DRAGON: High Performance Computing of the flow past a circular cylinder from critical to supercritical Reynolds numbers

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Abstract

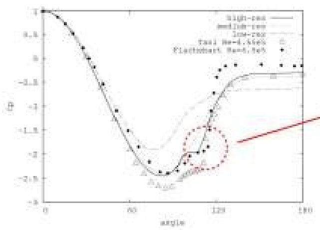
Results obtained from large eddy simulations (LES) of the flow past smooth cylinders at critical and super-critical Reynolds numbers are presented. This work was performed within the context of the **PRACE project: "DRAGON: - Understanding the DRAG crisis: ON the flow past a circular cylinder from critical to trans-critical Reynolds numbers" (Project No. 2012071290)**, awarded with 23M hours. The results showed the robustness of the methodology used, and allowed to gain insight into the complex physics taking place at these high Reynolds numbers. Because drag reduction is closely related to energy savings, mechanisms associated with the drag crisis phenomenon have been object to investigation in the past years. In this research, aspects related to the complex physics present such as the change in the mechanism by which the boundary layer transitions to turbulence in the critical regime have been studied.

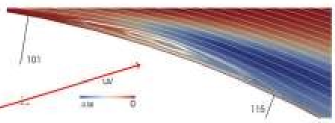
Main parameters for computations

Computational meshes NCV_t total number of CVs; $N_{CV\ plane}$ number of CVs in the plane; N_{planes} number of planes in the span-wise direction; L_z is the size of the span-wise direction.

Re	NCV_t [$\times 10^6$]	$N_{CV\ plane}$	N_{planes}	L_z
2.5×10^5	38.4	299683	128	$0.5\pi D$
3.8×10^5	48.6	379950	128	$0.5\pi D$
5.3×10^5	64.1	500516	128	$0.5\pi D$
6.5×10^5	83.2	650432	128	$0.5\pi D$
7.2×10^5	89.4	698949	128	D
8.5×10^5	105.1	820803	128	D
10^6	132.2	1032952	128	D
2×10^6	198.3	1032952	192	D

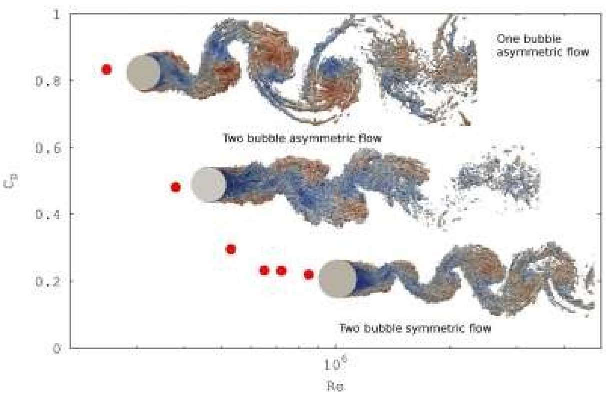
Laminar separation bubble (LSB) detection





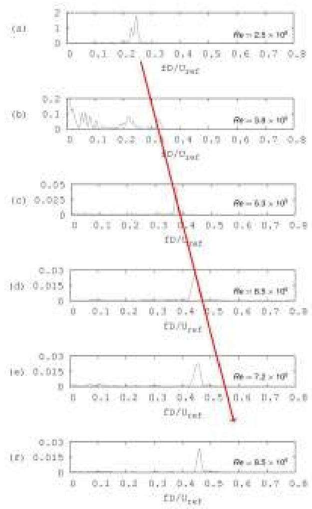
- A LSB on the rear side of the cylinder surface is detected
- This LSB is responsible for the drag reduction and wake narrowing

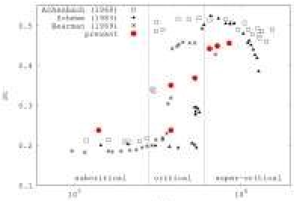
Wake regimes



- There is a pronounced decrease in the magnitude of the drag coefficient accompanied with an increase in the base pressure coefficient.
- At $Re = 2.6 \times 10^5$ pressure distribution is asymmetric. Transition to turbulence occurs earlier at one side of the cylinder boundary layer. Thus, separation in the turbulent side is delayed.
- Symmetry is recovered once a second LSB appear on the opposite side of the cylinder surface
- Wake is narrower at supercritical Reynolds numbers ($Re > 6.5 \times 10^5$).
- Wake coherence observed at all Reynolds numbers

Shedding of coherent structures

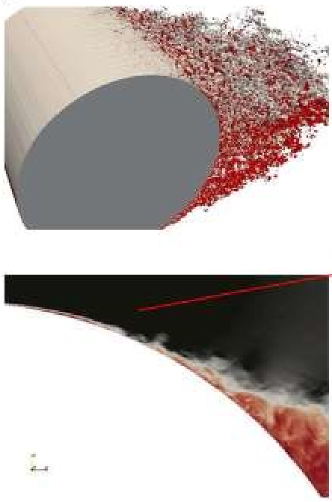


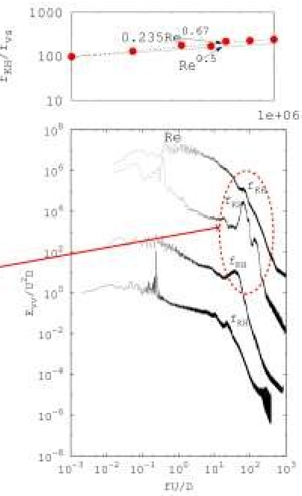


- Narrow band vortex-shedding frequency measured at all Reynolds numbers
- Coherent vortex shedding occurs at all Reynolds number. The idea of a un-coherent wake in the supercritical regime is questioned.
- Vortex shedding frequency increases in the supercritical regime.

Shear-layers transition mechanism

- First, instabilities appear in the attached boundary layer. Transition to turbulence occurs just after separation of the boundary layer.
- Transition to turbulence mechanism changes from a convective instability in the shear layer to a stream-wise vorticity mechanism in the attached boundary layer.





Main achievements of the project

- Well-solved LES of the flow past a cylinder with good agreement with experimental results. Important flow features described for first time.
- First time asymmetries in the boundary layer and in the pressure distribution have been captured by a numerical method
- Wake topology from critical to super-critical Reynolds numbers characterised
- Observations and measurements of the laminar separation bubble and its role in the drag crisis explained
- Two papers published, one in PoF and another in IJHFF) and two more in preparation.

Acknowledgements

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