Hypergravity influence on gliding arc in noble gases

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The effects of increased artificial gravity (in the range 1*g*-18*g*) on gliding arcs in four noble gases (He, Ne, Ar, Kr) were the subject of this experimental study. Besides the apparent gravity level, the gas flow was also a variable parameter. The results prove a significant influence of gravity on the gliding arc behaviour caused by the buoyancy acting on the hot plasma column. This upward force has a similar effect as increasing the gas flow. The gravity-induced changes were found to be more profound for heavier gases.

Arc discharges are industrially widely employed examples of atmospheric plasma discharges. Although they have been studied under variety of operating conditions, including extreme cases of hyper- and micro-gravity, less attention has been paid to the “dynamic version” of them. The gliding arc [1, 2] is formed between two electrodes with a typical slanted shape enabling the movement of arc channel upwards when the combination of buoyant force and/or gas flow drag is strong enough. The plasma properties are changing during the rise of the gliding arc channel, as the length of the plasma column increases to its maximum extent. When the power requirements needed for further sustainment of the elongated plasma channel can not be satisfied, the discharge extinguishes and a new arc forms between the nearest points at the two electrodes. This discharge evolution cycle then repeats itself.

The gliding motion of the arc is affected by many parameters. One of the most important and, simultaneously, one of the least experimentally studied factors is gravity. The buoyancy driving the arc upwards is closely related to the gravitational force and thus the increase of artificial gravity strongly influences the glide arc plasma. This effect manifests itself mainly as the faster movement of the plasma channel. The above mentioned effect and related phenomena were studied in our previous works [3, 4, 5] using the large diameter centrifuge [6] in ESA/ESTEC facility in the range of 1*g*-18*g*.

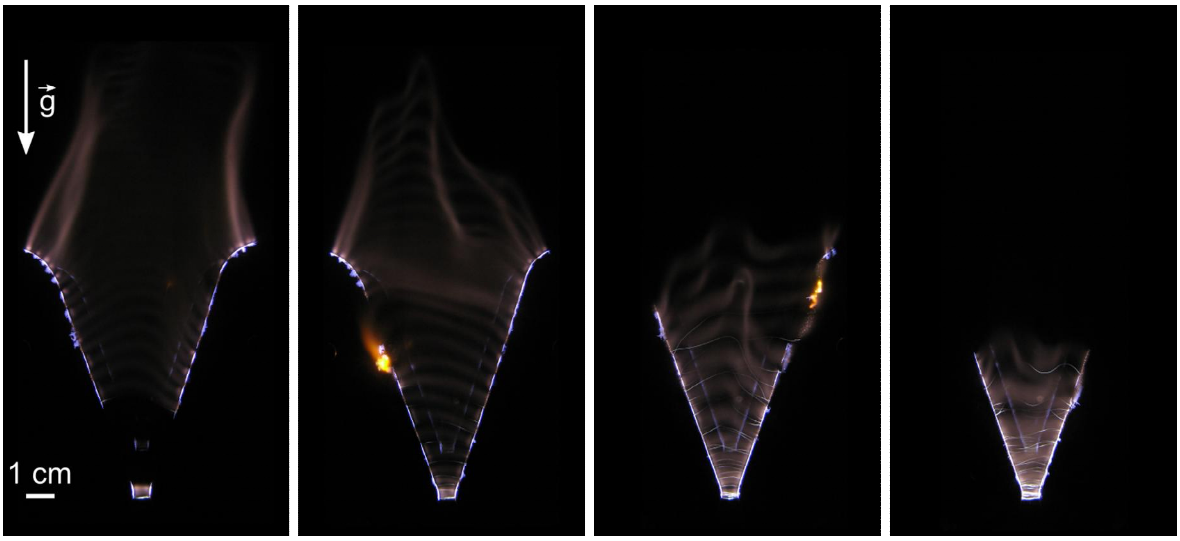

Fig. 1: Photographs of gliding arc in krypton (0.15 slm, 4 kV, 0.3 s exposure) under normal and hypergravity conditions. From left to right the apparent gravitational levels are 1*g*, 2*g*, 12*g* and 18*g*. Corresponding velocities of the arc’s upwards movement are 22.2 cm/s, 26.5 cm/s, 83.2 cm/s and 89.2 cm/s. Respective gliding frequencies are 1.7 Hz, 2.2 Hz, 11.2 Hz and 19.8 Hz.

As the buoyant force acting on the discharge depends not only on gravity, but also on the properties of the used gas, we decided to perform the experiments in four noble gases. Helium, neon, argon and krypton were chosen because of their similar properties (monoatomic and non-reactive gases), while they differ in other parameters, such as the ionisation potential and atomic mass. These differences affect both the plasma kinetics and the buoyancy.

The flow rate and the type of gas were varied so that the gliding arc was operated under a broad range of conditions. The nearly quarter-elliptic copper electrodes (minimum distance of 4.5 mm and an initial angle of 72°) placed inside the non-conductive 2 dm^3 discharge chamber were powered by a current limiting high voltage transformer supplying 0-10 kV at 50 Hz AC. In order to study the gliding arc in more detail, we simultaneously measured several glide arc parameters during each experimental run on large diameter centrifuge. These were: (i) visual appearance (shape and movement of glide arc, recorded either by high speed camera or in a form of long exposure photographs), (ii) electric variables (power, voltage and current on primary winding of transformer and discharge voltage and current), (iii) optical emission spectra, (iv) acoustic measurements of the typical periodic sound produced by glide arc appearance, movement and extinguishing and, finally, (v) the temperature inside the discharge chamber (for safety reasons).

Probably the most important of observed changes, which the glide arc underwent within the range of increasing hypergravity, was the increase of the velocity of its upwards movement. Consequently, the gliding frequency increased as well. The rise in the gliding frequency was even more enhanced due to the decrease in maximum height achievable by the glide arc (see Fig. 1). Such effects are similar to the effects of increased gas flow, which supports the conclusion that gravity and gas flow are partially interchangeable parameters. The optical emission spectra revealed changes in relative intensities of several spectral lines indicating a change in the electron energy distribution function. From electrical parameters, the most affected is the maximum discharge voltage reached just before the arc extinguishes. This voltage decreases with increasing apparent gravitational level, while discharge current remains almost stable. Generally, the gravity-induced changes of parameters were the most profound for gliding arcs in krypton, while some of the changes were almost untraceable for lighter gases - helium and neon.

Acknowledgment

This work was supported by European Space Agency SpinYourThesis! 2013 programme, Masaryk University and project CZ.1.05/2.1.00/03.0086 funded by European Regional Development Fund. We would also like to thank Mr. Alan Dowson from ESA-TEC-MMG for his support to these studies and Slovak-Czech Women's Fund for financing participation of one author (L.P.) at the conference.

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