Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2009

Characteristics of Arc Discharge of a JAEA Plasma Generator for KSTAR NB Ion Source

S.H. Jeong[1], T.S. Kim[1], D.H. Chang[1], B.R. Kim[1], C.S. Seo[1], J.T. Jin[1], K.W. Lee[1], B.H. Oh[1]
K. Watanabe[2], M. Dairaku[2], H. Tobari[2], M. Kashiwagi[2], T. Inoue[2], and M. Hanada[2]

[1)] *Korea Atomic energy Research Institute, Daejeon, Korea*
[2)] *Japan Atomic Energy Agency, Japan*
[*] *Corresponding author: shjeong2@kaeri.re.kr*

1. Abstract

As a part of Korea/Japan Nuclear Fusion Collaboration, Japan is developing one of a long pulse ion source, which is composed of plasma generator and accelerator, for KSTAR NBI system. Among them, a plasma generator had been developed in JAEA, and it has been tested at the NB Test Stand in KAERI. For this test the plasma generator has been assembled with an accelerator developed in KAERI for beam extraction. The design parameters of the plasma generator and the experimental will be presented in this topic.

2. Target performance of the ion source

The required performance for the KSTAR NB ion source is to extract D^+ beam of 65A at acceleration voltage of 120kV. It corresponds to 2.65MW injection power of D^o neutral beam when the beam transport efficiency of 85% and the neutralization efficiency of 40% are assumed. This requires very high arc efficiency of 0.65A/kW with D^+ beam and the maximum arc power of 100kW.

3. Design of plasma generator

The plasma generator was designed by using Eleorbit code[1]. The design result shows that electron distributes uniformly in the plasma chamber and electron confinement is good (Fig.1). The physical parameters of the plasma generator are as follows;

- chamber size : 25(W)×60(L) ×31cm(H)
- chamber volume : 45.5lits
- number of filaments : 12(1.8 mm dia.)
- beam extraction area of grid : 220 cm^2

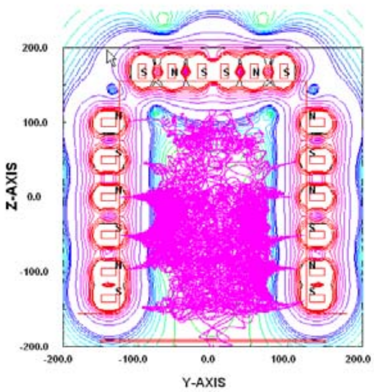

Fig. 1 The result of Eleorbit code. The cross sectional view of Y-Z plane of ion source.

4. Collaborative experiment

4.1 Arc discharge

Before starting arc discharge, the conditioning of the filament was carried out very carefully. In early stage it was operated at low voltage for preventing oxidation of filament surface and then increases filament voltage up to 12V step by step but not exceeds 200A of current per filament.

Arc discharge experiments were carried out in CV-mode from 30V to 70V of arc voltage for each filament voltages. Fig. 2 shows the I-V curve of arc discharge. The arc current reaches 1200A at 63V arc voltage when filament voltage is 12V and gas pressure is 3mtorr.

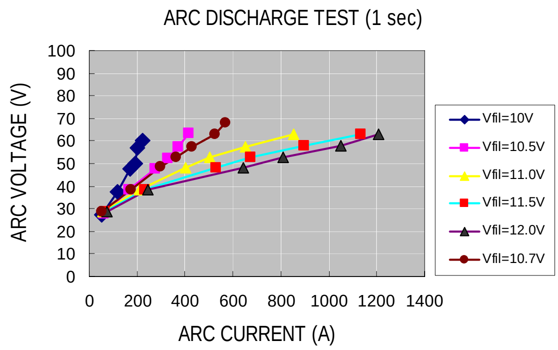

Fig. 2 Arc discharge characteristics

The ion saturation current (J_{is}) was measured by using Langmuir probe near the plasma grid at 74mm from the center of Y direction. Fig. 3 shows that the ion saturation current is nearly proportional to arc power. Considering the beam extraction area of grid, the expected beam current can be estimated as 88A of hydrogen beam when 80kW operation. It is corresponding to 62A of deuterium beam current.

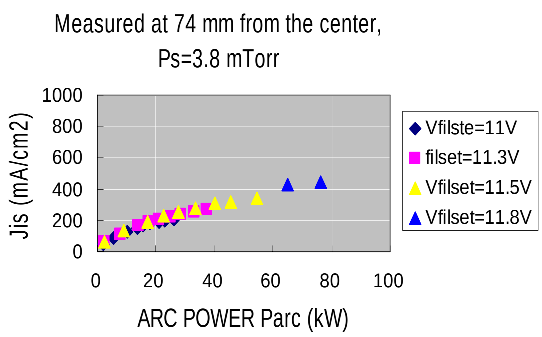

Fig. 3 Ion saturation current measurement

4.2 Plasma uniformity

One of the most important arc characteristic in an azimuthal cusp line source is the uniformity of the plasma density [2]. The Plasma density was also measured with two movable Langmuir probes, one is in Y-direction and the other is in Z-direction. The measured result shows that the plasma is uniform within the perturbation range of less than ±8%.

