residual stress of CICC. We measured residual stress for five samples. The detail condition of samples is listed in Table II.

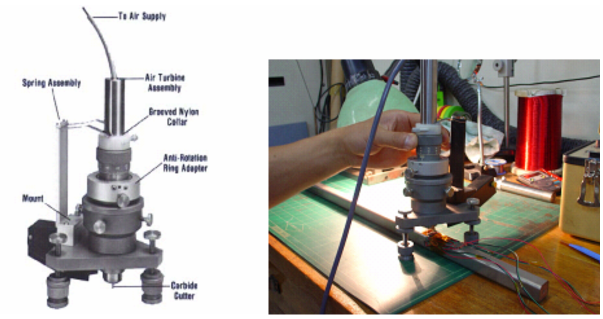

Figure. 4. Residual stress measurement device (Hole-drilling method)

TABLE Ⅱ
Samples of Result Stress

No	Sample Condition
Sample 1	Bending (R 460)
Sample 2	1st Blasting (6bar), Bending (R 460)
Sample 3	1st Blasting (6bar), Bending (R 215)
Sample 4	1st Blasting (6bar), Bending (R215), 2nd Blasting (2bar)
Sample5	1st Blasting (6bar), Bending (R215), 2nd Blasting (4bar)

5. The results of residual stress measurement

Figure 5 shows the results of this measurement. The result shows that the surface residual stress has been relaxed through the first grit blasting for the CICC, in case of 460 mm in Radius. For the CICC of lead (R 215mm) part, the surface residual stress has been relaxed through the first and the second blasting process.

6. Conclusion

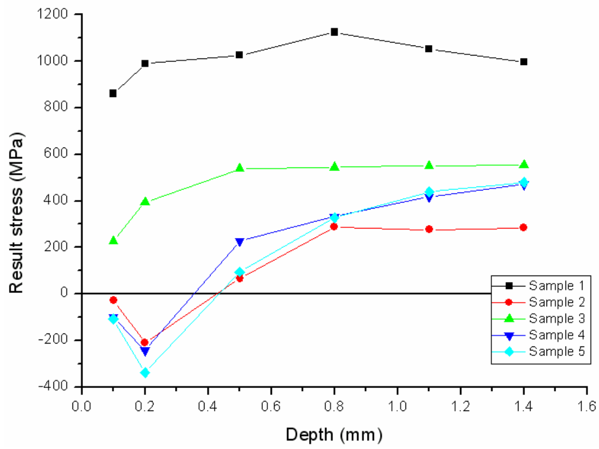

Figure. 5. Results of residual stress of CICC

We developed the process for the relaxing the residual stress of KSTAR PF1-4 CICC to prevent SAGBO during heat-treatment process. We measured the residual stress by hole drilling method for various samples also. The two-step blasting process, which is applied before winding process and after lead bending, was successful to relax the surface residual stress in CICC enough to avoid the SAGBO during the heat-treatment process.

REFERENCES

[1] KSTAR Magnet System Review, Samsung Advanced Institute of Technology, August 1999, ppT131/40-49
[2] Review on Structural and Thermal Thermal stability of the KSTAR Magnet System, May 10 2002, 5.4 Mechanical Test of Incoloy 908 Jacket Material
[3] Kato, T., et. al., "Advance Method Study for SAGBO Cracking During Heat Treatment of an ITER CS Model Coil Conductor Using INCOLOY 908 Jacket," Proc. of the CEC/ICEC Oregon, 1997