Mean electric field and total near-electrode voltage drops measurements for discharge in hydrogen at initial pressure of 32 MPa with current amplitude of 1.3 MA

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Abstract. Research results for discharge initiated by wire explosion in hydrogen at initial pressures of ≈ 32 MPa and current amplitudes of ≈ 1.3 MA are presented. The mean electric field in the discharge channel and mean near electrode voltage drops were determined in an experimental series with steel electrodes for different interelectrode gaps from 1 to 2 cm at the time of the current maximum. The near electrode voltage drop was of ≈ 3.5 kV, and electric field strength in the discharge channel was of ≈ 0.7 kV/cm at these conditions. https://doi.org/10.33849/2023308

1. INTRODUCTION

The interaction of intense energy flux with matter at extreme conditions is one of the most exciting areas of science [1]. A pulsed discharge with a current in mega-ampere range is one of the most effective and conventional ways to obtain plasma with extreme parameters [2–6]. The discharge can be used as a laboratory model of astrophysical objects [7]: for physical simulation of astrophysical jets [7, 8], modeling radiative transport in star photosphere [9], equations of state for matter [1], etc [1, 7, 10]. High-current discharges in a high-density gas give certain advantages in obtaining the extreme states of matter [2, 11–13] and, in turn, have specific characteristic features [2, 11, 13–15].

Near-electrode voltage drops and the electric field in the discharge channel are one of the most important characteristics of a gas discharge [14, 16–18]. The near-electrode voltage drops set the energy flux to the electrode surface [14, 16, 17], and the field in the channel determines the energy balance in the discharge channel [14, 17]. Usually, these values can be measured from dependence of the voltage drops across the channel on the discharge gap length [14, 19–21]. Near-electrode voltage drops can take with this dependence extrapolation to zero length [14, 19–21].

The values of near-electrode voltage drops, not exceeding tens of volts for arcs with current up to tens of kiloamperes for various gas media and electrode materials [17, 19, 22], have a gradual increase with increasing pressure [14], mainly due to the anode drop [21]. The total near-electrode drops exceed hundreds and thousands of volts for a current rise rate above 10^8 A/s and current amplitude above 50 kA [13, 14, 20, 23, 24], especially for discharge in light gases [13, 20]. The electric field in the discharge channel is grown with increasing pressure [11, 13–15, 20].

New data about the voltage drops across the channel versus the discharge gap length at current maximum at initial hydrogen pressures of $\approx$ 32 MPa and current amplitudes of $\approx$ 1.35 MA are presented in the paper in the development of the research presented at the last several International Conferences on Equations of State for Matter [25–30]. The presented data naturally expands the data concerning similar parameters for discharges at lower currents and other initial pressures [23, 24, 30].

2. EXPERIMENTS, RESULTS AND DISCUSSIONS

The discharge was initiated by an explosion of copper wire with a diameter of 0.5 mm placed between hemispheric steel electrodes with a diameter of 2 cm (see the photo of the electrode in [12]). The electrodes were placed along the chamber axis. The initial gap L between them was in the range of 1–2 cm. The discharge chamber diameter was 6 cm. The internal free volume of the chamber with electrode units was ≈ 250 cm^3. Before the experiment, the discharge volume was evacuated to a pressure of 2.5 kPa and blown through with hydrogen to ensure the necessary purity of the working gas. The voltage across the discharge load was measured using a high-ohmic resistive divider with transformer decoupling, which was connected to the load contacts. The current was measured using the Rogowski coil. The measurement error was within 5%. A detailed description of the experimental setup was presented in [12, 31]. Six units of the modular capacitive system [32] were used at the initial voltage of 10 kV and storage energy ≈ 0.6 MJ in each experiment.

The parameters of the experiments in the series are presented in table 1. Current curves and corresponding voltage signals for the three experiments in the series are presented in figure 1. The variations of the discharge current amplitude and voltage are a feature of a mega-ampere discharge channel formation with equal initial parameters. Current and voltage curves for the same gap length of 1 cm are shown in figures 1 and 2 to illustrate the signal variation at the same initial parameters. Current amplitudes $J_{\max}$ were of $\approx$ 1.3 MA and initial hydrogen pressures P_0 were of $\approx$ 32 MPa. Approximate voltage values across the discharge gap $V_{J_{\max}}$ at the moment of current maximum are determined by linear fitting of the voltage signal in a time base of 20 μs near current maximum as shown in the

Таблица 1. Parameters of the experiments: L — interelectrode gap, P_0 — initial hydrogen pressure, $J_{\max}$ — current maximum and $V_{J_{\max}}$ — fitted voltage across the discharge gap at the moment of current maximum.

