Baking results of KSTAR vacuum vessel

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1. Introduction

The Korea Superconducting Tokamak Advanced Research (KSTAR) is an advanced superconducting tokamak designed to establish a scientific and technological basis for an attractive fusion reactor [1].

The fusion energy in the tokamak device is released through fusion reactions of light atoms such as deuterium or helium in hot plasma state, of which temperature reaches several hundreds of millions Celsius. The high temperature plasma is created in the vacuum vessel that provides ultra high vacuum status. Accordingly, it is most important for the vacuum condition to keep clean not only inner space but also surface of the vacuum vessel to make high quality plasma [2]. There are two methods planned to clean the wall surface of the KSTAR vacuum vessel. One is surface baking and the other is glow discharge cleaning (GDC). To bake the vacuum vessel, De-Ionized (DI) water is heated to 130℃ and circulated in the passage between double walls of the vacuum vessel (VV) in order to bake the surface. The GDC operation uses hydrogen and inert gas discharges [3]. In this paper, general configuration and brief introduction of the baking result will be reported.

2. Test equipment and Test methods

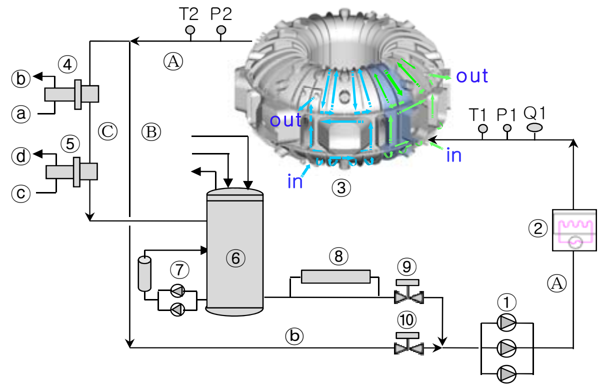
2.1 Test Equipment

The specification of the vacuum vessel is shown in Table 1. The vacuum vessel itself has a double wall with water passages between the walls. Toroidal rings, poloidal ribs, and port stubs are installed in the vacuum vessel.

Table 1: Vacuum vessel specification

Material	STS 316 LN
Thickness	12 T
Weight	42 ton
Width	1.88 m
Height	3.387 m
Inner diameter	2.22 m
Outer diameter	5.98 m
Surface area	80 m²
Target pressure	5×10^{-7} mbar

Fig 1 shows a simplified schematic of the vacuum vessel baking & cooling (B&C) system. There are 8 ports for DI water inlets and outlets with 90° spacing along the toroidal ring on the vacuum vessel upper and lower parts. There are 8 channels in the vacuum vessel. Each channel contains 1 ton of water. The length of each passage is about 40 m.



Ⓐ cooling & baking pipe Ⓑ baking pipe Ⓒ cooling pipe ① circulation pump ② electric heater ③ vacuum vessel ④ pre-cooler ⑤ cooler ⑥ storage tank ⑦ polishing system ⑧ u.v system ⑨, ⑩ cooling & baking on-off valve ⓐ cooling tower water supply (32℃) ⓑ return (37℃) ⓒ chilled water supply (7℃) ⓓ return (12℃)

Fig. 1. Schematic diagram of the VV B&C system

2.2 Test Methods

It took about 2 days for the DI water to heat the vessel up to 100℃. The DI water temperature was reached via an electric heater with a temperature of 110℃. The temperature rate of rise was 1.65℃/hr. The DI water was cooled after the completion of heating. Fig. 2 shows the temperature trend of the 1st baking.

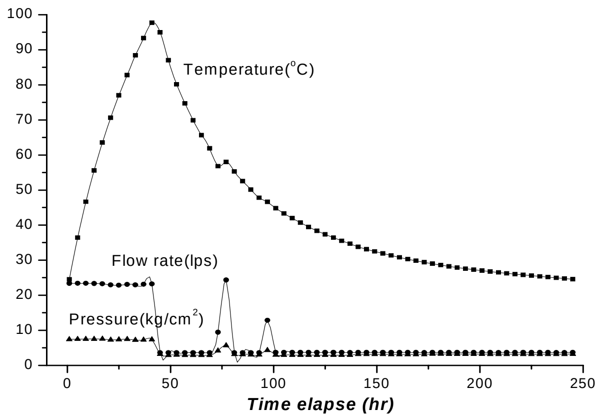


Fig. 2. Graph of 1st baking temperature

In the 2nd baking operation, it took 3 days for the heating of the DI water up to 110℃. The 2nd goal temperature was reached by a 130℃ electric heater. The heated water temperature was maintained for 9 days after reaching 100 ℃. Impurities from the baked surface were exhausted by vacuum pumps. The temperature trend for the 2nd baking operation is shown in Fig. 3.

