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Understanding of the Dynamo Effect by the Difference in Formation Method of the RFP Plasma

RFPプラズマの異なる形成法によるダイナモ効果の理解

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Reversed field pinch (RFP) is one of the toroidal current carrying systems for nuclear fusion research. The magnetic configuration of the RFP plasma is mainly self-generated by the dynamo electric field. There are two methods for the RFP formation. One is the “added-reversal method”, and the other is the “self-reversal method”. In added-reversal method, the toroidal magnetic field is reversed forcibly. It can form a good confinement of the RFP configuration. However, it is difficult to understand function of dynamo physics in detail. On the contrary in the RFP plasma by a self-reversal method, the toroidal magnetic field is reversed by only dynamo electric field spontaneously. Although the confinement is not so good, it will be possible to understand the dynamo physics in detail.

1. Self-Organization

In general, the structure in nature spontaneous develops toward the uniform state, because entropy increases. However the favorable energy source and also favorable dissipations exist in a same time, the initial structure is often maintained with a quasi-steady. Consequently, the especial non-uniform structure is materialized against the normal dissipation. This process is so called “Self-Organization”. The self-organization is one of the most essential phenomena in nature. The magnetic field structure of the sun or the earth is self-organized by the dissipation of the gravitational energy source [1]. These energy conservations of a magnetic field are considered to be dynamo events. Dynamo is the mechanism of a conversion from the thermal, mechanical or electromagnetic energy to the specific magnetic configuration. However a lot of interesting phenomena with dynamo have been measured in nature, the physics of the self-organization with dynamo effect and its process of the development are still not fully cleared up. In this research, the self-organization process with the dynamo activity is investigated experimentally in the reversed field pinch (RFP) plasma [2-4].

2. Reversed Field Pinch Plasma

The RFP plasma is one of the toroidal current carrying systems for the nuclear fusion research. Because of the low magnetic field, the RFP plasma has the possibility that it can realize a high economy nuclear fusion reactor having.

The RFP plasma is confirmed by the helical magnetic field, which is composed of the toroidal and poloidal magnetic fields. Figure 1 shows the magnetic field structure and toroidal and poloidal magnetic field distributions of the RFP plasma. The characteristic of the RFP configuration is that the direction of the toroidal magnetic field reverses. Such magnetic field structure has a strong magnetic shear. During the RFP discharge, its configuration is strong self-organized by the dynamo electric field. Dynamo phenomenon in the laboratory plasmas is caused by the conversion from the electromagnetic energy to the magnetic configuration. The plasma fluctuations play an important role in a formation of the RFP plasma. However the electric field due to

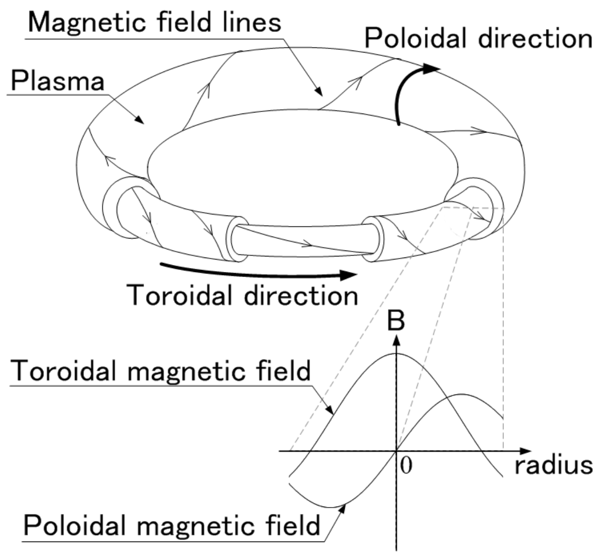

Fig.1. The magnetic field structure and toroidal and poloidal magnetic field distributions of the RFP

the fluctuation is generated the RFP configuration, the fluctuation causes a loss of the energy and particles. In the RFP plasma, anomalous phenomena with dynamo have been measured, for example, an anomalous plasma resistance, a strong ion heating, etc. These interesting phenomena are caused by the non-conserved energy flow with dynamo events. It is important for the improvement of the plasma confinement to understand the dynamo effect with the plasma fluctuation.

