Interaction Between Subsonic Gas Flow and a Glydarc Electric Discharge

J. E. Harry;* Q. Yuan;* M. Dubus**

* Department of Electronic and Electrical Engineering, Loughborough University of Technology, Loughborough, LE11 3TU, U.K.
** GREMI - B. P. 6759, University of Orleans, 45067 Orleans, Cedex 2 France

Abstract

An investigation was carried out on the interaction between the gas flow and a Glydarc electric discharge. The characteristics of the electric discharge voltage and the discharge current are given at different gas flows and computer simulation of gas profiles in the discharge region is shown. The apparent positive gradient of the electric discharge voltage-current characteristic is explained.

1. Introduction

A Glydarc electric discharge has the advantage of its inherent simplicity and produces a cold plasma that is potentially useful in chemical processes. This discharge can operate at atmospheric pressure and above and is potentially used in air pollution treatment processes. Several experiments had been carried out to study a Glydarc used for the dissociation of harmful gases such as SO_X and NO_X and to reduce the breakdown voltage at atmospheric pressure[1][2]. A physical model has been also developed to describe the process of a Glydarc[3]; however the characteristic of the discharge voltage and the discharge current of a Glydarc with subsonic gas flows at atmospheric pressure have not been previously investigated.

2. The characteristic of the discharge voltage and current of the Glydarc

2.1 The experimental arrangement

A series of tests was carried out on the behaviour of a Glydarc electric discharge in subsonic gas flows. The experimental arrangement of gas and power supply is shown schematically in Fig. 1.

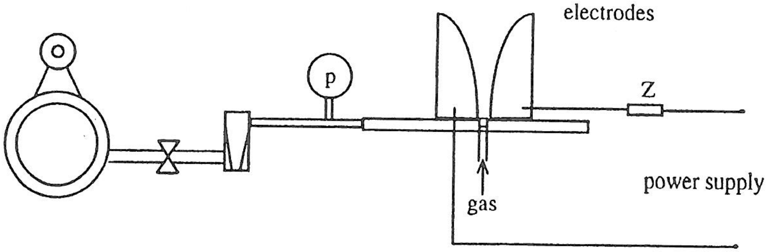
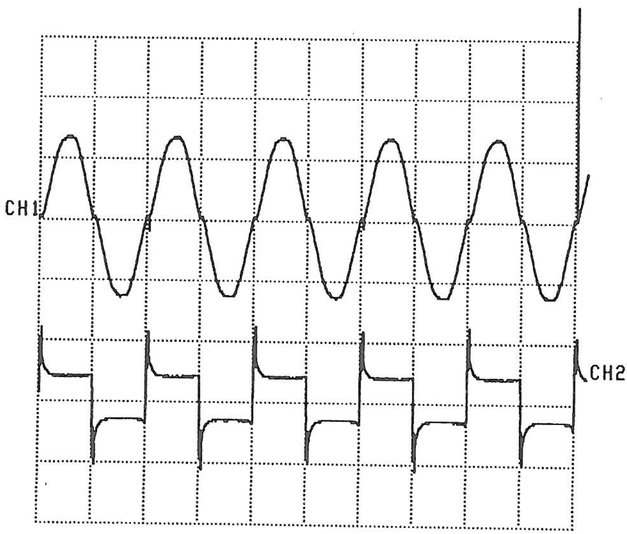


Fig. 1 The schematic diagram of the experimental arrangement

The gas (air) was pumped by an oil free compressor at a pressure up to 8 bar. The high voltage power supply had an open circuit voltage of 9 kV and a maximum current of 3A. The discharge current was measured by an analogue current meter and monitored by a digital stored oscilloscope.

2.2 The discharge voltage and current



Ch 1: 134 mA/div.
Ch 2: 1 kV/div.
Time base: 10 ms/div.

Fig. 2 The waveforms of the discharge voltage and the discharge current

Fig. 2 shows the Glydarc discharge voltage and the current wave forms measured with the oscilloscope. Both the voltage and the current wave forms were non-sinusoidal thus the readings of the measurement instruments should be treated with care[4]. The discharge current was discontinuous with the angle of start of conduction Φ measured from current zero. The discharge voltage was measured by a voltmeter.

Fig. 3(a), (b) and (c) show the characteristic of the discharge voltage and the discharge current using ac and dc respectively. The discharge voltage increases when the discharge current increases. The increase of the discharge voltage between the high flow rate 80ℓ/min. and 100ℓ/min. is not significant because the cooling effect of the gas flows has reached its maximum effect; and the discharge length does not increase further.

