Numerical Simulations of Wire and Foil Electrical Explosion under Helical EMG Current Drive for Warm Dense Matter Generation

S.F. Garanin*, A.M. Buyko*, S.D. Kuznetsov*, R.E. Reinovsky†

* Russian Federal Nuclear Center – VNIIEF Sarov, 607190, Russia
† Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Study of properties of Warm Dense Matter (WDM), i. e. substance at densities of the order of that of solids (from 10 % normal density to 2-3 times solid density) and moderate temperatures (1-10 eV), is in recent times an active field of investigations.

Experiments to study electrical explosion of thick wires (0.5-2 mm in diameter) driven by currents of about 1 MA were conducted recently [1] on the Zebra facility at the University of Nevada, Reno. The objective of these experiments was to study plasma formation on the surface of conductors under the influence of megagauss magnetic fields. These experiments demonstrated formation of plasma with temperatures of tenths of eV depending on the magnetic field level. Results of numerical simulations of these experiments [2] agree with the experimental results. The simulations suggest that in addition to the hot low density coronal plasma generated on the surface of the metal, the interior of the aluminum wire/rod relaxes to a region of homogeneous dense plasma of temperature about 4 eV and 60% of initial solid density, i.e. the substance in the state of WDM.

The study of megagauss magnetic fields interaction with metal surfaces using simple geometries paved the way for the use of the simple geometries (posts, confined by megagauss magnetic fields, and foils, loaded by MA currents) for the study of WDM [3] properties (equations of states, kinetic coefficients, opacities). It is possible to apply the helical explosive magnetic generator (EMG) with an opening switch to obtain the WDM. Thus, application of EMGs Æ200 mm and the explosive opening switch demonstrates possibility to obtain current ~5 MA with character rise time 0.3 μs. Higher energy can enable study of WDM in larger volumes. However in the experimental geometry with the central rod the measurements of the WDM parameters is a challenging diagnostic problem, because the WDM is located in the central region of the conductor and shielded by the corona, through which most part of the current flows for high EMG currents, that complicates direct electric measuring of its parameters (Fig. 1).

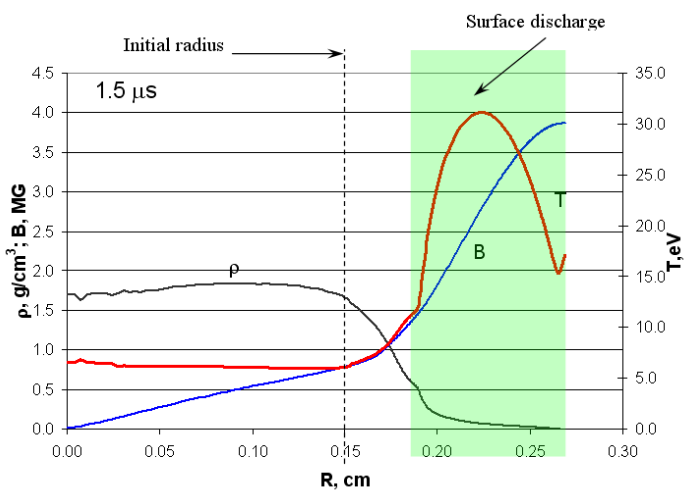

Figure 1. Density, magnetic field, and temperature profiles for the 3-mm-diameter Al rod explosion under 5 MA current drive at the time $t = 1.5$ μs.

A system for the generation of the WDM, formed in the electric explosion of thin metal foil, surrounded by an insulator, in the cylindrical geometry (experiments close by the design to the study of FOS

transferring magnetic flux into infinite load) is also considered. This system provides the homogeneity of the WDM and presents better possibilities for the diagnostics. The physical scheme of the load in the proposed experiment is shown in Fig. 2.

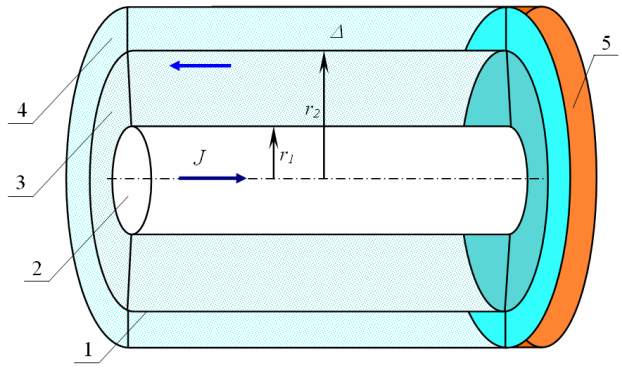

Figure 2. Physical scheme of the load. (1) Foil, (2) central rod, (3), (4) insulator cylinders, (5) end flange.

As the calculations suggest (e. g. Fig. 3) for the Cu and Al foils in such a system, fed from the EMG with FOS, it is possible to obtain significant WDM volume with the density of the order of initial solid density and the temperature ~ 2-3 eV. Parameters of WDM on time, which can be measured experimentally, are also obtained from calculations. Method to restore pressure in WDM based on movement of external boundary of the foil from pure hydrodynamic calculations was applied and produced good results. Applicability of this method is based on the assumption that the material with well-known properties is found and possibility of direct measurements of the foil external surface movement exists.

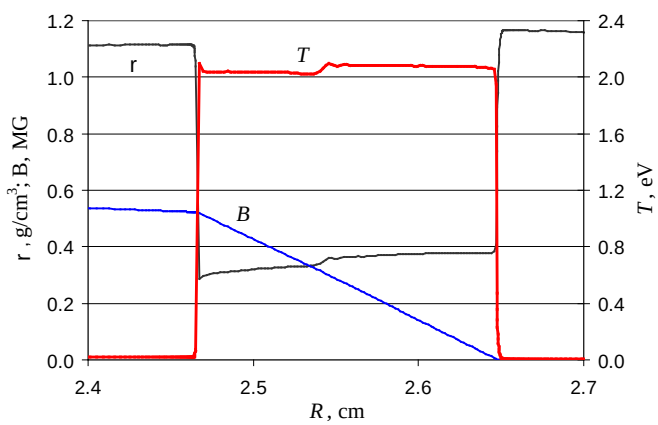

Figure 3. Distribution of MHD values over the exploded foil cross-section. Al foil. *t* = 5.5 *mks*.

References

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[3] R.E. Reinovsky, W.L. Atchison, S.F. Garanin, A.M. Buyko, et al. "Pulsed high magnetic fields for exploring the dynamic properties of materials," presented at XIII Int. Conf. on Megagauss Magnetic Field Generation and Related Topics, Suzhou, China, 2010.

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