Analysis of Stress due to Plasma Disruption Current in the KSTAR ICRF Antenna

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1. Introduction

The stress analysis of KSTAR ICRF antenna has been performed by ANSYS^{TM} analytic code. The stress of antenna is caused by the torque of Faraday shield tube which is produced by the induced-current in the case of tokamak plasma disruption. The stress of antenna box and cavity has been analyzed with respect to structural deformation inside the KSTAR RF port. From this analysis, the techniques and mechanism will be prepared, which put ICRF antenna in the rigid position of KSTAR port.

2. Methods and Results

The change of magnetic field is due to the plasma disruption current decay from 2 MA to 0 in 2 ms and vertical drift in the ICRF antenna position [1,2], the cavity current is induced by this varying magnetic field. This induced-current in Faraday shield tube and cavity leads to the stress in the antenna structure. The cavity current has been calculated with the research for KSTAR design [2] and other tokamaks [3,4]. As a result of previous research, the peak current of Faraday shield tube is about 1 kA/tube, and the loop voltage is about 20 V. For the calculation of antenna stress, we assume that the tokamak toroidal magnetic field is 2.68 T (steady), poloidal magnetic field is variable-steady model, and cavity current is peaked 1 kA per tube [2].

Fig. 1 illustrates the schematic ICRF antenna, and configuration of Faraday shield tube. The material of Faraday shield tube is Inconel 625, and antenna box is SUS316.

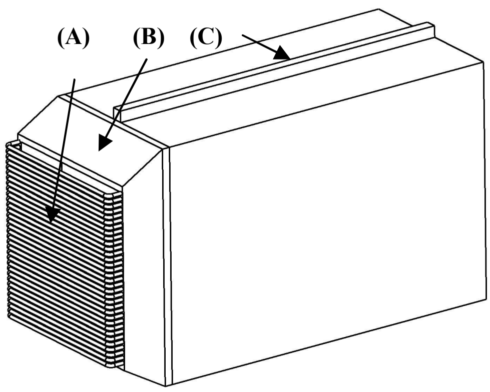

Figure 1. Schematic diagram of ICRF antenna, Faraday shield tube (A) and cavity (B).

The dimension of antenna is 730W×1030H×1865L mm^3, antenna is composed of the shell-type main box of 20 mm thickness, inter-plate of 35 mm, cavity of 200 mm length, and Faraday shield tube of Φ5/8″(Fig. 2).

Figure 2. Single component of 5/8″ Faraday shield tube.

The ASME yield stress (S_m) for Inconel 625 of Faraday shield tube is about 252 MPa for temperature up to 149 °C, and the allowable thermal stress is 3 S_m, if there are no other stresses. The Faraday shield tubes of ICRF antenna satisfy these requirements from the early design study [2]. In addition, the stress of antenna structure must be analyzed, so the ANSYS^{TM} analytic code is used in this work.

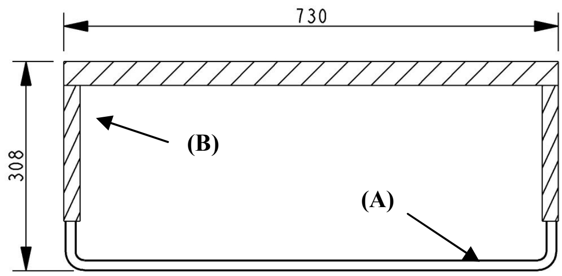

Figure 3. Current loop of Faraday shield tube (A) and cavity wall (B). The orientation of disruption-induced current is count-clockwise.[mm]

The main forces on the antenna frame are caused by the torque of side part (Fig. 2-A) in the Faraday shield tube. The cross product of tube current and local toroidal magnetic fields generates the bending forces, which lead to the stress of antenna frame. Fig. 3 shows the single loop of induced-current, there are 33 Faraday shield tubes in the KSTAR ICRF antenna. The analysis of these mechanism is performed by the procedure of 3D-Model, CFX^{TM} meshing and ANSYS^{TM} structural analysis.

The optimum installation techniques are determined. The ICRF antenna will be positioned into the KSTAR port with two bottom rail, and the mechanism of key and keyway (Fig. 1-C) will be adopted in the bottom and top of antenna at the duplicated position, so both key and keyway structures will fasten the connection of antenna with KSTAR port. This antenna structure will stand up to the stress of antenna in this work.

3. Conclusion

The stress of ICRF antenna caused by plasma disruption current of KSTAR tokamak is analyzed by using the simplified model and ANSYS^{TM} analytic code, and the optimum installation method in the vacuum port is prepared for the antenna structure. Next step, the thermal analysis of antenna and other plasma-induced forces will be considered. The ICRF antenna will be operated stably by using these stress analysis and appropriate installation mechanism.

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