The positive slopes of the V-I characteristic are mainly due to the gas flow and the varying length of the discharge. The gas flow convects heat from the discharge region and as a result the electrical conductivity of the discharge column decreases. The variation of the maximum discharge current with high velocity gas flows is smaller at lower gas flows due to the limited range of the high power supply.

The discharge length can vary over a large range even when the discharge root is in the same position. The separation between the Glydarc electrodes increases with distance from the gas inlet, the shortest distance between them is 1 mm. Once the electric discharge occurs, it follows the curvature of the electrodes going upwards and the electric discharge length increases. When the maximum discharge length is reached, the electric discharge extinguishes. The discharge repeats the same process again starting from the shortest gap between the electrodes.

3. Computer simulation of the Glydarc discharge gas profile

The Glydarc electrode with gas flows was simulated by using the FLUENT software programme(version 4.2) to investigate the gas profiles.

The general approach to modelling turbulent flows using time-averaged equations involved augmenting the transport properties to account for the effects of turbulent eddy flow. This involved replacing the fluid viscosity (μ) with an effective turbulent viscosity (μ_t) which was a function of the flow. μ_t was calculated considering the kinetic energy of turbulence (κ) to its rate of dissipation (ε). This was the $\kappa-\varepsilon$ model of turbulence. The $\kappa-\varepsilon$ model in FLUENT was originally designed for non-ionised gases it is still also applicable to the weakly ionised gases.

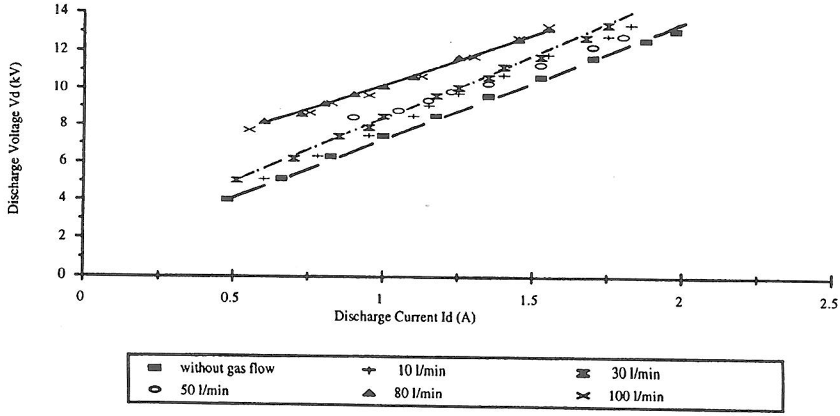


Fig. 3(a). Variation of discharge voltage and current using dc

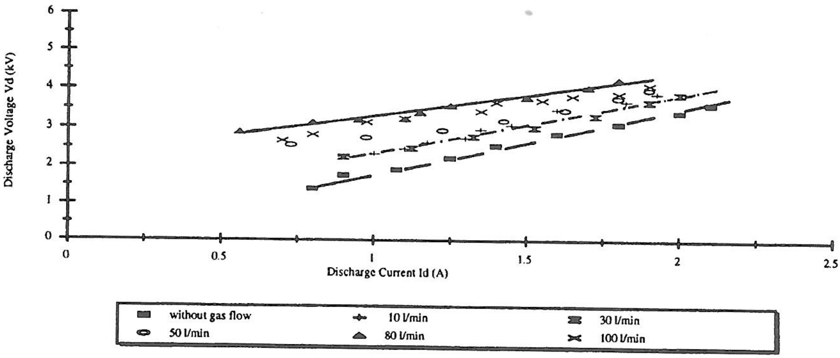


Fig. 3(b) Variation of discharge voltage and current using ac

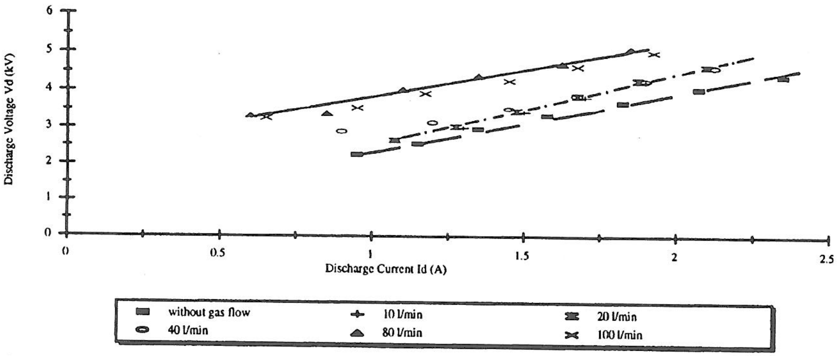


Fig. 3(c) Variation of the discharge current and voltage using ac with a series inductance of 2 H

