PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

THEMATIC Research Field: UNDERSTANDING SKIN-FRICTION TURBULENT DRAG REDUCTION VIA SPANWISE FORCING

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Reducing the turbulent skin-friction drag is a long-standing effort in fluid dynamics; the importance of flow control and drag reduction is growing steadily because of environmental and economical reasons. This research work is centered on spanwise forcing, which includes a set of active strategies to alternately force the near-wall flow in the vicinity of a solid wall in the spanwise direction. Spanwise forcing, to which we have provided seminal contributions from the very beginning, has gained popularity in the modern research literature. However, the physical mechanism of its effectiveness has not been fully understood, and practical (i.e. passive) implementations of the concept have not been identified yet. The research goal of this doctoral project is to design and carry out via high-accuracy numerical simulations some thought experiments aimed at physical understanding, and to leverage such physical understanding to progress towards passive realizations of spanwise forcing. Despite the large number of studies and journal papers available so far, the physics of spanwise forcing is not entirely understood yet. This unsatisfactory situation can be traced back, at least in part, to an original misunderstanding where the oscillating-wall concept has been interpreted as the preferred actuation strategy to inject the forcing action into the flow. However, what is the required "forcing action" was and still is not clear. In other words, by uniquely focusing research onto the oscillating wall and its spatially distributed variants, so far the

	research community has failed to understand what is the key property of the forcing that enables the reduction of the friction drag. This constitutes a fundamental step to be achieved before translating the active spanwise forcing concept into something passive, and is the main topic of the present research proposal.
Methods and techniques that will be developed and used to carry out the research	The expected work is entirely numerical, and the flow model to be used is uniquely the direct numerical simulation (DNS) of the Navier--Stokes equations: given the emphasis on the physics, the current RANS and LES models to deal with near-wall flows modified by spanwise forcing are just not reliable enough. In this work, we plan to employ three different DNS solvers. Solver 1 is a well-proven code for the DNS of the incompressible Navier--Stokes equations, in use since 25 years. It is based on a mixed discretization (Fourier expansions in the wall-parallel directions, and compact, explicit, high-accuracy finite differences in the wall-normal direction), an architectural design that has been later replicated by many, and remains at the edge of efficiency owing to its minimalistic structure. Solver 2 solves the compressible Navier--Stokes equations for an ideal gas, with the heat flux vector and the viscous stress tensor represented by Fourier’s law and the Newtonian hypothesis, respectively. The equations are cast in integral form and discretized using a second-order, energy-consistent finite-volumes method. In the presence of shock waves, detected by a modified Ducros sensor, the code switches locally to a third-order weighted essentially non-oscillatory scheme. Solver 3 adopts a finite-differences spatial discretization, and implements an innovative immersed-boundary formulation that conjugates simplicity with extreme computational efficiency, and fully restores the accuracy of the underlying numerical scheme in the vicinity of solid boundaries of arbitrary complexity. In terms of computing resources, the proposed work will be partly conducted with small-scale computing resources, like PC and small clusters, because of the combination of efficiency, the relatively low Reynolds number required, and the high-throughput character of the task. On the other hand, some large-scale numerical simulations will rely on the

	supercomputer infrastructures of the national super-computing center CINECA, located in Bologna.
Educational objectives	The PhD candidate will prove him/herself on a challenging program of fundamental research. He/she will gain first-hand experience in a broad array of disciplines, ranging from High-Performance Computing techniques to advanced programming skills, from CFD to the physics of turbulent wall-bounded flows. It should be remarked that only part of these techniques belong to the conventional skillset of a person with background in aerospace engineering. Hence, the present work constitutes an unique opportunity to build an exceptionally strong curriculum and to enable knowledge transfer in related fields.
Job opportunities	The job opportunities created by this research project are naturally all those in the general field of fluid mechanics, with computational fluid dynamics obviously prevailing. The bleeding-edge techniques and tools used and developed throughout the research work will make for a significant number of job opportunities. Besides the classic employment fields related to aeronautical engineering, the project will expose the PhD candidate to modern programming techniques and to diverse application fields. As a result, in addition to the conventional CFD-related jobs, potential placement will be possible in a vast array of research-oriented companies, ranging from top-tier HPC centres to research divisions in civil and military institutions.
Composition of the research group	2 Full Professors 0 Associated Professors 2 Assistant Professors 5 PhD Students
Name of the research directors	Maurizio Quadrio

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano - via La Masa 34, 20156 Milano - Italy - tel. +390223998323 - fax +390223998334 - email: maurizio.quadrio@polimi.it - web site: www.aero.polimi.it

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.