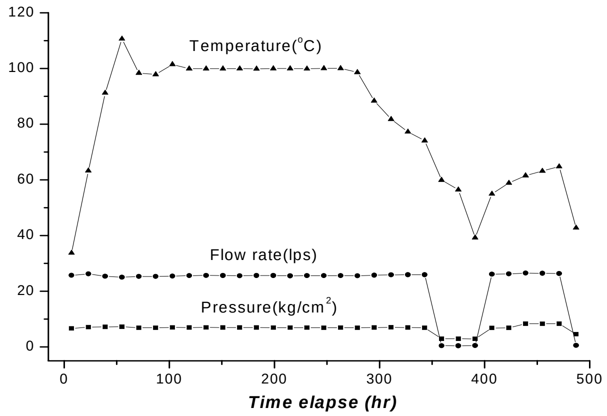


Fig. 3. Graph of 2nd baking temperature

3. Test results

The partial pressures of the major gases were reduced after the 1st baking, because it was the 1st baking operation after the installation. Table 2 shows the partial pressure results of the 1st baking operation. According to table 2, mass 18 was reduced after the baking. Notably, mass 12 and mass 44 were dramatically reduced after the 1st baking operation.

Table 2: Results of vacuum vessel 1st baking

mass No.	Baking before (Torr)	Baking after (Torr)
mass 2	7.50×10^{-9}	6.04×10^{-9}
mass 4	1.03×10^{-10}	6.00×10^{-11}
mass 12	1.07×10^{-9}	4.98×10^{-11}
mass 18	1.46×10^{-7}	2.71×10^{-8}
mass 28	1.87×10^{-8}	4.62×10^{-9}
mass 32	3.86×10^{-9}	1.59×10^{-9}
mass 44	1.22×10^{-8}	6.57×10^{-10}

Table 3: Results of vacuum vessel 2nd baking

mass No.	Baking before (Torr)	Baking after (Torr)
mass 2	1.95×10^{-8}	2.92×10^{-8}
mass 4	9.77×10^{-12}	8.52×10^{-11}
mass 12	4.87×10^{-10}	3.49×10^{-10}
mass 18	1.88×10^{-8}	9.90×10^{-9}
mass 28	1.03×10^{-8}	5.35×10^{-9}
mass 32	8.14×10^{-10}	6.76×10^{-10}
mass 44	4.45×10^{-9}	2.11×10^{-9}

We had to check what effect there was from the first baking. So we opened the vacuum vessel ports. After checking, we kept the vacuum vessel at a very low pressure to perform ion cyclotron resonant heating (ICRH) antenna conditioning twice. It was predicted that the partial pressure of helium might increase due to conditioning twice. But we didn’t inject hydrogen and helium for the antenna conditioning.

The second baking was performed 3 months after the 1st baking and after the antenna conditioning. After the 2nd baking, the partial pressures of all of the gases in the vacuum vessel were reduced except for hydrogen (mass 2) and helium (mass 4). The detailed results of the second baking are shown in Table 3.

4. Conclusions

The partial pressures of most gases were greatly reduced during the 1st baking operation although the relatively large surfaces such as ports and pumping ducts were not baked. The vacuum pressure of the vacuum vessel was reduced from 1.64×10^{-7} Torr to 8.05×10^{-8} Torr after the first baking. After the second baking, the vacuum pressure of vacuum vessel was reduced from 4.85×10^{-8} Torr to 3.47×10^{-8} Torr.

The inner surface of the vacuum vessel should be in a clean state for improved plasma performance. We will install a wall boronization system and increase the baking temperature to 130℃ [4]. The next baking operation of the KSTAR vacuum vessel will be performed in the maintenance stage between 1st and 2nd campaign of KSTAR.

ACKNOWLEDGEMENT

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REFERENCES

[1] LEE, G.S., et al., “Design and construction of the KSTAR tokamak,” Nuclear Fusion, **Vol. 41**, (2001) p1515

[2] S.H. Jeong, et al. “Development of the KSTAR fueling and discharge cleaning systems”, 3rd stage report of development and operation for Korea superconducting tokamak advanced research project (report of research commission)

[3] S.T. Kim, et al. “KSTAR gas fueling and glow discharge system”, 2007 KAPRA & KPS/DPP Conference (2007)

[4] K.S. Lee, et al. “Operational characteristics of the KSTAR gas fueling and wall conditioning system”, 2008 KAPRA & KPS/DPP Conference (2008)