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PLASMOIDS IN THE PULSE-EXCITES TORCH ARC[1])

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The pulse-excited torch arc burning in Fe vapours in air at atmospheric pressure has been photographed by a high speed camera. The discharge ignition and extinction caused the plasmoids to occur at the ends of path of negative sparks, which form a steplike discharge. Within the point of an increased space charge of positive ions the plasmoids originate.

ОБРАЗОВАНИЕ ПЛАЗМОИДОВ В ВОЗБУЖДАЕМОЙ ИМПУЛЬСАМИ ФАКЕЛЬНОЙ ДУГЕ

В работе описывается, как при помощи аппарата для скоростной киносъемки фотографирована возбуждаемая импульсами факельная дуга в парах железа в воздухе при атмосферном давлении. При зажигании и гашении разряда в конце путей отрицательных искр, образующих отупенчатый разряд, возникают плазмоиды, которые рождаются в точке увеличенного объемного заряда положительных ионов.

I. INTRODUCTION

The object of our study was a unipolar high frequency (in the following abbreviated hf) discharge burning in free air atmospheric pressure and fed by a power source of 40 Hz. The discharge was generated periodically by 0.01 s pulses followed by interruptions of the same duration. The iron electrode having a diameter of 4 mm became strongly heated and its point melted. The discharge burnt hence in Fe vapours. According to [1] this may be denoted as a pulse excited torch arc.

II. EXPERIMENTAL ARRANGEMENT

The discharge was fed by 800—1000 W of hf power supplied from a selfexcited generator in Hartley's connection. Photographic records of 100 periodic ignitions

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and extinctions (in time of 2 s) were made by a high speed camera giving 40 pictures for each hf pulse. The ignition and extinction presented in all records have the same course; in all cases there can be observed bright spherical regions — plasmoids, appearing above the electrode layer and having a similar shape and size as in [2].

III. ANALYSIS OF PROCESSES IN THE TORCH DISCHARGE

The origin of plasmoids observed during the ignition and extinction of the pulse excited torch arc in Fe vapours and seen in the high speed camera picture can be explained by processes analogical to those which occur in a pulse excited torch discharge [3].

Over the electrode layer, visible in all pictures, there can be seen a spherical plasmoid, appearing often even before the ignition of the discharge (Fig. 1). Selected pictures of a pulsed torch arc in Fe vapours, corresponding to one radiopulse, photographed by a high speed camera. (Δt-time of the outset discharge. Reduced to 2 : 1) The positive ions were not neutralized by recombination in this case and the plasmoid survived the time of 0.01 s between two hf pulses without energy supply.

The beginning of the first hf pulse gives rise to an initial positive streamer, the pre-onset streamer; on the elctrode, where this streamer starts as well as on its end, there appears a charge of positive ions. It can be detected already 14.5 ns after the onset of the pre-onset streamer [4].

When the polarity of the electrode alternates, the electrons move in the discharge path of this streamer to and fro and increase the concentration of the above mentioned ions by collisional ionization, especially at the ends of the path; the velocity of the electrons reaches in these regions values for which the cross section of the ionizing collisions is maximum [3].

The pre-onset streamer does not reach its maximum length just in the first halfwave of the hf voltage, but rather after the discharge path has become thermalized and hence more conductive. Only in this case the favourable conditions for ionization arise at its end too.

During the formation of this part of the discharge its shape is influenced by the presence of the space charge; the radial component of the positive ions concentration gradient causes the curvature of the discharge path end. As shown in [5], this discharge path presents all the typical features of a negative spark and, therefore, we will use this name for it in the following text.

The negative spark arising from the electrode region in Fig. 2 extends in the time of 10^{-3} s and almost joins the plasmoid (Fig. 3). The space charge of positive ions created at the end of this first negative spark plays an important role by the formation of further parts of the discharge, since it creates here analogous

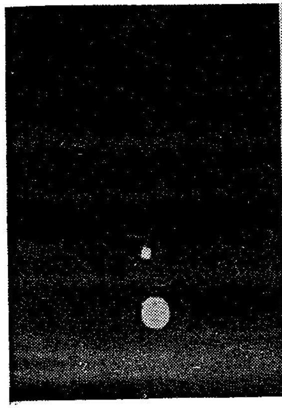

Fig. 1. $\Delta T = 0$ ms.

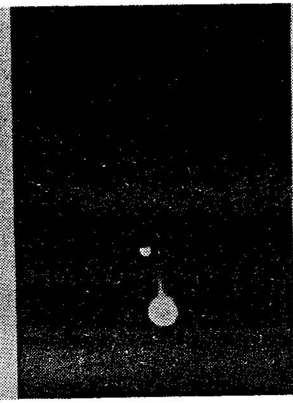

Fig. 2. $\Delta T = 1$ ms.

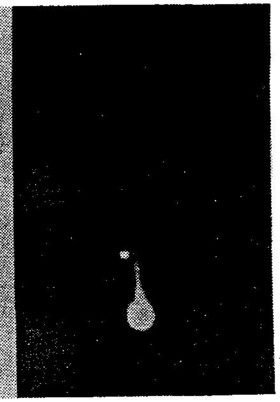

Fig. 3. $\Delta T = 1.5$ ms.

