















Vortex definitions (0)

Basic criteria for vortices:

• High vorticity magnitude.

Problem: Cannot separate vortices from shear.

• High (positive or negative) helicity.

Problems: Not Galilean invariant. Works only for longitudinal vortices.

• Low pressure.

Problem: Constant threshold often fails.





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Definitions of vortex core lines (l) Definition based on normalized helicity: 1. Vorticity and velocity parallel: [Levy et al. 1900] Normalized helicity cos S(u, ?)takes (absolute) maximum of 1 at places where $u \times ? = 0$ This is a vector equation for points on the core line. However, its 3 scalar equations are not independent, as can be seen by the identity: $ugu \times ? = 0$

Finding parallel vectors

Naive approach: solve only 2 of the 3 equations.

Problems: the pair of equations can

 have additional solutions: the 3rd equation must be checked (with tolerance = ?)

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 lead to ill-defined intersections: must choose a different pair, giving consistency problems.



Definitions of vortex core lines (II)

Definition based on $\nabla \mathbf{u}$:

complex eigenvalues, and *u* is eigenvector of ∇*u* [Sujudi and Haimes 1995] Reasoning: In a local reference frame moving with *u*:
the critical point type is spiral-saddle
its axis is aligned with *u*complex eigenvalues, and (∇*u*)*u* parallel to *u* [Roth and Peikert 1998]
Using the same criterion (∇*u*)*u* = 1*u* more efficiently (no eigenvector computations). The term (∇*u*)*u* is the acceleration (in a steady flow).
The criterion is equivalent to saying that the curvature of

The criterion is equivalent to saying that the curvature of the local streamline vanishes.

Definitions of vortex core lines (III) Due definitions based on pressure. Stalley lines of pressure. [Miura and Kida 1997, Peikert and Roth 199 Stallean invariant, in contrast to previous methods. Needs second derivatives. Applicable to "modified pressure" as in λ₂ method (no second derivatives needed) Pressure minima in sections perpendicular to vorticity lines. [Banks and Singer 1994] Prediction/correction scheme for searching minima



Conclusion, Pros and cons

- + Automatic extraction of flow features can be used for preprocessing large data sets prior to visualization.
- + Physically meaningful criteria can be applied.
- Several definitions of vortex (core lines) exist. Their choice depends on the type of flow.
- An expected feature scale must be known. Extracted features can look wrong when viewed in a largely different scale.

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Real world applications

Vortices in Pelton manifold:

Goal: Reducing the separation vortex and possibly other vortices for a qualitatively better jet (circular cross

section, stability).





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