structure of current sheets and manifestations of two-fluid plasma properties

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Current sheets differ in structure both in natural conditions (including the Earth magnetosphere) and in laboratory experiments. Of a special interest is finding out relations between a sheet structure and an impact of various processes in current sheet dynamics. As was demonstrated earlier, there exists a fundamental similarity of current sheets in the tail region of the Earth magnetosphere and in laboratory conditions [1, 2]. This similarity is an evidence of the universal character of physical processes in space and laboratory plasmas. Investigations of structure and dynamics of current sheets in laboratory experiments allow us obtaining results, which may be useful for analysis and modeling the space phenomena.

One of the most intriguing problems is clearing up conditions when two-fluid plasma properties could come to play, resulting in generation of the Hall electric fields and currents in current sheets. It follows from general physical reasoning that the Hall effect should take place primarily in relatively thin current sheets with a thickness (or a minor transverse size) that is close to the ion inertial length.

In experiments with the device CS-3D the measurements were performed of current density distributions along the normal to the current sheet mid-plane in two cross-sections. It was shown that these distributions in “physical quantities” did not depend practically on the sort of a gas, in which current sheets were formed: the maximum current densities were (4 ÷ 5) kA/cm2, and the sheet thicknesses were about 1 cm. By contrast, in dimensionless units, when the current sheet thickness was normalized on the ion inertial length, the current distributions changed significantly under changing the working gas: in Ar and Kr the sheet thicknesses were of the same order as unity, or even less than unity, while in He the thickness was several times larger than unity. In other words, we can produce experimentally either thin or thick current sheet under changing a gas filling the vacuum chamber. It should be forthcoming that phenomena caused by the Hall effect could take place mainly in thin current sheets [3, 4].

Excitation of the Hall currents may be indicated by appearance of the quadruple longitudinal magnetic field directed along the main current in the sheet [5]. By comparing longitudinal magnetic field components in current sheets formed in Ar and He gases we demonstrate that the Hall effect is really much more pronounced in thin current sheets. These results allow giving interpretation for a set of spacecraft observations in the tail region of the Earth magnetosphere.

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References

1. Artemyev A.V., Petrukovich A.A., Frank A.G., Nakamura R., Zelenyi L.M. // J. Geophys. Res. 2013. V. 118. P. 2789.
2. Frank A.G., Artemyev A.V., Zelenyi L.M. // JETP 2016. V. 123. P. 699.
3. Frank A.G., Ostrovskaya G.V., Yushkov E.V., Artemyev A.V., Satunin S.N. // Cosmic Res. 2017. V. 55. P. 46.
4. Yushkov E.V., Frank A.G., Artemyev A.V., Petrukovich A.A., Nakamura R. // Plasma Phys. Rep. 2018. V.44 (12).
5. Frank A.G., Bugrov S.G., Markov V.S. // Phys. Plasmas. 2008. V. 15(9). P. 092102.