INDUSTRIAL CONSTRAINTS AND REQUIREMENTS FOR AERONAUTICAL FLOW CONTROL APPLICATIONS

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Abstract: Active Fluid Mechanics is a new exciting field of investigation which enables the extension of aircraft aerodynamic efficiency limits presently reached by means of classical "passive" shape optimisation process , and leads to new control devices complementary to classical control surfaces.
This new aerodynamic approach is based on flow management by means of small actuators and sensors which can be mini or/and micro sized such as Micro Electro Mechanical Systems (MEMS) based on silicium technology.
The key point of such flow control is to select the best receptive locations on the aircraft where a micro-actuation can be performed at low energy cost and produce a macro-effect on the whole aircraft performances.
Important progresses in analysing and understanding the basic mechanisms governing turbulent flows (stability analysis, coherent structures, multi- scales interactions,…) have been made in a recent past, and have opened a wide field of flow control applications.
The present paper will focus on particular flow control requirements for aeronautical applications (military and civilian), namely the boundary layer separation control (high lift improvement, buffeting limit improvement, highly curved inlet duct), the boundary layer transition control (Hybrid Laminar Flow Control) , the afterbody jet mixing increase and vectoring , and the yaw control of an aircraft forebody at high angle of attack.
Some experimental results will be presented as well as numerical results obtained by use of the Dassault-Aviation in-house unstructured Navier-Stokes code in RANS and URANS mode, and special attention will be drawn towards the industrial needs for specific actuators .

1. Introduction

The ability to manipulate a flow field to improve the efficiency and performance of an aircraft is of immense technological importance. As such, there is an increasing amount of interest in flow control to bring about the improvement in the maneuverability and performance of an aircraft. In this respect Dassault-Aviation has performed for many years numerous numerical and experimental studies in collaboration with ONERA and several universities (Ecole Centrale de Lyon, LEA Poitiers, IMFT Toulouse, LPMO Besançon, LML Lille, IEMN Lille among others) and with the support of French DGA and DPAC. These studies ranged from fundamental ones with PhD (O.Davodet[1], N.Getin[2], I.Boué[3], and G.Petit[4]) to more applied ones like flow control of high angle of attack forebody vortices[5,6] , jet mixing enhancement[7,8] and vectoring , or boundary layer separation[9,10] among others. Dassault-Aviation has also contributed to EC efforts on flow control through ELFIN, AEROMEMS , EUROLIFT and AVERT projects.
For instance laminarity control is nowadays feasible at low energy cost and with a very localised region of actuation[11,12] , thanks to the development of three dimensional bounday layer stability theories[13,14,27,28] as shown below in § 2.5.
This example among others shows how it is important to know as accurately as possible the flow physics in order to manipulate the flow at the right place with the right action , and above all to be in a position to be able to analyse correctly why the flow is reacting in the desired way.

More generally for flow control, new diagnostics tools like instantaneous flowfield measurement (PIV) , and improved unsteady numerical simulations (URANS , DES, LES) are mandatory for better understanding and control of turbulent flows.The flow manipulation can take place at the wall or in the free shear layers, and can be passive (no auxiliary power needed) or active (energy required in an open or closed control loop). A good review of flow control can be found in[22,23].This new Aerodynamics, called Active Aerodynamics , must meet at least the following important requirements:

- increase the aircraft aerodynamic efficiency (boundary layer separation management, vortex flow management,..)
- create new control devices to complement the classical control surfaces
- ability to act on a macro fluid flow by means of a micro action
- ability to be used on real aircraft environment (layout, systems, maintenance, safety, certification, in flight conditions)

This new Active Fluid Mechanics is a multidisciplinary field of investigation, at two different levels. At the scientific level it involves researches in Flow Physics, Computational Fluid Dynamics, Control theory, and Actuators and Sensors technologies. Multidisciplinarity is also present at the industrial level since Flow Control can be applied with great benefit not only in the Aerospace community, but in the automotive industry, the sea and railway transportations and in the chemical industry. This point is very important since it will be possible to manufacture actuators and sensors in great quantity, thus at lower price, because commonly used by these various industries. This Active Fluid Mechanics multidisciplinarity implies a strong and tight interaction between scientists and engineers on a common basis of applied mathematics / computer science / multiphysics, and Dassault Aviation has a strong implication and contributes to federate these activities within research networks.

2. Flow Controls of aeronautical interest

Flow control is sought for military and civil aircrafts. For military aircrafts (figures 1 and 2) the requirements are manyfold. One among others is to enhance aircraft maneuverability and its ability to experience high angles of attack, as well as to regularise the global aerodynamic efforts and moments.

Figure 1 : Various flow controls on a fighter

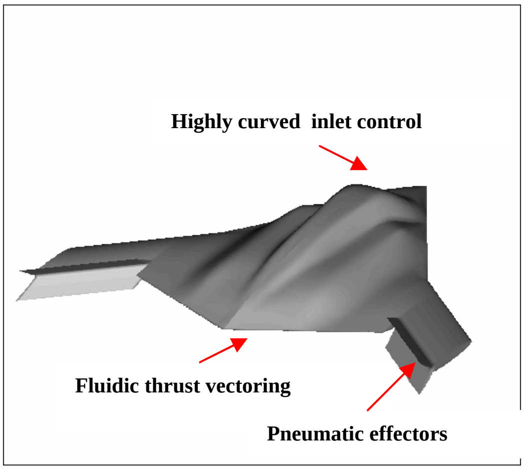

Figure 2 : Various flow controls on a UCAV