ROLE OF PARALLEL AND PERPENDICULAR FLOW SHEARS IN THE EXCITATION AND THE SUPPRESSION OF SEVERAL TYPES OF LOW-FREQUENCY PLASMA INSTABILITIES

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ABSTRACT

We have developed the two plasma sources using a concentrically three-segmented plasma (ion) emitter, with which the parallel and perpendicular flow shears can be controlled, respectively. In the case of parallel flow-shear experiments, the drift-like, ion-acoustic-like, and Kelvin-Helmholtz instabilities are found to be excited by the parallel shear. In the case of perpendicular flow-shear experiments, on the other hand, the drift-like instability which exists in the edge region is suppressed by the perpendicular shear in the central region. The combined effects of radial density gradient and parallel/perpendicular flow shears are important for controlling the low-frequency instabilities in magnetized plasmas.

INTRODUCTION

Magnetic field-aligned and transverse sheared plasma flows in space, laboratory, and fusion-oriented plasmas have been regarded as playing an important role in the generation of plasma fluctuations and turbulences, which induce cross-field transport. Concerning one of the dynamic couplings between the Earth's ionosphere and magnetosphere, the satellite observation is significant that the characteristic of the plasma flow shear changes as the altitude becomes higher. Namely, the magnitude of the shear in the field-aligned (parallel) plasma flow decreases gradually with shears in the transverse (perpendicular) flow relatively constant with altitude. Therefore, plasma processes associated with a transition from parallel flow shear to perpendicular flow shear appear to be important and interesting. In this sense, we claim that the external control of parallel and perpendicular ion flow shears is a key of experimentally clarifying general features of the topic associated with the origin of induced plasma-turbulence and transport. The aim of the present work is to carry out laboratory experiments on low-frequency instabilities excited and suppressed by parallel flow shears and perpendicular flow shears, which are independently controlled using newly-developed two plasma sources.

EXPERIMENTAL RESULTS AND SUMMARY

Experiments are performed in the Q_T-Upgrade machine of Tohoku University. In the case of parallel flow-shear experiments, we attempt to modify a plasma-synthesis method with oppositing electron and potassium ion emitters. The ion emitter is concentrically segmented into three sections. The field-aligned ion flow with radially different energy, or the parallel ion flow shear, is generated in the radially uniform plasma potential when each section of the segmented ion emitter is individually biased at a positive value above the plasma potential. This parallel shear is found to give rise to several types of low-frequency instabilities. One is observed around the radial center. This instability is localized around the region of the parallel flow shear, the characteristic of which changes when the sign of shear is reversed. From this result, the instabilities are considered to be related to the Kelvin-Helmholtz instability driven by the parallel flow shear and the ion-acoustic-like instability modified by the shear [1]. Another is observed in the edge region where the density gradient is relatively large. This instability appears to be related to the drift-like instability, which is also modified by the parallel shear in the central region.

In the case of perpendicular flow-shear experiments, on the other hand, a plasma is produced by a three-segmented tungsten hot plate in a single-ended Q machine. When each of the hot plate is individually biased, the radially different plasma potential, or radial electric field is generated. This electric field causes the ExB flows and flow shears perpendicular to the magnetic-field lines. When the radial electric field in the central region is almost zero, the low-frequency instability is observed in the density gradient region (edge region). The fluctuation amplitude of this instability gradually decreases as the radial electric field in the central region increases. The frequency of the fluctuation corresponds to that of the drift instability. This result indicates that the drift-like instability excited in the edge region is suppressed by the radial electric field, or perpendicular flow and flow shear.

In summary, we have developed the two plasma sources which can control the parallel and perpendicular flow shears, respectively, and observed the drift-like, ion-acoustic-like, and Kelvin-Helmholtz instabilities excited and suppressed by the shears. Finally, we emphasize the importance of combined effects of radial density gradient and parallel/perpendicular flow shears on low-frequency instabilities in magnetized plasmas.

REFERENCES

[1] V. V. Gavrishchaka, S. B. Ganguli, and G. I. Ganguli, "Origin of low-frequency oscillations in the ionosphere," *Phys. Rev. Lett.*, vol. 80, pp. 728-731, January 1998.