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Edited by P. Papp, J. Országh, L. Moravský, A. Ribar, Š. Matejčík

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HIGH SPEED CAMERA IMAGING OF MINI GLIDARC DISCHARGE

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The gliding arc discharge plasma reactors are known as a source of non-equilibrium plasma at atmospheric pressure. In the present study, the high speed camera has been used for imaging of discharge propagation and subsequent calculation of the velocity of discharge propagating generated in mini GlidArc reactor at different flow rate and composition of working gas mixture.

1. Introduction

The gliding arc (GlidArc) is a source of low temperature plasma, that is often effectively used for the process of disposal and treatment of different gaseous pollutants [1-5].The basic gliding arc is an arc discharge generated between two diverging electrode, that is blown along the electrodes by very fast transverse gas flow. The gas nozzle is placed between the electrodes in their axis of symmetry. The arc initiates at the shortest gap between two electrodes and after that is elongated by the fast gas flow from its initial position [5-7]. As the arc is elongated, its current is at its maximum and the voltage at the minimum. (quasi-thermal regime).. The elongating arc demands more power to be sustained, until it reaches the maximum that the power supply can provide and then subsequently drops on both plasma and external resistance. This is the transition point for the regime of GlidArc operation [5, 6]. Due to continuous gas flow, the length of the arc continues to grow, but the power supplied by the source is insufficient to balance the convective energy losses to the surrounding gas and discharge disappears.

"Mini GlidArc" reactor that we used in the experiment has small discharge space, where initial distance between electrodes in the ignition point can be equal to one tenth of a millimetre . The reactor allows many possible adjustments and settings, e.g. continuous change of distance between the electrodes. The electrodes move axially and radially with respect to the axis of symmetry of the electrodes and the gas nozzle. The discharge mechanisms of “Mini GlidArc” are alike the traditional GlidArc. One of the key parameters determining the amount of generated active particles in the plasma, is the shape and size of the arc discharge.

Plasma reactors with gliding discharge can be operated with DC, AC and pulsed power supplies [4]. The "Mini GlidArc" reactor is supplied by high voltage power supply with no separate ignition system, which can deliver certain part of the energy in the single cycles of plasma. The reactor has the possibility to work in different conditions, e.g. in various gas mixtures containing nitrogen, oxygen and carbon dioxide. This work objective was to identify the factors affecting the length and propagation velocity of the discharge.

2. Experimental

Measurements were made in the setup shown in Fig. 1. AC high-voltage power supply was applied to supply the Mini GlidArc plasma reactor. The flow and composition of the gas mixture was adjusted by gas flow controllers. High speed camera Casio EX-F1 capable to shoot 1200 frames per second was used to capture the discharge between electrodes to be able to the evaluate the discharge propagation and calculate its velocity. For accurate processing of ten consecutive images of the discharge were used and video editing and graphics processing programs were applied.

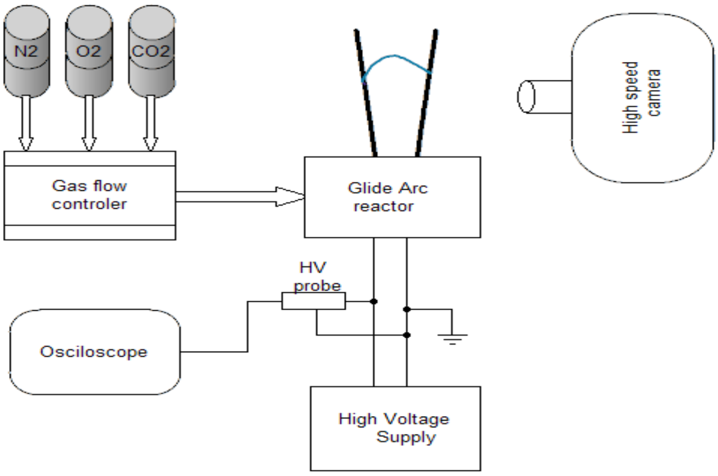

Fig. 1. Schematic diagram of the experimental setup.

The sequence of images in Fig. 2. shows individual steps of the discharge propagation between electrodes in the gas mixture of 30% of O_2 in N_2 (total gas flowrate 7 L/min). The duration of the discharge calculated on the basis of the results from the high speed camera was approximately 8.33 ms.

