Gliding Arc Discharge (GAD) Experiment

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Abstract
The Gliding arc (GA) is unique non-thermal plasma that has relatively high plasma density, power and operating pressure in comparison with other non-equilibrium discharges. GA discharge has been constructed that can be operated at high atmospheric pressure consists of two electrodes, one of which connected to the ground and the other connected to the high voltage power supply. A resonant microwave probe technique is used in making local measurements of the charge density. For this purpose the probe is inserted into the plasma, the probe consists of a section of two-conductor line which is excited by means of an appropriate microwave system. The electric field produced by the resonance system extends into the surrounding space but is fairly localized.

Keywords: Gliding arc, non-thermal plasma, resonance, discharge, microwave

Introduction
The gliding arc (GA) is an intermediate system between thermal and non-thermal discharges, and is able to provide simultaneously high plasma density, power and operating pressure with high level of non-equilibrium, high electron temperature, low gas temperature and possibility of stimulation selective chemical processes without any quenching. The main peculiarities of GA are the "memory effect" and essential influence of convective heat and mass transfer on plasma properties and the space/time arc evolution.

Gliding arc generates regions of both thermal and non-thermal plasma at the conditions of atmospheric pressure and ambient temperature [1]. The plasma is weakly ionized and characterized by the lack of local thermodynamic equilibrium since the energy of the electrons is markedly higher than that of the heavy species. It has been reported that the gas temperatures in the non-equilibrium regions are approximately ~11600 K (1eV) electronic, 2000-3000 K vibration, and 800-2100 K translational [2]. For this reason the plasma generated by gliding arc discharge is generally classified as non-thermal. The chemical interactions are regarded as those of quenched plasma [3]. The broad interest in gliding arc discharges results from the unusual chemical properties and enhanced reactivity of the heavy activated species (atoms, radicals, and excited molecules) produced in the plasma.

Gliding arc is considered one of the most attractive of the advanced oxidation techniques because of low equipment and energy costs and its greater efficiency [4]. Higher power levels used with this discharge are thus are more applicable to industry than other viable alternatives such as corona discharge [3].

Most recently, humid air has been used in gliding arc reactors to increase the number of heavy reactive species. The species produced are NO\textsuperscript{+}, OH\textsuperscript{-}, N\textsubscript{2}+, and O\textsubscript{2}+. These species present highly acidic and oxidizing properties towards aqueous solutes and have been shown to lead to the formation of NO\textsubscript{2}, HNO\textsubscript{2}, HNO\textsubscript{3}, H\textsubscript{2}O\textsubscript{2}, among others [5, 6].

Methodology of generation of plasma discharges
The arc initiates at the shortest gap between the two electrodes, after which it elongates by transverse gas flow. At this point in time, the current in the arc is at its maximum value and the voltage at the lowest (quasi-thermal regime). A transverse gas flow is introduced that moves the arc from its initial position and elongates. The elongating arc demands more power to sustain itself, until it reaches the maximum
that the power supply can provide. At this point the power drop on both plasma and external resistance is known to be 50% of the total power [7, 8, and 9]. This is the point transition for the regime of operation of the GA. 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.

**Experimental Setup**

The gliding arc experiment consists of two identical electrodes made of copper with arc length about 3.6 cm and area about 4.2 cm². The gap between two electrodes a few millimeters, one of them is connected to DC power supply and the other one connected to the ground. The gas was injected from narrow tube located from narrow gap between two electrodes. The gas flow can be controlled via flow meter type OMEGA. The two electrodes and the gas pipe were located inside wood block. Figure (1) indicates a photograph of gliding arc discharge and electrical circuit of it.

Fig. 1. A photo of gliding arc discharge operating in atmospheric pressure air and electrical scheme for conventional GA.

**Experimental Results**

The traditional microwave technique to determine electron densities is based on measurement of the MW radiation absorption and phase shift. This method works only when characteristic length of plasma is much greater than the wavelength of probing microwave radiation. In the case of Gliding Arc the diameter of plasma column is 2-5mm and the wavelength should be considerably less than the GA radius. In that case we should work already with IR radiation. The idea of this method is very simple: transmitting and receiving antennas are immersed into plasma (Fig. 2) and the amount of microwave power transmitted through plasma is measured. At the frequency equal to the plasma frequency (directly depended on electron density) resonant absorption is observed. In the case of Gliding Arc the electron density is expected on the order of $10^{11}$-$10^{12}$ cm⁻³.
A two-conductor line is inserted along the axis of the discharge tube; it is excited from the microwave signal generator via the coaxial cable. Fig. (3) indicates that driving signal emitted from a microwave (Period = 20ms, width = 9.9ms, rise = 2.8ms) signal generator type TZA-102 (SHF 3.8- 7.5 GHz). The signal from the output of the measurement of the conductor line is applied to digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth. The oscillogram is shown in Fig. (4), RF modulated Mw signal has the following characteristics: Period = 20ms, width = 34.5 µs, rise = 1.5 µs.
Conclusion
The gliding arc discharge has been constructed and operated using nitrogen gas under atmospheric pressure. The local plasma density was measured using simple method of microwave technique in the vicinity of non-equilibrium plasma region. Results obtained using this method the electron density of the GA about \( n_e = 1.5 \times 10^{11} \) cm\(^{-3}\).

References