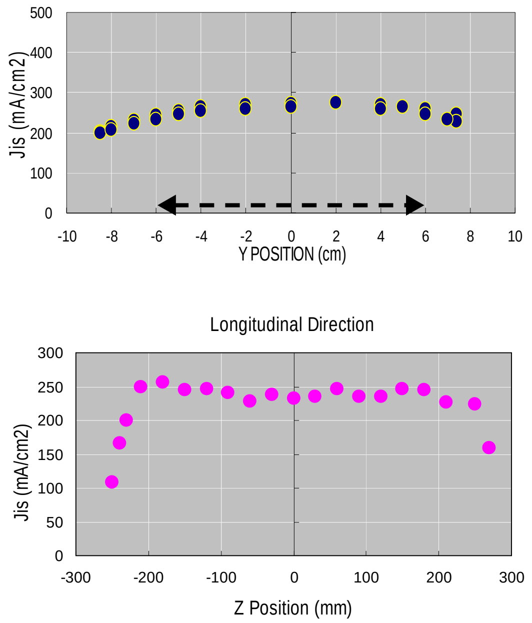

Fig. 4 plasma uniformity

4.3 Arc efficiency

Beam was extracted with hydrogen arc discharge, and the arc efficiency of the ion source was estimated. Fig. 5 shows the arc efficiency v.s micro perveance (uP) characteristics. In order to make perveance scan data, we changed 4 operation parameters such as arc voltage, filament voltage, acceleration voltage, and feeding gas flow rate. The normal operation parameters are 55V of arc voltage, 11V of filament voltage, 75kV of acceleration voltage, and 40sccm of gas flow rate. For this experiment the scanning ranges of each parameter are 40-70V_{arc}, 10-11V_{fil}, 60-75kV_{acc}, and 320-560sccm respectively.

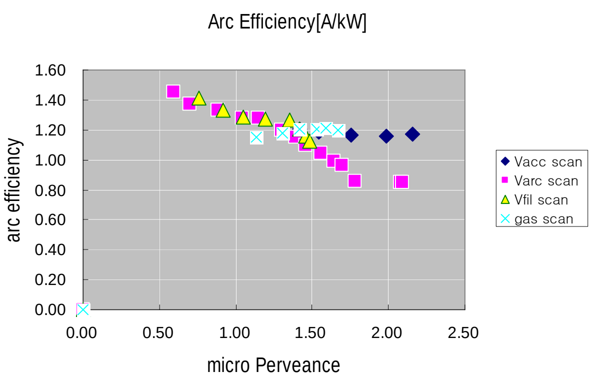

Fig. 5 Arc efficiency of the ion source which is assembled JAEA plasma generator and KAERI accelerator.

During the scanning of both of arc and filament voltage, arc efficiency is decreased from 1.4 to 0.8A/kW, and perveance is increased from 0.6 to 2.2uP. This result comes from variation of arc power. For the cases of scanning of acceleration voltage and gas flow rate, the estimated arc efficiency is 1.2A/kW, which is nearly constant value. Arc efficiency is only little changed although the arc discharging gas is to be changed from hydrogen to deuterium. This means that 55kW arc power is enough to get a target beam current of 65A.

4.4 Long pulse arc discharge

In order to confirm a long pulse operation the temperature of anode outer wall surface was measured with IR thermometer for 200sec arc discharge of 70kW. The temperature rise was about 33 ℃ and there was no over heating components.

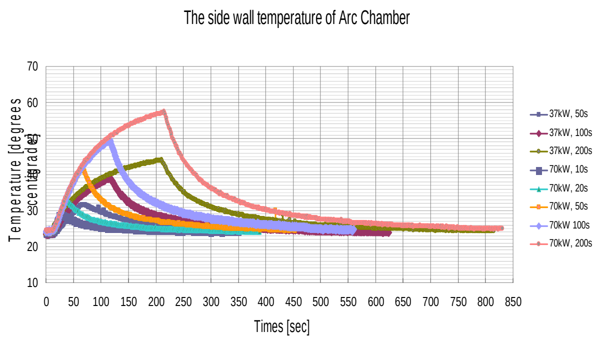

Fig. 6 Side wall temperature of arc chamber[3]

5. Conclusions

JAEA plasma generator assembled with the KSTAR accelerator has been tested at NB Test Stand at KAERI. The summary of the experiments are as follows;

- plasma uniformity has been confirmed within ±8%.
- Long pulse arc discharge up to 70 kW and 200 s was confirmed.
- The target beam current of 65 A can be extracted from 80kW arc discharge.
- A high H^+ arc efficiency of 1.2 A/kW was obtained in the beam extraction experiment.

From these experiments, it was confirmed that the JAEA plasma generator satisfied the performance for the long pulse ion source in KSTAR NBI.

REFERENCES

[1] Y. Ohara, M. Akiba, H. Inami, Y. Okumura, and S. Tanaka, J. Appl. Phys., **61**, 1323(1987).

[2] S. H. Jeong, D. H. Chang, S. R. In, K. W. Lee, B. H. Oh, B. J. Yoon, W. S. Song, J. Kim, and T. S. Kim, Rev. Sci. Instr., **79**, 02B310(2008).

[3] K. Watanabe, et.al., the 3rd Japan-Korea Workshop on Plasma Heating and Current Drive Systems, Toki, Japan, Aug., 5-7, 2009.