Flow control using plasma actuators

Abstract

Nowadays, the aircraft industry is searching for new technologies that would bring a considerable improvement on fly performance of the airplanes. One of the big challenges is to reduce the friction drag on the wings. This would lead in lower fuel consumption, reducing the fly costs and also the environmental impact. Once a laminar flow presents a lower drag coefficient when compared to a turbulent one, is it an important goal to manipulate the boundary layer transition region and avoid the kinetic energy dissipation, what is called flow control.

Flow control techniques are not only interesting for the aircraft industry, but they also have important applications within the automobile industry, wind turbines, and many other fields. Inside of this context, flow control methods which do not need additional operational energy are called passive flow control methods. One known example of passive flow control is the use of small protuberances, or small cylinders positioned at the solid surface to act as vortex generators inside the boundary layer. But parameters as free stream velocity or flow direction can strongly influence the expected performance. One can say that the success of these methods is strongly dependent of a certain combination of parameters. On the other side, methods which use small devices which need additional energy for modifying the flow are called active flow control methods. Despite of some operational costs, active flow control methods have as main advantage the possibility for power adjustments. One example is the use of blowing and suction actuators, for modifying the boundary layer velocity profile. The problem concerning these actuators for aerodynamic applications is the heavy construction implications. From this point of view, the use of plasma actuators for flow control is an attractive alternative to promote the boundary layer profile modification. The absence of moving parts, and the easy manipulation of power, can be interesting characteristics for aerodynamic applications.

Plasma actuators, also called Dielectric Barrier Dischargers (or DBDs), consist basically of two electrodes, covered by an insulating material, in which a high Voltage is applied. As a consequence of that, the air barrier is broken and the discharge produces a flux of ions in the region next to the electrodes. More generally speaking, for fluid mechanics purposes, the whole process can be described as a wall jet which is caused by a body force.

Until now, the fully understanding of the working principles of a plasma actuator has not been reached. There are difficulties related to the scale problem. For the electromagnetic field, the scales are about 4-8 orders smaller than the scale of interest for solving the flow field equations. That is the reason why a very precise coupled model between these two problems (plasma generation and fluid flow) was not a very attractive option, and a precise numerical model for quantitative analysis was still missing. The new investigations on this field show a good approach to identify the body force resultant of a plasma actuator based on Particle Image Velocimetry (PIV) measurements. These results are used as base for a quantitative analysis.

The numerical simulations were conducted using the in house code FASTEST (Flow Analysis Solving Transport Equations with Simulated Turbulence). FASTEST uses Finite Volume Method for solving the incompressible Navier-Stokes equations, with block structured mesh and it is parallelized with MPI (Message Passing Interface). Despite the high computational costs, Direct Numerical Simulations (DNS) were used, for reaching a better comprehension of the complex physics involved on the problem. Modal stability analysis is also conducted in order to validate the amplification rates of the computed TS waves. Some basic assumptions were considered: low environmental disturbances and parallel, two dimensional steady base flow, superposed with small wavelike velocity disturbances.