2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Nonmodal evolution of the current-driven instabilities of plasmas with shearing current

V. S. Mykhaylenko[1], V. V. Mykhaylenko [2], Hae June Lee[3]

[1]Plasma Research Center, Pusan National University

[2]BK21 Plus Information Technology, Pusan National University

[3]Department of Electrical Engineering, Pusan National University

vsmikhailenko@pusan.ac.kr

It is acknowledged last time that the usually applied normal mode analysis fails to predict the behavior of the instabilities of the fluid and plasma shearing flows [1-7]. The origin of this problem is in the traditional application the modal eigenmode approach to the shearing flows with constrain the modes to have static structure not changing with time. The modal approach neglects by the obvious physical effect when it applies to shearing flow: the perturbations in the shearing flow are convected by the shearing flow and experience the distortion by the shearing flow. This distortion is growing with time and forms the time dependent process, which is governed by the flow shearing. This effect is accounted for by the non-modal theory grounded on the methodology of the shearing modes [3, 6, 7, 8]. These modes are the waves that have a static spatial structure in the frame of the background flow and are observed in the laboratory frame as the perturbations with time dependent structure determined by the flow shearing. The temporal evolution of the shearing modes is investigated by the employment of the initial value scheme, which does not impose any constrains on the form that solution may take.

The principal difference between fluids and plasmas is the possibility of the relative motion of plasma species (electrons and ions), i.e. of the current in the applied electric and magnetic fields. The current driven instabilities of a plasma are the most ubiquitous in space, controlled fusion, and laboratory plasmas. Generally, the electric and magnetic fields are inhomogeneous in plasmas and the current velocity formed by the relative motion of plasma species is spatially inhomogeneous and sheared. The investigations of the current velocity shearing effect on the temporal evolution of the instabilities, turbulence and anomalous transport in plasmas with inhomogeneous electric field can't be performed with employment of the modal approach and is missing to date.

The new analytical nonmodal approach to the investigations the instabilities driven by the sheared current is presented and applied to the analysis of the evolution of the instabilities in the crossed inhomogeneous electric and magnetic fields. We found analytically new results of the strong nonmodal growth for numerous instabilities driven by the shearing current which dominates the normal mode growth when the shearing rate of the current velocity is above the growth rate of the current driven instabilities with uniform current. It includes also the nonmodal growth for the subcritical perturbations, which are suppressed in plasma with steady uniform current. This result completely changes the physics of the current driven instabilities with a shearing current for which the validity of the normal mode linear theory is generally accepted.

The work was funded by National R&D Program through the National Research Foundation of Korea (Grant NRF-2017R1A2B2011106), and BK21PLUS, Creative Human Resource Development Program for IT Convergence.

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