2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Dynamical structure formation due to complex plasma flow past an obstacle

S. Jaiswal[1,2,3], M. Schwabe[2], A. Sen[3], P. Bandyopadhyay[3]
[1] Physics Department, Auburn University
[2] Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR)
[3]Institute for Plasma Research
e-mail: surabhijaiswal73@gmail.com

Fluid flow past an obstacle is a fundamental phenomenon which has vast interdisciplinary applications such as in oceanography, space [1] and atmospheric dynamics. This phenomenon has been widely studied in the fluid mechanics but has not received much attention in plasma physics. Although there are very few theoretical investigations has been reported [2] but experimental verifications are still lacking. In this work, we report on the experimental observation of dynamical structure formation due to complex plasma flow past an obstacle. The experiments have been carried out in a ∏-shaped Dusty Plasma Experimental (DPEx) device [3] where kaolin particles immersed in a DC discharge argon plasma form a dusty plasma and a floating/biased sphere mounted on the cathode creates an obstruction to the flow. The dust flow is induced by suddenly reducing the mass flow of neutrals through mass flow controller in a well-controlled way [4]. The flowing dust particles are repelled by the electrostatic field of the negatively charged sphere and a microparticle free region (dust void) is formed surrounding the obstacle. The distant dust particles are attracted towards the floating obstacle and reflected when they get to a certain distance, causing a ring-shaped structure around the obstacle. We characterize the shape of this structure over a range of dust flow speeds and obstacle biases. We found that the shape of this structure can be affected by a change in the flow velocity. At higher flow velocity the distribution of dust become asymmetric with respect to upstream and downstream region of the obstacle as shown in figure 1(b).

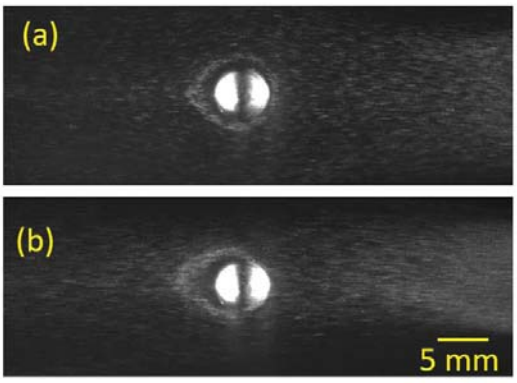

Figure 1: Experimental Images of microparticle flow around a floating obstacle for flow rate changes of (a) 11 ml/min (b) 19.25 ml/min

For a supersonic flow of dust fluid around a negatively biased obstacle, a bow shock [5] is formed on the upstream side of the obstacle, whereas nonlinear structures are propagating in downstream for a particular range of flow velocities when the Reynolds number

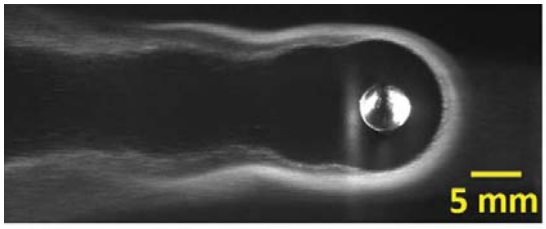

Figure 2: A snapshot of the phenomenon of bow shock along with the downstream propagation.

Re≥50. The wave structure reminds the phenomenon of Von-Kármán vortex street which in general form at the Reynolds number of approximately 47. The flow generated structures can be physically understood in terms of the dust dynamics under the combined influence of the ion-drag force, the neutral streaming and the electric force.

Acknowledgement: S. Jaiswal acknowledge financial support of DLR-DAAD research fellowship and an additional support by the NSF EPSCoR program (OIA-1655280).

References

[1] C. Mazelle, D. Winterhalter, K. Sauer, J. G. Trotignon, M. H. Acuña, K. Baumgärtel, C. Bertucci, D. A. Brain, S. H. Brecht, M. Delva, E. Dubinin, M. øieroset, and J. Slavin, Bow Shockand Upstream Phenomena at Mars, in: Mars' Magnetism and Its Interaction with the Solar Wind, pp. 115-181, Springer (2004).
[2] P. Guio and H. L. Pe´cseli, geophysical research letters, **31**, L03806 (2004).
[3] S. Jaiswal, P. Bandyopadhyay, and A. Sen, Rev. Sci. Instrum. 86, 113503 (2015).
[4] S. Jaiswal, P. Bandyopadhyay, A. Sen, Plasma Sources Sci. Technol., 25, 065021 (2016).
[5] Y. Saitou, Y. Nakamura, T. Kamimura and O. Ishihara, Phys. Rev. Lett. 108, 065004 (2012).
[6] S. Jaiswal, P. Bandyopadhyay, and A. Sen, Phys. Rev E 93, 041201(R) (2016).
[7] S. Jaiswal, P. Bandyopadhyay, and A. Sen, Phys. Plasmas 23, 083701 (2016).