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Design and application of GDC on EAST Tokamak

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ABSTRACT

On EAST Tokamak, DC glow discharge (GDC) is developed to clean the first wall of plasma. It can effectively control the recycling of H, C, O impurities and improve the wall conditions. There are four GDCs which distribute equally on the EAST Tokamak vacuum vessel wall. Each GDC is equipped with an anode, a stainless steel cover and four support legs. The anode is insulated from cover with Al_2O_3 ceramics. After a round of experiment, the value of insulation resistance of GDC decreases remarkably due to metallization. To protect the insulation parts and heighten the reliability, ceramic protection covers are used on the GDCs. The other measures which can heighten insulation grades are also taken. After upgrade, the insulation resistance of each GDC between anode and ground is raised highly. When the pressure reaches 4 Pa, H_2-GDC and He-GDC is strarted. Boronation and siliconization are also applied to the device wall conditioning. After GDC cleaning, the impurities and partial pressure of remainder gases in vacuum vessel (VV) is decreased greatly and vacuum degree of VV can reach high easily.

1. Introduction

Glow discharge cleaning is a basic wall conditioning method to decrease the oxygen (O), carbon (C), hydrocarbon and other impurities from the plasma facing wall and improve wall conditions in tokamak device [1–3]. It originates from the air discharging under low pressure.

After the treatment of mechanical polishing, chemical cleaning, baking, and other Ultra High Vacuum technologies, the stainless steel surface and plasma facing wall still contain C, O and their compounds which are the main sources of low-Z impurities generated by chemical sputtering during plasma discharge. The metallic atoms, sputtering redeposit atoms and metal-oxide atoms which have been produced by the interaction of the plasma with walls and limiter are left loosely on the wall surface and have a much higher sputtering yield and vaporization rate [4–7].

The first wall of EAST tokamak is totally coated with graphite tiles. GDCs are used to remove impurities absorbed by the graphite. There are four DC GDCs which distribute evenly on vacuum vessel wall. The schematic of GDCs distribution is shown as Fig. 1. The power source of GDC is connected to the anode through insulation cable, insulation electrode and its flange. Then the circuit is formed through GDC, operation gases and VV wall. Two GDCs anodes share one DC power supply. The voltage of power supply can adjust between 0 and 1200 V. And the current can range from 0 to 8 A. The GDCs can discharge, boronize, siliconize and etc. with different operating gases such as H_2, He, $C_2B_{10}H_{12}$, SiH_4 according to vacuum requirements to clean first walls.

Before glow discharging, the VV wall and plasma facing wall are baked to 200 °C for several days, the highest baking temperature can even reach 350 °C.After glow discharging, the remainder gases such as H_2, D_2, H_2O, O_2, CO, CO_2 and CH_4 reduce remarkably.

2. Design and update of glow discharge

There are four GDCs situated at Port C, G, K and O of the EAST device respectively. The fixing position of GDCs is far behind movable limiters. During operation, only two of them operate. The other two is for spare.

The prototype of GDC is from ASDEX. Each GDC consists of an anode, a lamp mantle-shaped cover, four support legs and several insulation ceramic parts. The size of anode is 25 mm in diameter and 450 mm in length. And the material is stainless steel 316. It is convenient for manufacture and has a higher strength. Two power cables are introduced to the anode from two sides. One is for use and the other two is for spare. The cover is linked to VV wall directly through support legs. The material of cover and support legs is still stainless steel 316. The anode is insulated from other parts with Al_2O_3 insulation ceramics. The VV wall acts as cathode in the circuit.

The prototype of GDC is shown as Fig. 2. The height of insulation ceramics cylinder is about 3 mm. And there is no shield for these insulation ceramics. The distance between cover and transition plate is about 2 mm. After a round of test, the insulation resistance of GDC reduces remarkably due to metallization. The insulation resistance of GDC even turns to zero on some occasions. So the structure of GDC must be upgraded.