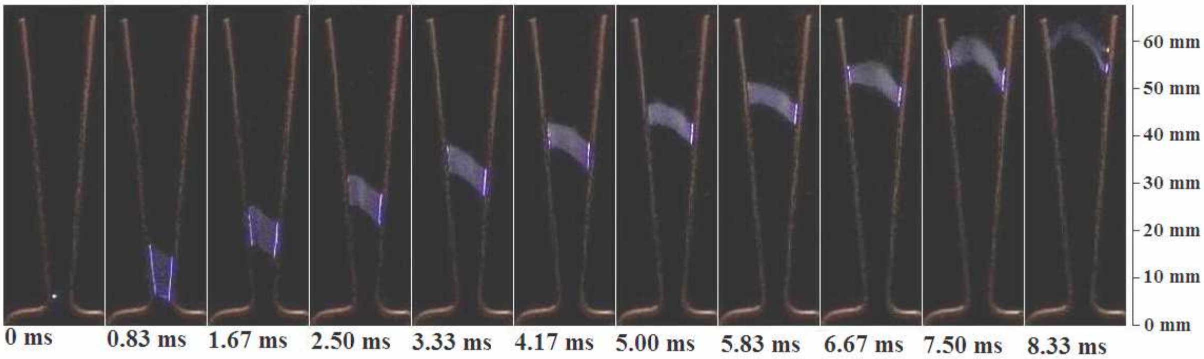

Fig. 2. Sequence of images of the gliding arc propagation taken by the high speed camera (30% of O_2 in N_2, 7 L/min, 1200 fps).

Measurements were made for nitrogen, oxygen, carbon dioxide and mixtures of these gases. Examples of images obtained for different mixtures are shown in fig. 3.

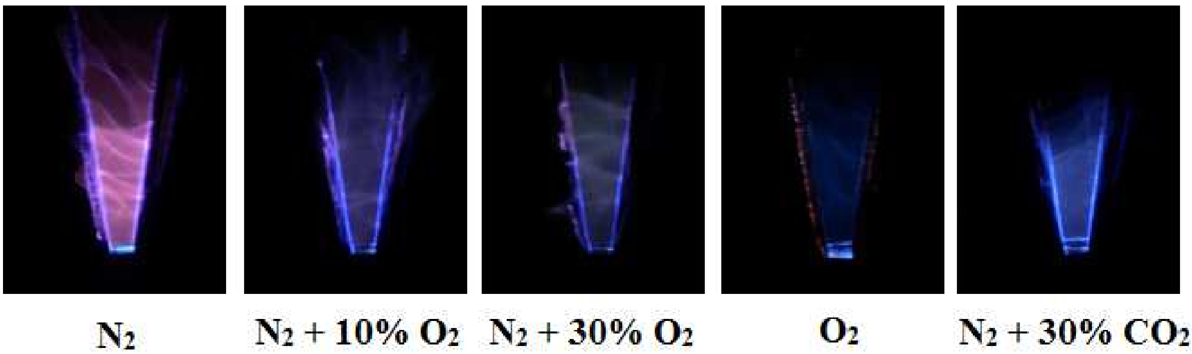

Fig. 3. Effect of gas mixture (exposure time 1/4 s).

