Whalley R, Choi KS.

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Physics of Fluids 2010, 22(9): 091105.

AIP | Physics of Fluids

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Richard Whalley and Kwing-So Choi

Citation: Phys. Fluids 22, 091105 (2010); doi: 10.1063/1.3481439
View online: http://dx.doi.org/10.1063/1.3481439
View Table of Contents: http://pof.aip.org/resource/1/PHFLE6/v22/i9
Published by the American Institute of Physics.

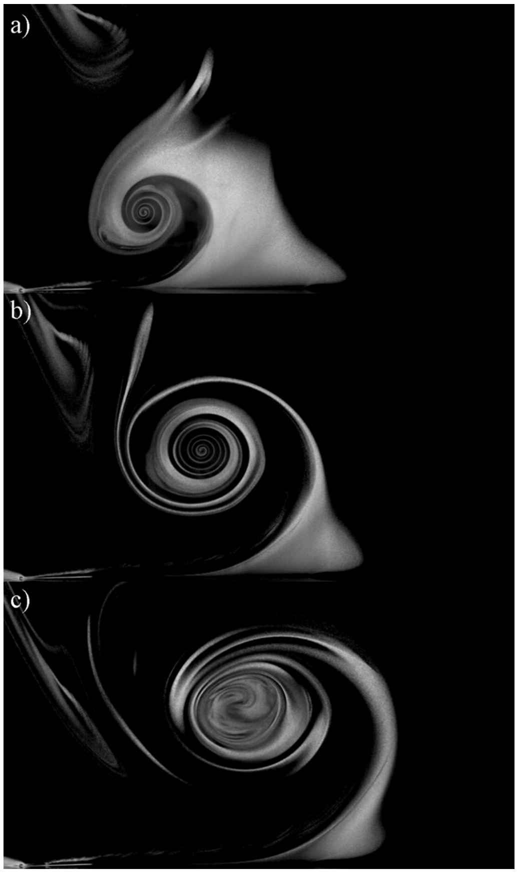

FIG. 1. Starting vortex with 0.12 mN/m forcing at (a) 120 ms, (b) 210 ms and (c) 300 ms after plasma initiation (enhanced online) [URL: http://dx.doi.org/10.1063/1.3481439.1].

Starting, traveling, and colliding vortices: Dielectric-barrier-discharge plasma in quiescent air

Richard Whalley[a] and Kwing-So Choi[b]
Faculty of Engineering, University of Nottingham, University Park, Nottingham NG7 2RD, United Kingdom
(Received 2 August 2010; published online 30 September 2010)
[doi:10.1063/1.3481439]

Dielectric-barrier-discharge (DBD) plasma is generated when high voltage alternating current is applied across two electrodes separated by a thin dielectric material. This causes local ionization of atmospheric gas over the exposed electrode, which couples momentum to the surrounding air inducing a jet tangential to the wall.[1]

We have conducted a series of smoke flow visualizations in quiescent air at atmospheric conditions. Figure 1 shows images taken with a high-speed camera, where we observed a wall jet being formed on initiation of a DBD plasma, accompanied by a starting vortex.[2] The starting vortex rolls up, increases in size and travels along the wall. This is qualitatively similar to a junction vortex.[3]

[a]Electronic mail: eaxrw@nottingham.ac.uk.
[b]Electronic mail: kwing-so.choi@nottingham.ac.uk.

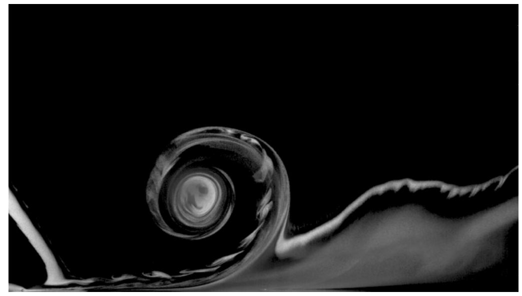

FIG. 2. Starting vortex with 2.8 mN/m forcing at 120 ms after plasma initiation.

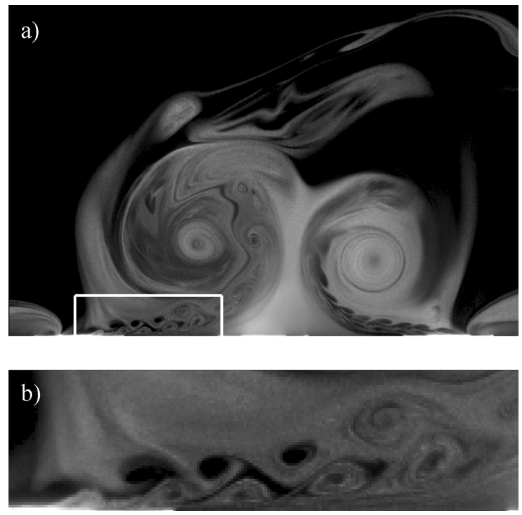

FIG. 3. Colliding vortices with 2.8 mN/m forcing at (a) 170 ms after plasma initiation and (b) showing the Kelvin–Helmholtz instability.

When the Reynolds number is increased by increasing the plasma forcing strength, we see the development of the Kelvin–Helmholtz (K-H) instability in the wall jet (see Fig. 2). The instability waves are then wrapped around the core of the starting vortex.

Figure 3(a) shows an image of starting vortices created by two opposing plasma actuators. The wall jets from the plasma actuators collide to form a wall-normal jet at the center of the picture. As a result, the starting vortices are pushed away from the wall as they develop. Trains of vortices due to the K-H instability are clearly seen in the jets [see Fig. 3(b) for an enlarged picture], which are ingested by the starting vortices. It should be noted that the frequency of instability is nearly two orders of magnitude lower than that of the alternating-current power supply.

This work was supported by the EPSRC and the EU FP6 framework program AVERT.

[1]E. Moreau, "Airflow control by non-thermal plasma actuators," J. Phys. D: Appl. Phys. **40**, 605 (2007).
[2]T. N. Jukes, K.-S. Choi, T. Segawa, and H. Yoshida, "Jet flow induced by a surface plasma actuator," Proc. IMechE Part I: J. Systems and Control Eng. **222**, 347 (2008).
[3]J. J. Allen and T. Naitoh, "Scaling and instability of a junction vortex," J. Fluid Mech. **574**, 1 (2007).

1070-6631/2010/22(9)/091105/1/$30.00