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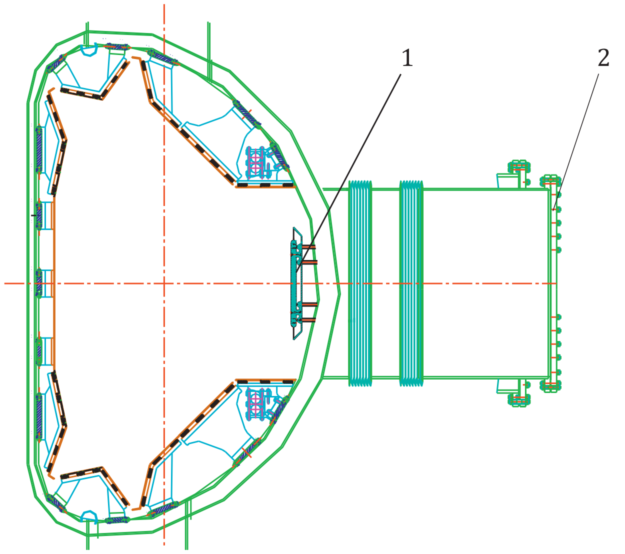

Fig. 1. Schematics of GDCs distribution 1. GDC, 2. Port (C, G, K or O).

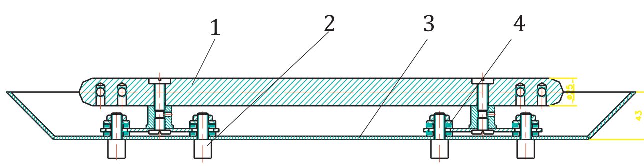

Fig. 2. Prototype of GDC (1) anode, (2) support leg, (3) lamp mantle-shaped cover and (4) insulation ceramics cylinder.

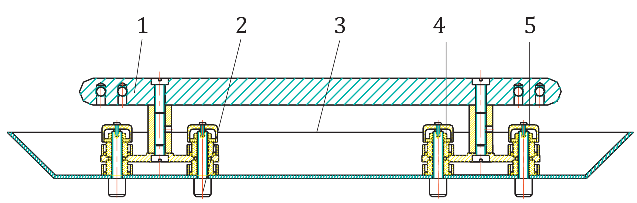

Fig. 3. The 2nd generation of GDC (1) anode, (2) support leg, (3) lamp mantle-shaped cover, (4) insulation ceramics cylinder and (5) shield cover.

During the first structure upgrade, the height of insulation cylinder is increased. Accordingly the distance between stainless steel cover and transition plate is enlarged. The shield covers are added to protect insulation cylinders (as Fig. 3). Material for shield cover is also Al_2O_3 insulation ceramics. However, after a round of test the resistance value of GDC still drop sharply due to metal sputtering between the insulation cable and anode. Another structure upgrade should be carried out.

To protect the insulation cable of outlet from metallization, the extension ceramics pipes made of Al_2O_3 insulation ceramics are added on both sides of anode (as Fig. 4). The cable is linked to anode through inside of pipe from both sides.

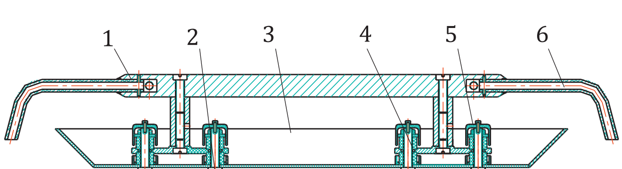

Fig. 4. The 3rd generation of GDC (1) anode, (2) support leg, (3) lamp mantle-shaped cover and (4) Insulation ceramics cylinder, (5) shield cover and (6) extension pipe.

Fig. 5. The 3rd generation of GDC before (left) & after (right) discharging.

The 3RD generation GDC installed on the EAST device is shown as Fig. 5. The left picture was taken before discharging. And the right one was taken after discharging. The insulation resistance of GDC must be measured with megohmmeter before or after discharging. It is aimed to find the variation tendency of the resistance. The value of measurement will be listed in next section.

After two times upgrade, the insulation grade and the performance of GDC is raised evidently. The reliability of GDC is also improved consequently.

3. Experiment on GDC

3.1. Insulation resistance test

The insulation resistance must be measured before or after discharging to ensure whether it is alright or not after the GDCs is installed on the EAST device.

Before structure upgrade, the insulation resistance value for each GDC before the discharging is about 23–25 MΩ when the applied voltage is 1170 V. After upgrade, the insulation resistance value before the discharging changes to 50–60 GΩ. So the insulation resistance value increased remarkably due to the upgrade.

However, the insulation resistance value will still decrease gradually during discharging. The value of insulation resistance value changes to 24 MΩ or so after discharging. It has a big difference with the value before discharging. But after a period time observation, you will find the varying rate of value tends to change slowly. It can still meet the requirement of glow discharging.

3.2. H_2 glow discharging

After machine opening or a disruption, H_2 glow discharging (H_2-GDC) is employed to clean impurity such as oxygen (including oxide) and oil absorbed on the wall [8]. Before H_2 glow discharging,