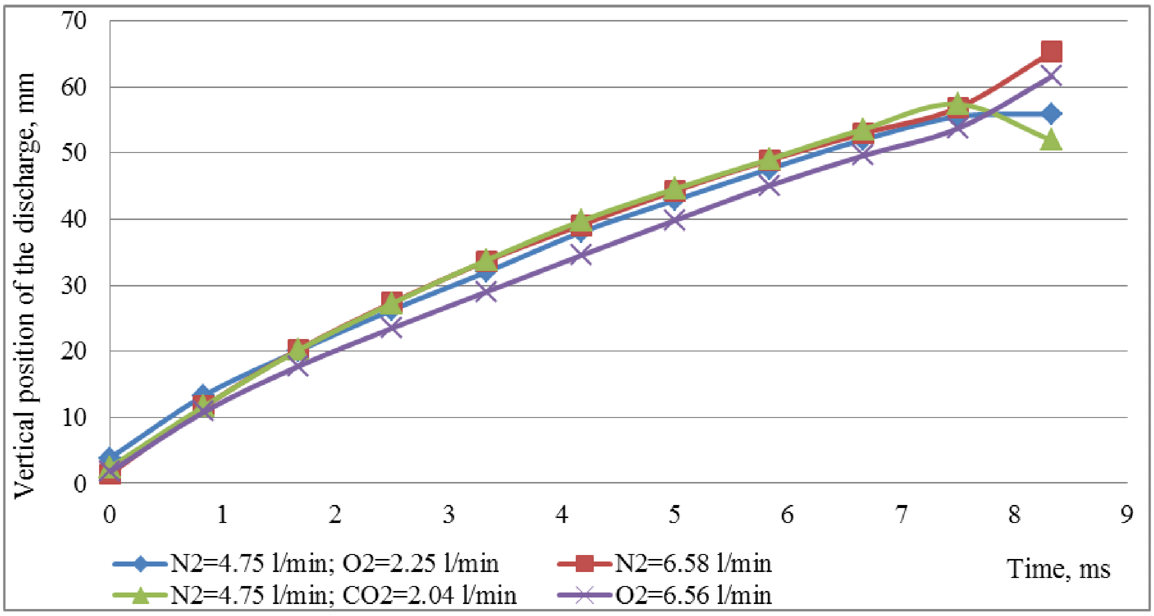

Fig. 4. Vertical position of the discharge propagation in different gas mixtures and at the constant flow rate.

Fig. 4. depicts the vertical position of the discharge front in different gas mixtures of nitrogen, oxygen and carbon dioxide and at constant total flow rate of approximately 6.60 l/min.. As can be seen on the figure, the composition of gas mixtures had no significant effect on the discharge propagation. At the last stages of the discharge the propagation slows down, which is correlated with the uneven fading of the discharge at the end of its life cycle.

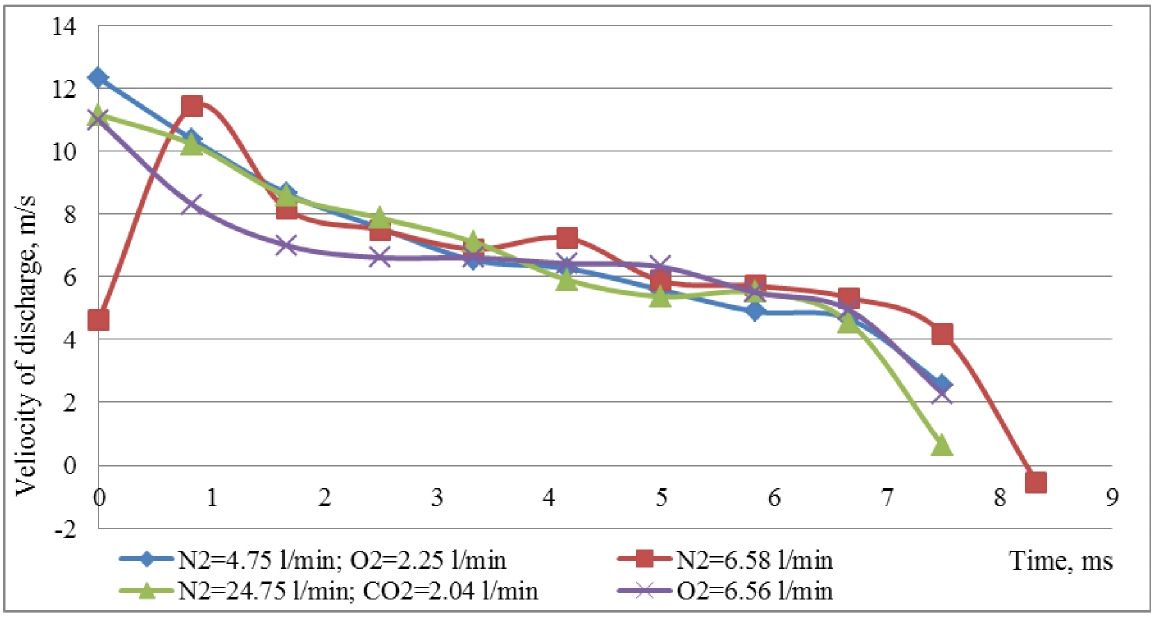

Fig. 5. Velocity of the discharge for constant gas flow rate and different gas mixtures.

The discharge propagation velocity along the electrodes is shown in Fig. 5. and is similar for any gas flow rate. The highest velocity of electric arc discharge can be observed at the beginning of the cycle, while with the slight growth of the arc volume , its velocity decreased. The end of the recession curve is correlated with its disappearance.

