On the Modeling of the Initial Stage of the Electric Explosion Process of a Wire Array

Ali Alhammadi(1,2), Evgeny Gurnevich(1), John J. Pantoja(2), Asilah Almesmari(2), Felix Vega (2), and Chaouki Kasmi(2)
(1) Belarus State University, Minsk, Belarus
(2) Technology Innovation Institute, Abu Dhabi, United Arab Emirates
ali.alhammadi@tii.ae

Abstract**—**The paper presents a model for the exploding wire array process in Copper. It uses a circuit model that couples the basic LRC circuit equations with zero-dimensional thermodynamic calculations that track the effect of heating on the heat capacity and resistance of the wire.

Keywords-Exploding wire, electric explosion, copper, resistivity, heat capacity

I. INTRODUCTION

Exploding Wire Array (EWA) are fast switches used in pulse power applications [1]. A typical testing circuit to characterize EWAs is shown in Fig. 1.

The proposed RLC circuit equations couple the thermodynamic calculations that track the effect of heating on the heat capacity and resistance of the wire [2]. The model considers EWA's physical parameters, such as the length, cross-section, and the number of wires, to shape the output pulse current amplitude and waveform. The breakdown of electric strength must be able to match the generated voltage for the full EWA circuit.

The study focuses on Exploding Wire Arrays manufactured in copper, following the Zero-dimension method used in [1].

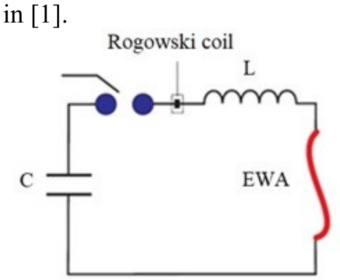

Figure 1. Exploding-wire array testing circuit

II. THEORETICAL METHOD

The model determines the current as a function of the time in an exploding cooper wire array, when the energy stored in a capacitor bank (C) is discharged into the wire array through a series inductance, as shown in Fig. 1.

This can be calculated using:

$$\frac{dI}{dt} = -\frac{R}{L}I - \frac{I}{LC}q$$

where: I, R, q are current, resistance, charge in the circuit of Fig. 1, and L, C are inductance and capacitor. The effect of heating on the heat capacity of copper is calculated based on the data provided in [2]. The current as a function of the time to be calculated.

$$\Delta H(t) = \frac{1}{m}\int_0^t R_{wire}(t)I(t)^2 dt$$

where ΔH is the heat generated per unit mass of the wire, m is the mass, and t is the time. For illustration, Fig. 2 shows the current calculated for an EWA with 28 wires, 0.1 mm diameter, C= 6.60 µF, charging voltage 60 kV, and L= 3.90 µH. The figure shows the calculated current assuming time dependent parameters (with parameters) and parameter independent of the time (without parameters) up to the liquid phase. A similar process was developed to study the response of Aluminum and Tungsten wires.

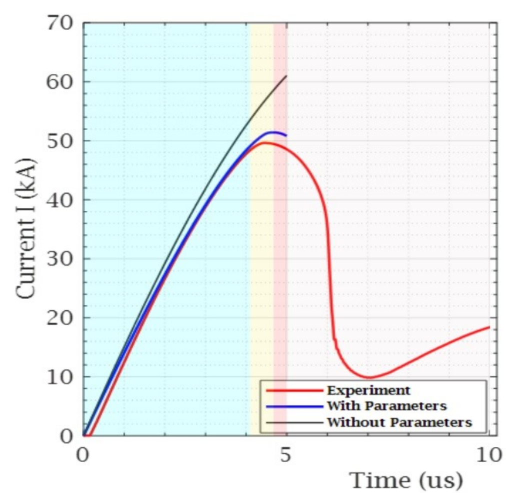

Figure 2. Comparison of experimental and calculated results. In light blue is highlighted the solid phase, in yellow is the melting phase, and in light red is the liquid phase.

REFERENCES

[1] A. Alhammadi, E. Gurnevich, C. Kasmi, F. Vega, and J. Pantoja "Resistivity of copper at the initial stage of an electric explosion process." 3rd URSI Atlantic / Asia-Pacific Radio Science Meeting, Gran Canaria, Spain, May 29 – June 3, 2022.
[2] Berning P. R., Coppinger M. J. CCDC Army Research Laboratory Aberdeen Proving Ground United States. An Exploding-Wire Circuit Model. 2020
[3] Mesyats G. A. Pulsed power / G. A. Mesyats, New York: Kluwer Academic/Plenum Publishers, 2005. 568 c.