L (cm)	P_0 (MPa)	$J_{\max}$ (MA)	$V_{J_{\max}}$ (kV)
1.0	31.5	1.35	4.3
1.0	32.2	1.25	4.1
1.5	29.0	1.1	4.4
1.5	32.0	1.2	5.0
1.9	33.3	1.4	5.0
2.0	31.6	1.2	4.6
2.0	32.2	1.3	5.0

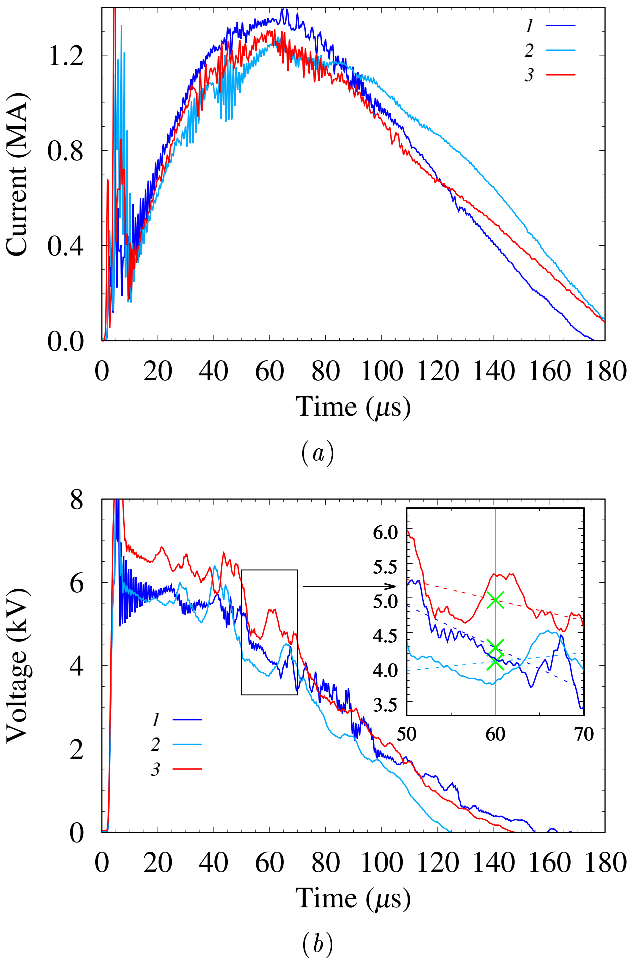

Figure 1. Discharge current (a) and voltage across the discharge gap (b): *1* and *2* — interelectrode gap is 1 cm, and *3* — 2 cm.

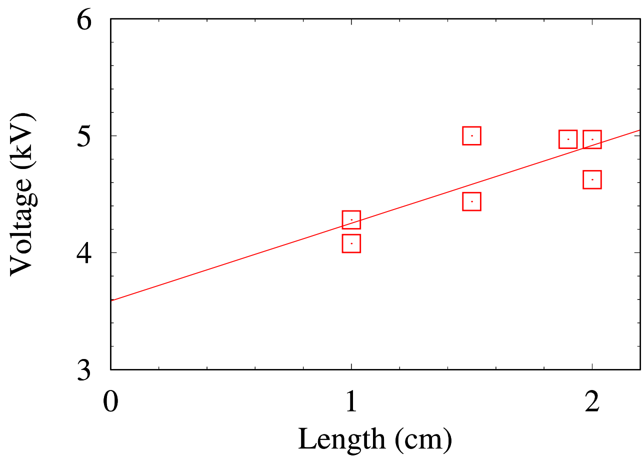

Figure 2. Voltage across the discharge gap at the moment of current maximum.

additional frame in figure 1(b). The linear fitting procedure is required for averaging voltage pulsations due to discharge channel oscillations.

The dependence of $V_{J_{\max}}$ on the discharge gap length L is shown in figure 2. The cutoff value upon approximation of this dependence to zero length and the dependence slope can be considered as estimates of the mean near electrode drops and mean electric field strength in the discharge channel. The main assumption for this approximation is the formation of a uniform discharge channel with short near-electrode sections.

3. CONCLUSION

The mean electric field in the discharge channel and mean near-electrode voltage drops were determined in an experimental series with steel electrodes for different interelectrode gaps from 1 to 2 cm at the time of the current maximum. The near electrode voltage drop was of ≈ 3.5 kV, and electric field strength in the discharge channel was of ≈ 0.7 kV/cm at these conditions. The data are consistent with the previously obtained data with other ranges of initial parameters concerning dependencies of the field and near electrode voltage drops versus pressure, current, and current rise rate.

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