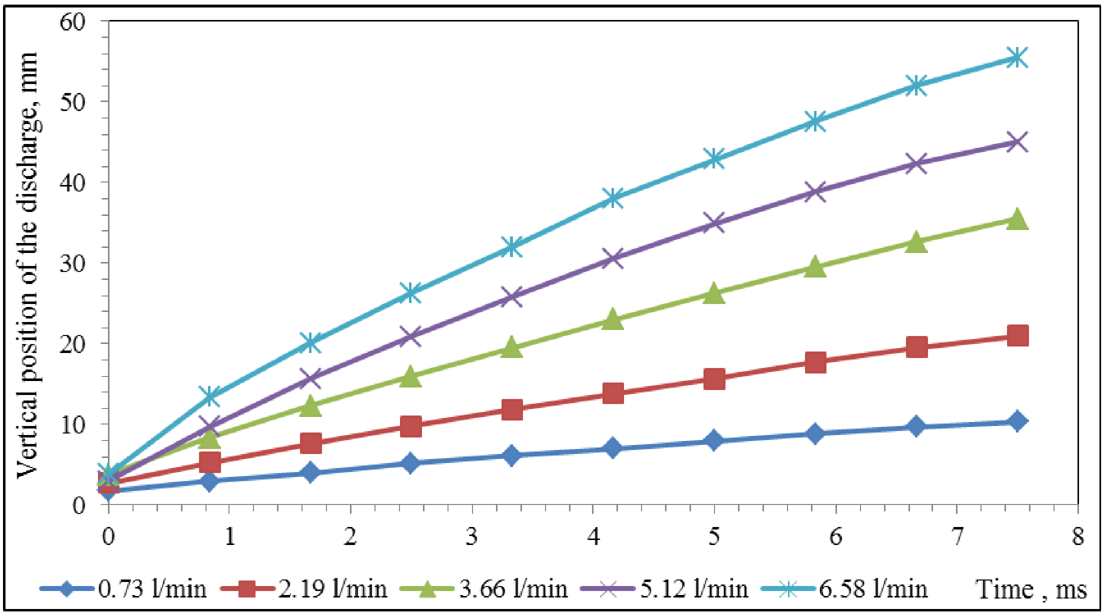

Fig. 6 Vertical position of the discharge propagation for different flow rates (N_2).

Figure 6 shows the results obtained for the different gas flow rate in nitrogen. Increase of the flow rate resulted in significant elongation of the arc, which could be explained by the strong influence of gas-dynamic forces on the shape of the discharge. This was particularly evident in the final stage of discharge, for example 67% flow rate increase (from 2.19 l/min to 3.66 l/min) allowed 68% increase in length. Uncertainty of the front propagation was calculated and is displayed as the standard deviation in Fig. 7. For most of the measurements, the uncertainly increased with time and length of discharge, due to the more complex shape of the arc during the final stages of its propagation.

