Mixing enhancement for turbulent jets with plasma actuator control

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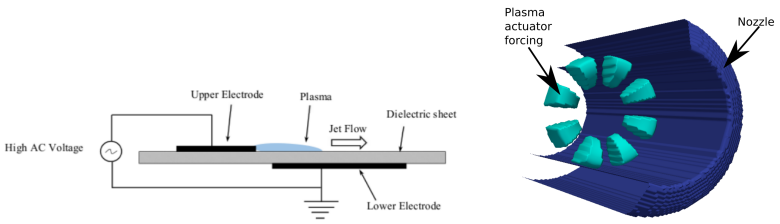
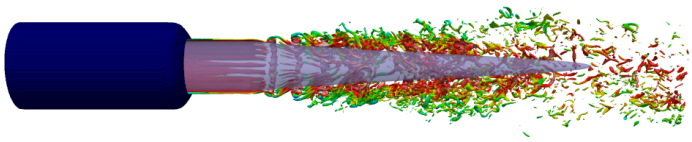
Passive or active methods can be used to achieve effective control of turbulent jets. The former includes the use of tabs [1] or chevrons, which are currently used at the nozzle exit of modern aircraft jet engines. The fact that they are always there can have a detrimental effect on the flow when they are not necessary. More recently, active control solutions have been studied extensively because they can be turned on only when needed. In the present work, an active flow control solution based on plasma actuators is used. Following the work of Samimy's group [2], an array of 8 radially distributed Dielectric Barrier Discharge (DBD) plasma actuators is placed just before the nozzle exit as shown in figure 1 in order to manipulate the initiation, evolution and growth of the jet main instabilities. Implicit Large Eddy Simulations of turbulent jets are performed at a Reynolds number of 460,000 (speed of 33 m/s in a wind tunnel) using the high-order flow solver Incompact3d [3]. The nozzle with the array of plasma actuators is modelled inside the computational domain using a customised Immersive Boundary Method (IBM) based on a direct forcing approach that ensures a zero-velocity boundary condition at the wall of the nozzle. The plasma actuator model incorporated in Incompact3d [4] is based on a phenomenological two-equation model developed by Suzen and Huang in 2005 [5].

Different configurations of the modes of operation for the plasma actuators are investigated. More specifically, a continuous forcing and various pulsating motions are introduced. Visualisations showed a reduction of the potential core length and an increase in the jet expansion as shown in figure 2, results that are promising for mixing enhancement. In order to better understand the mixing properties of the flow, a passive scalar is used so that Probability Density Functions (PDFs) can be calculated to find the best control strategy for mixing enhancement.

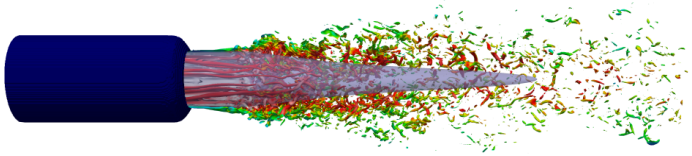


(a) Schematic for a generic DBD plasma actuator (b) Plasma Actuator locations inside the nozzle of the jet

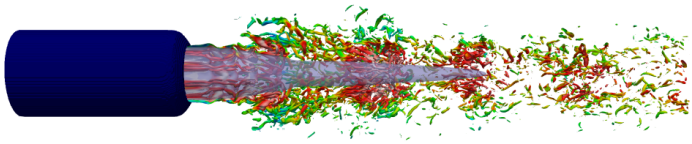
Figure 1: DBD plasma actuator schematic and locations inside nozzle



(a) Baseline case



(b) Continuous action



(c) Pulsating action at St=0.3

Figure 2: Potential core contours (blue) with instantaneous vorticity contours, coloured by the streamwise vorticity.

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