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THE ROLE OF LIMITER IN EGYPTOR TOKAMAK

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Abstract

In Egyptor Tokamak, the limiter is used for separation of the plasma from the vessel. In this work, an overview of limiter types, and construction of limiter in Egyptor Tokamak is discussed. Also, simulation results of the radial electron density distribution in case of limiter are presented. The results of the simulation are in agreement with the experimental and analytical results.

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INTRODUCTION

The impurities in the Tokamak plasma give rise to radiation losses, the restriction of their entry into the plasma plays a fundamental role in the successful operation of Tokamaks. They cause radiative power loss and can lead to significant fuel dilution. At high concentrations the impurities prevent the plasma being heated, this is a problem during the start up phase. Impurities are emitted from the walls usually by physical sputtering and chemical erosion [1]. The impurities which are most easily released are those adsorbed on the surfaces with low binding energies. The concentration of impurities in the plasma must be kept below tolerable levels with respect to fuel dilution and radiation [2]. Concentration of 2-5% carbon, and 0.5-2% oxygen and the order of $10^3$ to $10^6$ for metals are usually considered acceptable, with large variation depending on the temperature and on the simultaneous presence of different species [3]. This requires a separation of the plasma from the vessel wall. The Tokamak plasma must be bounded by limiters or magnetic divertors. The first is to define an outer boundary of the plasma with a material limiter. In this work an overview of limiter types, and construction of limiter in Egyptor Tokamak is discussed. Also simulation results of the radial electron density distribution in case of limiter are presented.

TYPES OF LIMETER

Limiter is a technique to define an outer boundary of the plasma with a material limiter. A limiter is a solid surface, which defines the edge of the plasma. Limiters take various geometrical forms [4]. The simplest concept is a circular hole in diaphragm, placed normal to the toroidal field, the hole diameter being smaller than the vacuum chamber. This is the first type known as a poloidal limiter. The second geometrical form is rail limiter and the third is toroidal limiter. The limiter plays a number of roles in the operation of Tokamak: firstly it protects the wall from the plasma when there are disruption, runaway electrons, or other instabilities. Also it localizes the plasma surface interaction and the particle recycling. Materials of limiters have to satisfy a number of criteria. The criteria for the choice of first wall materials can be concluded in the following way:
1. Low impurity production rate to avoid significant fuel dilution and to minimize energy loss.
2. Low erosion losses.
3. Sufficient mechanical strength.
4. They must withstand thermal shock (high heat loads), such as molybdenum or tungsten.
5. Gas retention and release properties.

BOUNDARY LAYER

In case of using limiters, the plasma edge in the Tokamak is determined by the limiters. Field lines outside the surface determined by the limiters are called separatrix. The magnetic surfaces inside the separatrix are closed, while outside they are open where they intersect wall or limiter components. Considering a flux tube outside the boundary, particle balance is determined by cross field diffusion together with loss rate along field lines to the limiter. Figure (1) shows a schematic diagram of plasma edge in case of limiters.
Fig. (1) Schematic diagram representation of the plasma edge.

Ions diffused across the separatrix are represented by the flux $\Gamma$ and they move along the magnetic field lines with flux $\Gamma_{11}$, to impinge on the limiter as such or as charge exchange neutrals. They may be reflected or adsorbed or otherwise trigger powerful release mechanisms as desorption or sputtering. On the other hand, atoms and molecules which escape from the wall or limiters undergo different processes like excitation, dissociation, charge exchange and often most important of all ionization.

**EXPERIMENTAL FACILITY**

**Construction of Egyptor**

Essential parts of the Tokamak experiment “EGYPTOR” typically components of “UNITOR”. Whereby cooperation between Egypt and Germany “UNITOR” was transferred to Authority of Atomic Energy in Egypt [5]. The vacuum vessel, coil systems, control units and discharge cleaning oscillator of “UNITOR” were designed and constructed by Bob Taylor, UCLA [6]. Charge units, capacitor banks, vacuum systems, as well as the control units for voltage, pressure and temperature by means of the microprocessor system were built by the facilities of Physics Institute II, University of Düsseldorf. The main parameters of EGYPTOR: major radius $R = 0.3$ m, and minor radius $a = 0.1$ m. In the first phase of “UNITOR” installation of a toroidal magnetic field $B = 1.2$ T and a plasma current up to $50$ kA are provided by the power supplies. This lead to electron densities and temperatures of $4 \times 10^{13}$ cm$^{-3}$ and $150$ eV respectively. The ion temperature reaches $50$ eV, and the discharge current pulse width was nearly $45$ ms [7].

**Construction and Specification of Limiter for Egyptor**

In Egyptor Tokamak for the simplicity of construction and installation we used the rail type as indicated in figure (2).
Two parts are installed along the diameter of torus. This limiter has the following specification: the material is stainless steel; the geometrical lengths are (150 mm x 15 mm x 10mm) as shown in figure (2). The position of the limiters is 10 mm in front of the first wall. The vacuum is kept at high quality as before the installation.

EXPERIMENTAL RESULTS

"UNITOR" Operation with Rail Limiters

In 1983 it was proposed to install beryllium rail limiters in Unitor to study the compatibility of this material with the Tokamak plasma [7]. Two beryllium rail limiters were installed at nearby opposite toroidal positions. Each limiter consisted of a massive beryllium block with an area of 3x6 cm² facing the plasma 3 cm in the toroidal and 6 cm in the poloidal direction. The beryllium limiters are mounted on holders movable in radial direction, thus varying the minor radius of the plasma. A typical power load on the beryllium surface was about 2 kW/cm². Figure (3) shows the pulse width of the plasma current as the function of radial limiter position is measured for beryllium limiters and compared with the result of other limiter materials. The duration of plasma current is a sensitive measure for the degree of plasma contamination. Figure (3) also shows that beryllium gives longer pulses than graphite. In case of beryllium rail limiter the number of disruption is considerably reduced.

Initial "EGYPTOR" Operation with Rail Limiters

After the limiter for the Egyptor device is installed, both fast battery of the ohmic heating system and the toroidal field battery are charged at V= 4 -9 kV, C= 87 µf, and V= 1 kV, C = 83750 µf receptively, the hydrogen gas pursuer is adjusted to 3x10⁻⁴ tor. The same procedure is repeated at different values of the fast battery and different gas pressure. It is noticed that, the optimum gas pressure for breakdown differs than before by 2, where the old value was 3x10⁻⁴, and the new was 5x10⁻⁴ at the operating conditions without any auxiliary cleaning. In case of limiter the simulator used
before in [8] has been carried to produce the radial density distribution in case of the minor radius becomes 9 cm. The computer run for the radial distribution of electron density is presented in figure (4).

![Figure 3: Duration of plasma current as function of radial limiter position for various materials](image)

**Fig. (3) Duration of plasma current as function of radial limiter position for various materials**

![Figure 4: The radial distribution of electron density](image)

**Fig. (4) The radial distribution of electron density**

**CONCLUSION**

It is concluded that a successful installation of the limiter for Egyptor Tokamak had been done. The initial plasma after the installation of limiter was the same high quality for vacuum pressure as before the installation. Also the radial density distribution in case of the limiter are obtained. The results of the simulation agree well with the previous experimental and analytical results.
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REFERENCES