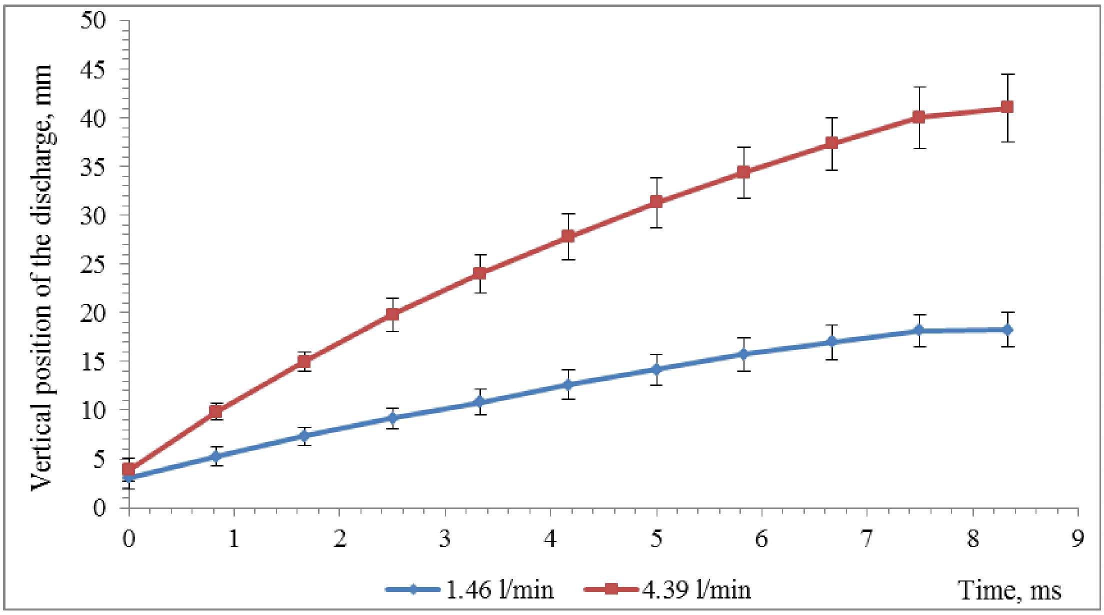

Fig.7. Uncertainty of measurement as the standard deviation for two flow rates (N_2).

Fig. 8. shows the change in velocity of the discharge during its life cycle. Increasing the flow rate also caused greater ranges of calculated velocity results for several series of discharges in oxygen.

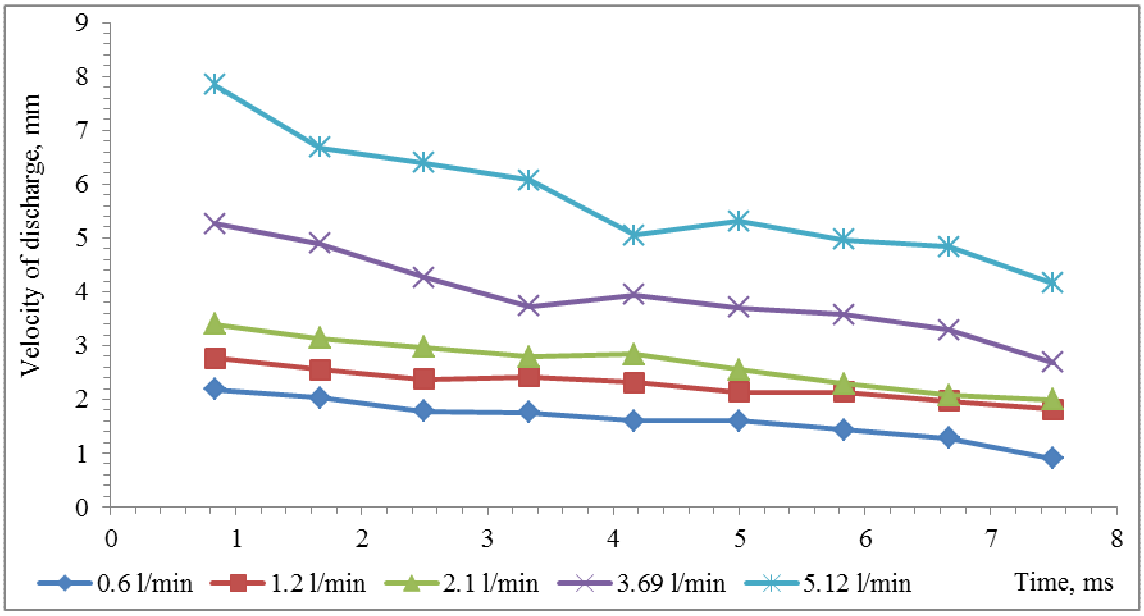

Fig. 8. Velocity of discharge for different flow rates (O_2).

Vertical velocity of the discharge was calculated from the average change in vertical propagation of the discharge in time. In general, velocity decreased in time. In some cases (for example: 3.7 l/min, 3,69 l/min), increase of the velocity was observed in the middle of discharge propagation. It may be the result of changes in the shape of the arc, which appeared to be more stretched in its central part.

For all mixtures and flow-rates, the lifetime of the discharge was the same. Thus, it depends mainly on the power parameters, such as frequency.

3. Summary

By using the high speed camera we characterized the gliding arc discharge in various gas mixtures and in the range of flow rates to measure its propagation velocity, height, and length. The obtained results show that the main factor affecting the length and velocity of the discharge is the gas flow rate. Different mixtures of gasses do not effect the height of the discharge and its life time depends mainly on the power parameters. The results may allow not only to determine the optimum gas flow rate for maximum performance, but also the operating point for the various required distances from end of the "Mini GlidArc" reactor.

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