WAVELET ANALYSIS OF ARC NOISES AT THRESHOLD CURRENTS

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ABSTRACT
A wavelet analysis of the oscillations of the current, voltage, and visible radiation intensity of a vacuum arc discharge with tungsten and cadmium cathodes having a clean surface have been performed for near threshold current. The temporal resolution was better than 1 ns for electric measurements and better than 5 ns for light intensity measurements. It has been found that for currents close to the threshold current, the current, voltage, and light intensity oscillations are bursts of duration 17-25 ns for tungsten and 40 ns for cadmium.

1. INTRODUCTION
Now it can be considered commonly accepted that all phenomena observed in the cathode spot of a vacuum arc can be interpreted in terms of the model of cathode spot cells [1-3]. Investigations show that the experimentally observed current per cell is from a few amperes to 15 A and the residence time of a cell at one and the same place ranges from a few nanoseconds to some tens of nanoseconds [4-8]. It is reasonable to relate the fluctuations of the arc parameters, such as the voltage across the gap, the intensity of the light from the cathode spot region, and the discharge current, to the processes of appearance and disappearance of cells in the cathode spot. The observations of cathode spot cells were performed, as a rule, at currents of several tens of amperes and more at which a cathode spot contains several simultaneously operating cells and the distribution of the discharge current over the cells is unknown. At the same time, from the observations it follows that the current through an individual cathode spot fragment (cell) is only a few amperes [9]. Our study was carried out for the arc currents close to the threshold current, at which a cathode spot seems to be a single cell. The objective is to analyze numerically the fluctuations of arc parameters, such as the current, the light intensity, and the voltage across the arc, at threshold currents at which the arc cathode spot is a single cell, and to follow the variations, if any, in the time parameters of the cathode spot cells on increasing the arc current to several threshold currents.

2. EXPERIMENTAL SET UP
The cathodes were short pieces of tungsten or cadmium wire of diameter 100 µm and anode was 200 µm of diameter. The trigger electrode was a tungsten needle with a tip radius of about 20 µm. All experiments were performed in a stainless-steel vacuum chamber furnished with coaxial leads for signals. The bandwidth of the chamber together with the leads was over 1 GHz. The discharge current, the voltage across the gap, and the intensity of the light emitted by the discharge through the glass window were recorded simultaneously. The discharge current was measured with a shunt of resistance 0.34 Ω for tungsten, and 5.5 Ω for cadmium. The voltage across the gap was measured using a resistive voltage divider. The light emitted by the discharge was recorded with the help of photomultiplier with a rise time shorter than 5 ns. The cathode spot was initiated at the lateral surface of the cathode near the wire tip, so that the spot could be within sight of the photomultiplier. We used two schemes of powering the discharge:
1. Pulsed power supply from a cable generator of rectangular high voltage pulses (Fig. 1. The discharge current was varied by varying the resistance of the resistors R1, R2, and R3 and by controlling the peak voltage in the range from 16 to 25 kV).
2. Power supply of the discharge from a coaxial cable of wave resistance 75 Ω, charged to a dc voltage Uch (Fig. 2. The electric length of the cable is 340 ns. In this case, we measured the light intensity and the current, not measuring the gap voltage).

In both cases, the discharge is initiated by a
trigger voltage pulse of amplitude 16-25 kV and duration 40 ns. The trigger discharge current is 4 A for tungsten and 1 A for cadmium. The oil-free vacuum in the chamber was no worse than $10^{-6}$ Pa. Prior to measurements, the cathode tip was subjected to multiple ignitions of an arc with a hemisinusoidal current of amplitude 6 - 30 A and duration 120 µs and, as a result, the cathode surface near the site of ignition was molten by the arc itself.

3. RESULTS AND PROCESSING

Measurements were performed at near threshold currents (2.5 – 3 A for tungsten; 0.1 A for cadmium) and at currents equal to several threshold currents. Typical waveforms for tungsten are shown in Fig.3., and for cadmium in Fig. 4. The current, voltage, and light intensity waveforms were subjected to a wavelet analysis [10]. The essence of this processing is that a waveform (Fig. 5a) is investigated at each point with the help of the function an example of which is given in Fig. 5b, that is a wavelet. A wavelet has a time scale; in Fig. 5b this scale is denoted by $t$. The result of wavelet analysis is the time spectrum (Fig.5c.) of the waveform, which represents the power corresponding to bursts with duration $t$, which present in the waveform. Thus, the time spectrum in Fig. 5c shows that in the arc voltage waveform given Fig. 5a, the bursts of durations of 28 ns and 60 ns possess the greatest power.
In the case of tungsten for the discharge current range from near-threshold currents to 3.5 A, we have obtained average time spectra similar to that shown in Fig. 6, an example of time spectrum for cadmium at current 0.1 A is shown in Fig.7. These spectra are the result of averaging of some 20 time spectra obtained analysis of individual waveforms. It has been found that at the near threshold currents the current, voltage, and light intensity waveforms contain bursts whose duration is predominantly 17-25 ns for tungsten and 40 ns for cadmium. This result has been obtained with the use of different power supply systems. As the current is increased to above 4 A for tungsten and above 0.2 A for cadmium, the more long duration fluctuations appear in the light intensity waveforms. The analysis result for a light emission intensity of 6-A arc on tungsten is shown in Fig. 8. Time spectrum of light for current 0.3 A on cadmium is shown in Fig.9.
4. DISCUSSION

We are based on the idea that the cathode process of an arc discharge is the passage of the discharge current through a certain number of cathode spot fragments (cells). Each cell operates for a limited time and then disappears, i.e., the current stops flowing at this place and therefore the light emission ceases. Our results can be interpreted as follows: Irrespective of the discharge current, the operating time of the cells of a cathode spot on tungsten is in average about 20 ns and on cadmium is in average 40 ns. An increase in current has no effect on the essence of the cathode processes. The cathode spot still consists of cells with mentioned above lifetimes, but relatively more long duration light intensity bursts appear, which seem to be associated with coalescence of the cathode spot cells and splitting of the cathode spot. A similar repetitive increase in the brightness of a cathode spot on coalescence of individual cells was observed by Juttner [5], who investigated the light emission from the cathode spot of a 70-A arc with a titanium cathode.

5. CONCLUSIONS

- At near threshold currents the arc discharge current, the voltage across the gap, and the intensity of the light emitted from the arc region consist of bursts of duration 20 ns for tungsten and 40 ns for cadmium.
- For all currents we used in our experiment, the current, voltage, and light intensity waveforms contain bursts of duration about 20 ns for tungsten and 40 ns for cadmium.

6. ACKNOWLEDGEMENT

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7. REFERENCES