S2-P-024801

DENSITY DISTRIBUTION OF THE NEAR-SURFACE SUBSTANCE AT THE INITIAL STAGE OF THE PLASMA FORMATION PROCESS DURING THE SKIN EXPLOSION OF CYLINDRICAL CONDUCTORS [*]

I.M. DATSKO[1], N.A. LABETSKAYA[1], S.A. CHAIKOVSKY[1,2], V.A. VAN'KEVICH[1], V.I. ORESHKIN[1]

[1]Institute of High Current Electronics of the Siberian Branch of the Russian Academy of Sciences, Akademichesky Avenue 2/3, Tomsk 634055, Russia
[2]Institute of Electrophysics of the Ural Branch of the Russian Academy of Sciences, Amundsen 106, Yekaterinburg 620016, Russia, UD, RAS, Yekaterinburg, Russia

Plasma formation on the conductor surface is a key issue in terms of the energy imputed into the metal substance. For the magnetic field growth rates, which are characteristic for magnetically isolated transmission lines of multi-megaampere generators, this issue remains insufficiently studied. Therefore, the task of this work was to study the dynamics of plasma and its density on the metal surface at magnetic induction values up to 700 T and its growth rates of (2-7) T/ns. The experiments were carried out on a pulse-power MIG generator at a current amplitude of up to 2.5 MA and a rise time of 100 ns. The formation of plasma on the conductor surface was recorded by its glow in the visible range using a four-frame optical camera with an exposure time of 3 ns for each frame. In addition, vacuum photoemission diodes recorded the surface plasma reaching a temperature of more than 1 eV in the black body approximation. The surface plasma internal structure, the estimation of the substance density in it and its radial distribution were studied using X-ray radiography obtained by transmission with $h\nu > 0.8$ keV and an exposure time of 2-3 ns, which is formed in the "hot spot" X-pinch. According to the data of X-ray studies of the conductor's electric explosion, the distribution profile of the substance along its radius at various points in time was simulated by means of the developed calculation code using the Abel transformation. In the course of the experiments, the cylindrical conductor's electric explosion made of various materials and with various diameters was studied, which made it possible to study the formation of plasma at different magnetic field induction growth rates up to 7 T/ns. It is shown that current increase prompts the lighting up of "spots" on the cylindrical conductor surface, and they serve as sources of low-temperature and relatively low-density plasma, that is, they are centers of plasma formation. Subsequently, current channels develop in this plasma. The dependences of $\mu \cdot \rho$ on the conductor radius in the selected section of the X-ray radiography picture of its explosion are obtained. The value of the mass radiation absorption coefficient μ was determined from the X-ray transmission patterns of stepped filters made of the same conductor material as the exploding one. The dependences of the load substance ρ density on its radius at different moments of time from the current beginning are determined and plotted.

If the maximum field on the conductor surface is more than 600 T, which in our experiments was achieved with their initial diameter less than 1 mm, then for a duralumin conductor with an initial diameter of 0.95 mm in the visible range, its size increased at 104 ns up to 1.46 mm, and at 144 ns - up to 2.4 mm. In this case, density estimations of the substance that expanded by 65 μm to 80 ns relatively to the initial radius (that is, at a radius of 0.54 mm) are 0.17–0.19 g/cm^3, and at a radius of 0.5 mm from the axis, 0.45 g/cm^3. By 142 ns, a density of more than 0.15 g/cm^3 is reached at a radius of 0.7 mm, and at a radius of 1 mm, the substance density in the column is 0.01 g/cm^3. The streaks of instabilities at this time expand up to 700 μm from the initial conductor radius, and the density of matter in them is less than 0.01 g/cm^3. It can be concluded that the low density of matter at the boundary of the plasma column does not allow us to assume any significant fraction of the current carried by it.

[*]The work was supported by the Russian Science Foundation (grant No. 20-19-00364).