Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME/CFDSC/CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Investigating Lagrangian detachment versus Eulerian separation

Motahareh Sadr[1], Jérôme Vétel[1*]

[1]Department of Mechanical Engineering, LADyF, Polytechnique Montreal, Montreal, Canada
[*]jerome.vetel@polymtl.ca

ABSTRACT

The Lagrangian definition of separation in the sense of formation of a material spike of particles initially placed near the wall goes back 20 years and has since been further developed to three-dimensional (3D) and unsteady flows.

This spike could appear in different regions, e.g. upstream or downstream of the Prandtl separation point in two-dimensional (2D) flows or the convergence of skin friction lines in 3D flows, classically referred to as the separation line. While some recent works have proposed a criterion based on material surface curvatures for 3D flows with arbitrary time dependence, in practice, the method could be complex to apply, especially in the case of turbulent separation. To provide a simple and efficient tool that encompasses all properties of the Lagrangian definition, the repulsion rate parameter (ρ) introduced by Haller in his study of Lagrangian Coherent Structures was proposed in 2024. It is a measure of how normal perturbations grow or diminish with time, and hence its maximum must correspond to the Lagrangian separation.

The rate of change of this criterion can be expressed in terms of the divergence of the wall skin friction field for incompressible flows. Analyzing the parameter for various cases leads to results that differentiate between types of Lagrangian separation. Considering the flow over a prolate spheroid and tracing the repulsion rate on a plane placed near the surface, one can see that it reaches its maximum value upstream of the convergence line of skin friction. The same pattern is observed for an axisymmetric bump in a turbulent boundary layer. In contrast, in the flow over a cube attached to a wall, the maximum ρ is attained downstream of the line predicted by skin friction-based separation criteria.

Applications are numerous, especially in separation control techniques where passive or active control devices are often designed to focus on the area where separation is supposed to occur. The examples provided here show that Lagrangian separation can sometimes be located far from what is indicated by Eulerian criteria.