Karlsruhe Institute of Technology

Institute for Aerospace Studies
UNIVERSITY OF TORONTO

Institute of Fluid Mechanics istm
http://www.istm.kit.edu

Master's Project

Body Forces from Velocity Data – Can Phase-Resolved Integral Approaches Work?

Background

Active flow control by means of plasma discharges have proven to be a promising alternative to conventional actuator concepts. The working principle of such plasma actuators has been studied extensively, where one important aspect was and still is the determination of the imparted momentum from the plasma to the airflow. Particularly, several differential and integral approaches have been tested in so as to derive force distributions and net force values from experimental velocity data, respectively. Even though considered a quasi-steady force field in the first approximation, a phase-resolved determination of both force distribution and total magnitude is important to develop advanced models for numerical simulations. The phase-resolved force fields can only be derived form differential approaches like Navier-Stokes and vorticity equations. Since second and third derivatives of experimental data leads to high degrees of uncertainty, the uncertainty interval of the total magnitude is accordingly rather large. In contrast, the integral approaches (e.g. momentum balance across control volume boundaries) have demonstrated to be more robust in terms of measurement uncertainty. However, as the predominating time-derivative term is defined inside the control volume, only quasi-steady phase-to-phase variations of the force magnitude have been derived so far.

Content of the Thesis

The thesis centers around the question how best to develop a real phase resolved integral approach to overcome the shortcomings of either processing strategy. Various existing force-estimation approaches will be applied, where particular emphasis will be placed on the implementation of the formerly excluded acceleration term. Since the local acceleration includes a volume integral, an appropriate approximation of an equivalent surface integral will be the major scientific challenge of the thesis. The accuracy of this approximation should be estimated from the direct comparison of the new integral approach with the established differential methods. Three sets of velocity data are available for the study [1-3] such that the robustness of the developed approach can be tested across a rather wide range of operating conditions. The project can be hosted at UTIAS and/or at ISTM.

[1] Murphy, J.P., Kriegseis, J., Lavoie, P. (2013) 'Scaling of maximum velocity, body force and power consumption of dielectric barrier discharge plasma actuators via particle image velocimetry', *J. Appl. Phys.*, vol. 113, 243301 (10pp.)

[2] Naghib-Lahouti, A., Pimentel, R., Lavoie, P. (2014) 'Characterization of the time-dependent behaviour of dielectric barrier discharge plasma actuators', 45th AIAA Plasmadynamics and Lasers Conference, *AIAA paper* 2014-2807

[3] Kuhnhenn, M., Simon, B., Maden, I. Kriegseis, J. (2016) 'Interrelation of phase-averaged volume force and capacitance of DBD plasma actuators', *J. Fluid Mech.*, vol. 809, no. R1, pp. 1-11

Beneficial Skills

good knowledge in fluid mechanics, programming skills in MATLAB

Start: at any time

Contact UTIAS:

Philippe Lavoie, PhD, PEng

Institute for Aerospace Studies
University of Toronto

✉ lavoie@utias.utoronto.ca

Contact ISTM:

Dr.-Ing. Jochen Kriegseis, AR

Institute of Fluid Mechanics
Karlsruhe Intitute of Technology

✉ kriegseis@kit.edu