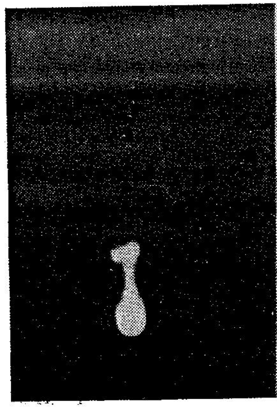

Fig. 4. $\Delta T = 2$ ms.

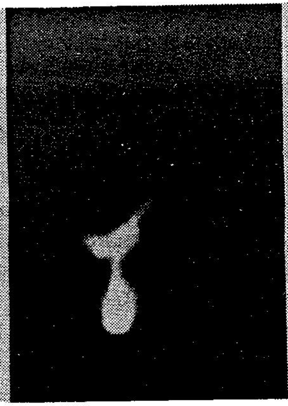

Fig. 5. $\Delta T = 3$ ms.

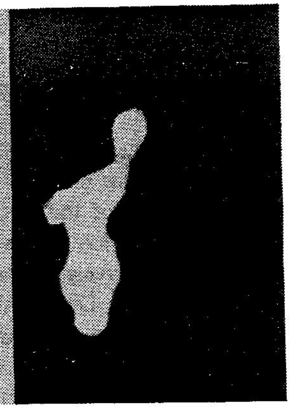

Fig. 6. $\Delta T = 5$ ms.

conditions for ionization as there occur near the electrode. Whenever the electrode operates as the cathode, there appears here — by the same mechanism as by ignition of the discharge near the electrode — a new, i.e. the second negative spark, which joins the first in almost perpendicular direction and creates a new zone of space charge analogous to the electrode region (Fig. 4). From this region it starts the new negative spark (Fig. 5). The streamers starting from the plasmoid on the spark opposite side become stronger and transform into a corona. The joined negative sparks form thus consecutively a wavy channel at the torch discharge, until the voltage of the last negative spark is not sufficent enough for further ionization (Fig. 6).

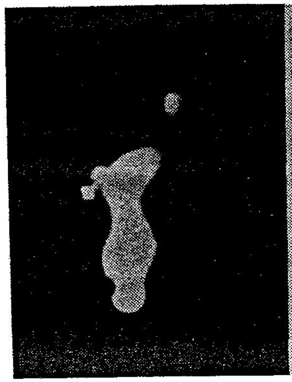

Fig. 7. $\Delta T = 12$ ms.

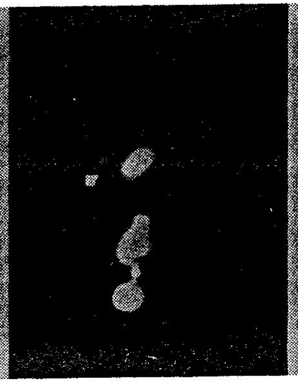

Fig. 8. $\Delta T = 14$ ms.

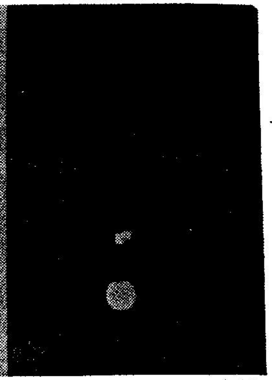

Fig. 9. $\Delta T = 20$ ms.

The electric field $E(r)$ close to the ends of each negative spark is composed of the electric field $E_s(r)$ of the positive ions space charge and the elctric field $E_0(r) \cos \omega t$ depending on the hf voltage at the end of the spark

$$E(r) = E_s(r) + E_0(r) \cos \omega t.$$

Due to the low mobility of the ions their electric field $E_s(r)$ may be considered as independent of the time t. Whenever the periodic component has a positive value at the point r_1 where $E_s(r_1)$ is maximum, the resulting $E(r_1)$ is maximum too and there are favourable conditions for the creation of a new discharge in the respective place. During the opposite halfperiod of the hf voltage there occur, however, favourable conditions for new discharge in another place r_2 where $E_s(r_2) = 0$ or negative. For this reason there are observed two types of discharge at the end of each spark, linked to it in different directions, namely the new negative spark with a sharply defined channel and the diffusion discharge on the opoosite side. Since this diffusion discharge occurs only when the electrode is positive, let us denote it as a positive corona.

At the beginning of the discharge afterglow there disappears first the channnel of the negative spark, whole the region with the positive ion space charge survives some time; in Fig. 7 the end of the negative spark disappeared and the plasmoid is still visible. After the decay of the whole discharge path the plasmoids may be observed not only in the places of the previous corona, but also at the point where the negative spark has iniciated (Fig. 8). As may be seen in Fig. 9, the latter plasmoids decay earlier than the former ones. In their position there remain positive ions and last till the start of a new hf pulse, supplying the energy for ignition of the next discharge.

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