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Objective identification of local vortices

Bjørn Holmedal[1*] and Lars Erik Holmedal[2]

[1] Department of Materials Science and Engineering, NTNU, 7491 Trondheim,
bjorn.holmedal@ntnu.no, www.ntnu.edu/employees/bjorn.holmedal

[2] Department of Marine Technology, NTNU, 7491 Trondheim
lars.erik.holmedal@holmedal@ntnu.no, www.ntnu.edu/employees/lars.erik.holmedal

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Quantification and visualization of vortices and flow structures have been challenging since the early days of fluid mechanics. The lack of objectivity of the available measures in rotating reference systems makes it difficult to recognise similar flow structures in differently rotating parts of the flow. The angular rotation vector is inherently non-objective in nature. However, the relative angular rotation, relative to a certain point in the fluid flow or to its mean rotation, is objective. Hence a work-around has been to apply otherwise non-objective quantities in a local coordinate system that is rotated similar as this point/mean, see e.g. [1-3]. Quantifications of flow structures based on the relative vorticity vector (or relative spin) are objective in this rotating system. A certain degree of freedom remains for how this reference point or mean of the flow can be rotated. However, a strict objectivity requirement is that rotations must degenerate correctly for the special cases where such flows correspond to a pure rigid body rotation. The most common approach is to apply the spatial mean of the vorticity vector for this purpose. However, in cases where the mean average flow is dominated by shear, the visualization of local vorticities will be polluted by the dominating shear contribution to the vorticity. A simple example is a Couette flow, being rotated by its mean vorticity to make the visualization objective.

A new objective approach is suggested, to overcome these challenges. It is based on a decomposition of the vorticity vector [4] into shear and rotational components. Selected examples of flow visualizations are discussed.

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