COHERENT STRUCTURES AND VORTEX IDENTIFICATION

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In this paper the local criteria for the identification of vortices are analyzed and discussed, and a new global criterion is proposed. In particular the Q, D and λ_2 methods are analyzed. These methods are based on three Hussain criteria (1993) for the identification of a vortex: the vortex core must be associated to a high vorticity zone; the presence of a vortex should be identified by means of a scalar quantity and this quantity should be Galilean invariant.

The D-method, proposed by Chong et al (1990), identifies a vortex in the region where the term

$$D=(Q/3)^3+(R/2)^2$$

is positive, where R and Q are the invariants of the velocity gradient.

In this paper the main drawbacks of this method are shown, which are related to an over estimation of the vortex extension.

The Q was proposed by Hunt et al in 1988. The invariant Q represents the local balance between the strain and the rotation of a fluid element. According to this method, where Q and R are both positive there is an unstable vortex. If Q is positive and R is negative there is a stable vortex.

The λ_2 method was proposed by Jeong e Hussain (1995). λ_2 is the second eigenvalue of the tensor S_2+W_2, where S and W are respectively the symmetrical and the antisymmetrical part of the velocity gradient. According to this method, there is a vortex where λ_2 is negative. In this paper we demonstrate that λ_2-method overestimates the vortex.

In this paper a new global criterion for the identification of vortices is proposed. In a two-dimensional motion a vortex is identified with closed stream lines. In the neighbourhood of a generic point P there is a vortex core if on the instant t, the projection of a streamline on the plane normal to the vorticity vector, has a spiral shape. In the simplest case, when the derivative of the velocity component in the vorticity direction with respect to the same direction is null, the projection of the velocity field on this plane is solenoidal. This two-dimensional velocity field can be expressed with the rotor of the potential vector, which has only one non null component in the vorticity direction. In this case the vortex pipes have sections of a constant area.

If a vortex core exists in the neighborhood of a generic point P, then the projections of streamlines onto the plane normal to the vorticity are represented by closed lines. In this simple case the condition of vortex existence in the neighbourhood of P is given by the existence of the relative minimum or maximum of the only non null component (in the vorticity direction) of the potential vector of the two-dimensional solenoidal field.

In the more general case, the velocity field, which is the projection of the three-dimensional one on the plane normal to vorticity, is not solenoidal. However it is possible to deduce from this two-dimensional velocity field, another two-dimensional one having null divergence. By analysing the stream function associated to this field, it is possible to identify the vortex core: the presence of the relative minimum or maximum of this stream function identifies the existence of the vortex core in the neighbourhood of point P.

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