Recent Progress in the Negative-Ion-Based Neutral Beam Injectors in Large Helical Device

Y. Takeiri, K. Tsumori, K. Ikeda, M. Osakabe, K. Nagaoka, Y. Oka,
E. Asano, T. Kondo, M. Sato, M. Shibuya, S. Komada, and O. Kaneko

National Institute for Fusion Science, Toki 509-5292, Japan

The negative-ion-based neutral beam injectors (negative-NBIs) have been operated for 10 years in Large Helical Device (LHD), which is the world's largest superconducting fusion-experimental machine. The LHD is equipped with three negative-NBIs, the injection energy of which is 180keV with hydrogen beams [1,2]. The injection power has been increased year by year and achieved to 15MW with three injectors, due to the successive improvement of the negative ion sources.

The ion sources produce high-current negative ions of more than 30A, corresponding to 30mA/cm^2 of the current density. Improvement of the voltage holding ability in the beam acceleration mainly contributes to the increase in the negative-ion beam power. As well as the multi-slotted grounded grid (GG) [3], enlargement of the round aperture of the GG is effective to raising the acceleration voltage. Higher transparency of the GG results in the reduction of the heat load of GG, which should contribute to the rise in the acceleration voltage. Reduction of the co-accelerated electrons is also important to the improvement of the voltage holding. The steering grid (SG), located just downstream the extraction grid (EG), plays a role in preventing the secondary electron generated inside the EG aperture from entering the acceleration gap. The combination of the shape of SG and EG apertures has an influence on the amount of the electron acceleration, and the reduction of the accelerated electrons leads to the improvement of the voltage holding.

The Cs consumption rate is a concern for a long-period operation. Higher-current H^- production needs higher arc discharges, and the evaporation of tungsten filaments is enhanced. Proportional to the tungsten evaporation, the Cs consumption is observed to increase. Related to the Cs recycling, the optical emission spectroscopy is applied to the measurement of the Cs distribution in the arc chamber [4]. Along a line of sight parallel to the magnetic filter field near the plasma grid, an increase in the neutral Cs is observed during the beam extraction.

Recent progress in the negative-NBIs in LHD is overviewed, highlighted to the improved performance of the high-power negative ion sources.

References

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Corresponding Author: Y. Takeiri
takeiri@nifs.ac.jp
National Institute for Fusion Science
Oroshi-Cho 322-6, Toki-City, Gifu 509-5292, Japan
Tel: +81-572-58-2210, Fax: +81-572-58-2622