Fig. 3 Characteristics of the Glydarc electric discharge voltage and current

The Glydarc discharge configuration was axi-symmetrical and the thickness of the electrodes was 1.5 mm thus two-dimensional symmetric calculation was adequate for sufficient calculation. The grid used for calculation was evenly spaced. The computational cells were 100x46. The gas at the input point was assumed uniform and the turbulent effect considered in the discharge region by using the general $\kappa - \varepsilon$ model in the program. Parameters used in the simulation are shown in the Table 1.

Table 1. Coefficients used in the simulation

domain size: 430 mm x 280 mm	gas: air
turbulent intensity: 10	density: 1.2 kg/m^3
turbulent schmidt number: 0.7	temperature: 293K
viscosity: 10^{-5} kg/m s	thermal conductivity: 0.0241 W/mK
molecular weight: 28	specific heat of fluid: 1004 J/kgK
binary diffusion rate: 2.88×10^{-5} m^2/s	pressure: 1.0133×10^5 Pascals

The model in the simulation assumed that the Glydarc was enclosed in an adiabatic cylindrical vessel and hence heat from the discharge was removed by convection of gas flows rather than by conduction.

The first simulation of gas profiles for the Glydarc electrodes were based on the existing electrodes. The gas profile is shown in Fig. 4. Later simulations were carried out for different electrode profiles. Fig. 4 suggests that the shape of the electrodes should be less divergent because less divergent electrodes could increase the interaction volume between the gas and the discharge.

Zone 1
Gas: 0.1 m/s

Zone 2
Gas: 2.5 m/s

Zone 1
Gas: 0.1 m/s

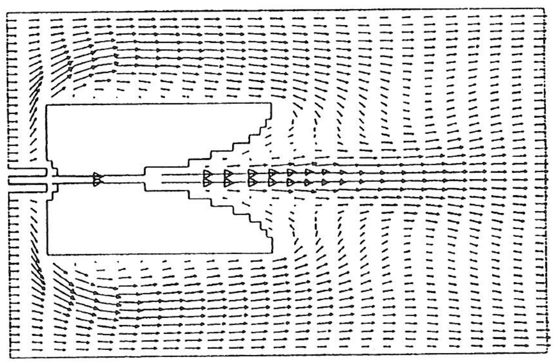


Fig. 4 The gas profile in a Glydarc discharge

4. Discussion

The objective of the gas flow in the glow discharge is to convect the heat out of the discharge region to keep the glow discharge from changing to an arc discharge and the discharge current to be increased. The discharge voltage increases with increasing the gas velocity and the discharge current. This is because the discharge length increases and the conductivity of the discharge decreases due to gas cooling effect.

The flowing gases in the Glydarc increase the volume of the non-thermal discharge provided the electric discharge is stable. The computer simulation suggests that less divergent electrodes should be more suitable for the Glydarc discharge. These may be potentially useful in designing the optimum Glydarc electrodes.

5. References

[1]Czernichowski, A; Gliding Arc. Application to Engineering and Environment Control, Pure and Appl. Chem., 66, (6) pp 1301-1310, (1994)

[2]Harry, J. E; Yuan, Q.; Reduction of Breakdown Voltage of Atmospheric Pressure Arc Discharge in the Glydarc Process Using an Auxiliary Supply and Electrode; Proceedings of ISPC11, 2, pp734-739, Loughborough, England, (Aug. 1993)

[3]Fridman, A.; Chapelle, J.; Czernichowski, A.; Lesueur, H.; Stevefelt, J.; Model of the Sliding Arc - Applications in Plasma Chemistry; Proceedings of ISPC 11, 1 pp 257-263, Loughborough, England, (Aug. 1993)

[4]Harry, J. E.; Measurement of Electric Parameters of AC Arcs, IEEE. Transactions on Industry and General Applications. 5 (5)pp 594 - 599, (1969)