Compact railguns for plasma studies

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Electromagnetic rail accelerators (railguns) are widely used to accelerate small bodies and plasma in studies of the effect of impact or high-speed flow on an obstacle. The problem of acceleration of small-size pellets (1-3 mm) to high speeds (more than 5 km/s) attracts considerable attention of researchers. This subject is important for investigations in the area of high-temperature plasma where pellets are used to bring fuel to the zone of thermonuclear reactions, to carry out diagnostics of plasma, and also to control the reactor operating regimes. Injection of pellets made of a material with a high atomic number is regarded as a tool for emergency shut-down of thermonuclear reactors. The speed of pellets on modern ITER-like setups must be higher than 5 km/s to bring a material to the central zone of the reactor. There are also other areas where high-speed pellets of the mm-size can be used. Also railguns can be used as a high-speed plasma jet source.

Acceleration of mm-size bodies to hypervelocities is a complicated problem because losses appreciably increase and the acceleration efficiency considerably decreases with decreasing accelerator calibre. In the report, the results obtained for the compact railgun developed at Ioffe Institute are presented. It is shown that the use of the "fast railgun" concept does not ensure high speeds in the case of small calibres because of a considerable rail erosion at the initial stage of acceleration. To solve this problem, an application of additional external pulsed magnetic field in the direction of the rails' magnetic field was suggested. Its magnitude should be approximately equal to that of the rails (~10 T). By using this approach, an original compact railgun for acceleration of 1-2 mm dielectric bodies to high speeds by the plasma piston was developed. It is shown that a 2x2 mm^2 dielectic body with a mass of 10 mg can be accelerated to 5.7 km/s at the acceleration distance of 160 mm.

Also in the report a results of the studies of the railgun without a solid pellet will be presented. It is shown that in this case it can be used as (i) strong shock wave generator, (ii) high-speed plasma jet source. In this studies the plasma was accelerated in the magnetic field of the current that flew through rails-electrodes and the plasma piston. The plasma chemical composition was determined by the material of the electrode surface ejected to the plasma piston due to the erosion caused by the discharge current. It was found that (i) the plasma parameters and plasma piston velocity depended on the working current in the discharge circuit and pressure of the gas that filled the channel p_1 and (ii) the plasma piston acceleration was accompanied by generation of strong shock waves with the parameters nearly unattainable in conventional shock tubes.

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