3. Added-Reversal and Self-Reversal Methods

There are two methods for formation of the RFP configuration. One is the “added-reversal method (AR method)”, and the other is the “self-reversal method (SR method)”. In the AR method, the toroidal magnetic field is reversed enforcedly by an external circuit. The RFP plasma, which formed by AR method, has the good plasma confinement, but it is difficult to understand the magnetic field reversal with the dynamo phenomena. In the SR method, the toroidal magnetic field is spontaneous reversed by only the dynamo effect. The RFP plasma has the poor plasma confinement, but the dynamo physics can be possible to understand.

4. Experimental Setup and Results

ATRAS is a middle sized RFP device with major and minor radii of R=0.5m and a=0.09m, respectively.

Figure 2 shows the typical waveform of the RFP discharge by using AR (dotted lines) and SR (solid lines) methods. In the AR method, typical parameters of RFP discharge are a plasma current of 50kA, pinch parameter of 2.1, reversal parameter of -0.5, and discharge duration time of approximately 1.6ms. In the SR method, maximum plasma current is also 50kA. In both methods, the maximum plasma current and loop voltage are almost same. In addition, the increasing rate of the plasma current is also almost same. On the other hand, the increasing rate of the averaged toroidal magnetic field is different and is large in case of the SR method as compared with that of AR method. In case of the SR method, the reversal of the toroidal magnetic field is weak as compared with that of the AR method. This result indicates that the plasma cannot generate the strong reversal magnetic field. We can see that the plasma discharge is terminated rapidly in case of SR method because the reversal toroidal magnetic field is weak and the safety factor of the plasma edge is nearly zero. The Θ/(1-F) seems to be almost same. The strength of plasma fluctuations also seems to be almost same.

5. Conclusions

Dynamo is important for the formation of the RFP configuration. However, since dynamo phenomena are caused by the MHD fluctuation, loss of energy and particles with the fluctuation becomes a serious problem. To understand the dynamo physics in the RFP plasma, the RFP configuration is formed by a SR method. The characteristics of the RFP plasma formed by a SR method were investigated. In the poster, experimental setup, results and conclusive summary are presented.

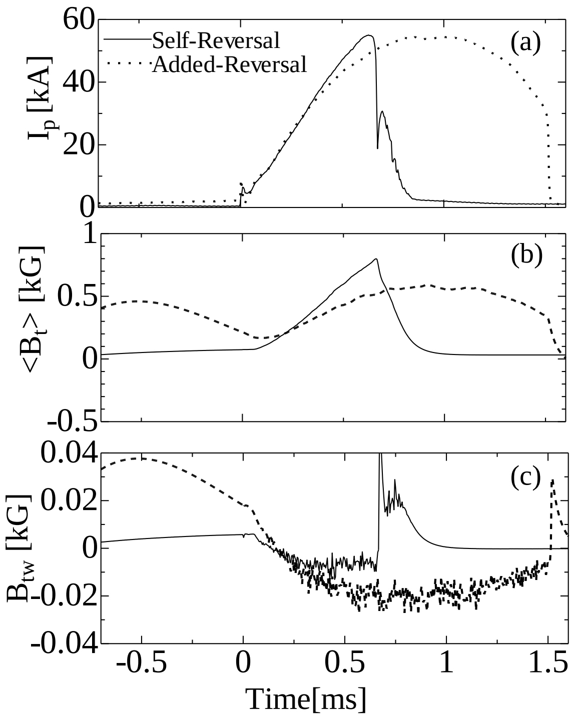

Fig.2. Typical waveform of the RFP discharge by using added-reversal (dotted line) and self-reversal (solid line) methods. (a) Plasma current, (b) the averaged toroidal magnetic field, (c) the toroidal magnetic field at the edge.

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