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NUMERICAL ANALYSIS OF COLD CORE FORMATION DURING WIRE ELECTROEXPLOSION

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Abstract

It has been shown experimentally that wire explosion is connected with cold core formation and leads to a complex profile of magnetic field [1, 2]. The focus of the paper is the attempt to analyze this phenomena by numerical modelling. A series of calculations has been carried out using 1D radiation Lagrangian MHD code ERA [3]. The model has been developed and the influence of different terms including into the model has been analyzed.

Task Statement and 1D Model

All presented results have been obtained by ERA code. The equations describing ERA two-temperature MHD model are published in papers [3, 4] include two-temperature MHD, radiation transport equations for lines and continua, ionization state variations, a host of tables for EOS, transport coefficients etc.

The current driving the wire explosion has the triangle form with front duration of 50 ns, decay duration of 150 ns and maximum amplitude of 210 kA. These parameters are close to experiments on wire implosion with small generator using. Initial diameter of aluminum wire was chosen 20 μm.

Three different cases have been considered (refer to phenomena determining the model):

1. Microturbulence effects were not taking into account
2. Accounting microturbulence effects and anomalous transport coefficients due to ion-acoustic and lower-hybrid-drift microinstabilities development
3. Previous case plus accounting of mixing of ion components including neutral atoms

Magnetic Field Profile

Results of calculation in the frame of model corresponding to the first case show that magnetic field is concentrated in very thin skin layer and prevent the expansion of plasma on wire. Maximum of expansion for this case is about 150μm. It is in contrast with existing experimental data on wire explosion. Accounting of anomalous transport decreasing the electrical conductivity in a coronal region and leads to the increasing of the magnetic field penetration depth. Therefore plasma expands up to 3÷5 mm. Because of anomalous effects the conductivity in coronal region is much smaller that in core. Growing current generates the magnetic field which penetrates into the core and freezes into the central part of wire. This field prevents imploding inner region of wire. After 50 ns current begins to fall and boundary condition for magnetic field determinates the complex profile

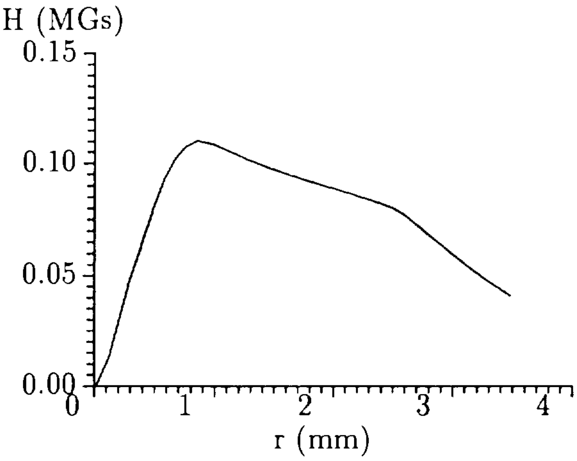

Figure 1: Magnetic field profile

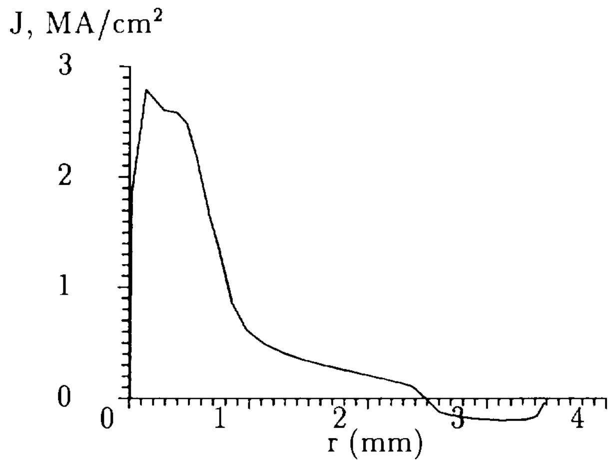

Figure 2: Density of current profile

of magnetic field as it is shown in Fig.1. In the coronal region the current flowing in opposite direction appeares (see Fig.2)

Cold Core Formation

Long existence of cold core could be explained by the formation of weakly ionized steam region. The steam region prevents heating of central core by radiation and electron heat conductivity ("screening" effect). Corresponding results are shown in Fig.3. They have been obtained taking into account of mixing with neutral atoms and without it. Second case (without neutrals) has been realized by supposing that minimal charge could not be smaller that 1.

In Fig.4 one can see the evaporated portion of wire mass vs. time for these two cases. The bound of evaporated matter has been calculated in suggestion of steam density of $\rho = 10^{-2} g/cm^3$.

Radiation play an essential role in wire dynamics (radiation loses is about 60÷80% from realized energy on wire). Line radiation is about 30% from total yield (plus bremmstrahlung and recombination radiation). Mainly the coronal region radiates and it deter-

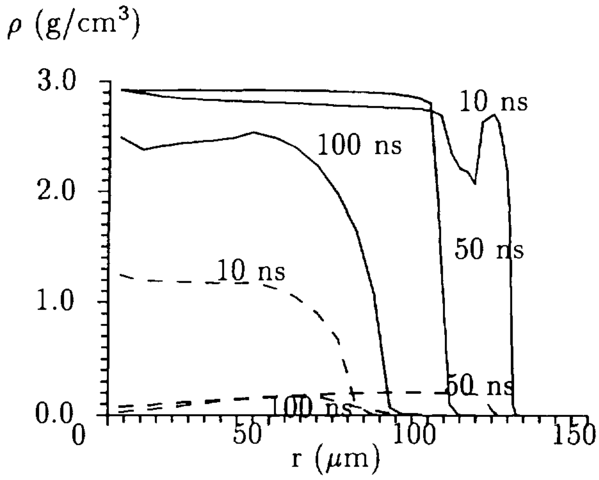

Figure 3: Cold core formation. Solid line – accounting of mixing of ion components including neutral atoms, dashed line – without accounting

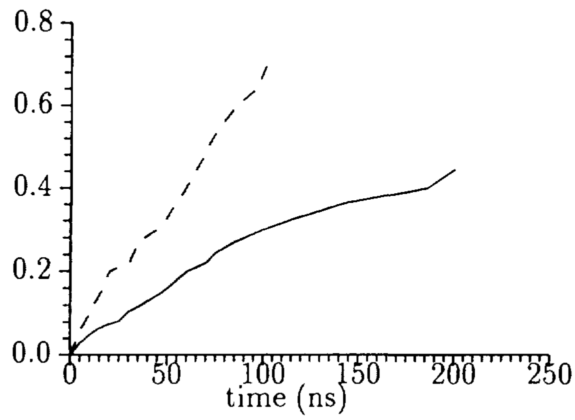

Figure 4: Portion of evaporated mass vs. time. Solid line – with accounting of mixing, dashed – without one

mins the temperature of this region.

Conclusion

It has been found that cold core formation is connected with 1) microturbulence effects consideration; 2) accounting of mixing of ion components including neutral atoms; 3) frozen magnetic field in the stage of pinch swelling 4) "Screening" effect by weakly ionized steam region.

One needs to continue the investigation and to analyze these processes by 2D code for real hot spot forming. It is interesting to study this phenomena in the frame of Electron MHD [5].

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