Quantum Computing CFD simulations for aeronautical heat exchangers

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Abstract

This document is meant to review and discuss the possible applications of Quantum computing in the area of computational fluid dynamics (CFD).

Quantum computing is a type of computation that harnesses the collective properties of quantum states, such as superposition, interference, and entanglement, to perform calculations [1]. The devices that perform quantum computations are known as quantum computers. Quantum Computing is currently a very active field of study and development, with expected applications in various fields ranging from the classical computer science problem, like cryptography and search problem, to engineering application, like structural optimization [2] and mechanical dynamics [3], but additional applications in different fields have been identified and developed [4], also for pure financial investments [5].

Indeed, several approaches have been proposed for the solutions of CFD problems with the use of quantum algorithms and / or quantum computers, as summarized in [6], being the rationale of the development the estimated scalability of quantum computing [7] and the analogy between Navier Stokes equations (NSE) with the Schrödinger equation through the Madelung transform, i.e., the Hydrodynamic Schrödinger equation (HSE) [8].

A review of the current state-of-the-art of quantum computing applied to computational fluid dynamics has been carried out, highlining how the technology is promising but still in an early stage of development [9][12] . Furthermore, a quantum algorithm for solving a classical two-dimensional fluid mechanic problem [13] is introduced in the present work, based on the "translation" to a quantum computing framework of the numerical procedure known as Lattice Boltzmann method, extending previous applications [10][11][16].

The rationale of this choice is that the method shows similarities with the quantum operations themselves and it can be extended to multiphase flows and to complex geometrical domains [14][15], typical conditions of interesting industrial problems such as the modelling of aeronautical heat exchangers and in general, the refrigeration cycle of aircraft environmental control system

Very preliminary results show that the quantum algorithm is able to achieve (even if under heavy mathematical simplifications) a result which is comparable with the results obtained with classically implemented Lattice Boltzmann codes, but the implementation shows the inherent difficulties to translate a classical code into a quantum framework (e.g., linearization, time required to simulate the quantum system on classical hardware) and the discrepancies due to the linearization [17].

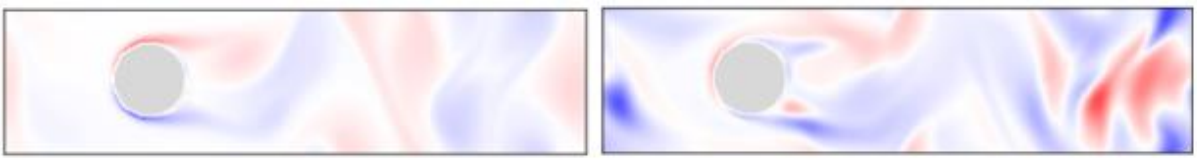

Fig. 1: Classical vs. quantum LBM algorithms (preliminary) results (vorticity)

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