L-transition from Right- to Left-handed Helical Vortices

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Recent progress in the understanding of vortex breakdown [1, 2] shows that the phenomenon may be explained as a spontaneous transition from right-handed to left-handed helical symmetry of the vorticity field. The difference between vortex structures with right- and left-handed helical symmetry is governed by the sign of torsion or helical pitch of the vortex lines (a positive pitch denotes a right-handed helical vortex and a negative pitch a left-handed one) [3]. As shown in Figures 1*a* and 1*b* a continuous transition from a right-handed helical vortex to a left-handed one may take place in two different ways. The pitch of the vortex line may either change from a positive value through infinity to a negative value (Fig. 1*a*) or it may change from a positive value through zero to a negative value (Fig. 1*b*). The first case we refer to as a L (linear)-transition and the second one as a R (ring)-transition. L-transition of a slender vortex has up to now only been observed in experiments carried out in rectangular vortex chamber [3]. The main objective of the present work is to analyze locally the zone where L-transition of helical symmetry occurs.

For this purpose we consider a viscous, incompressible and axisymmetric flow in a closed cylinder with a ratio of height to radius equal to 4 (Fig. 1*c*). The end covers either co- or counter-rotate with identical and constant angular velocity. Numerical solutions are obtained using a finite difference code [4]. Under the same angular disc velocity (with the Reynolds number equal to 2000) identical flows appear in the top and bottom part of the cylinder. The middle cross-section of the cylinder ($z = 0$) may be considered as a symmetry plane of the flow. At counter-rotation the middle plane corresponds to a rigid wall with axial and swirl velocities equal to zero. In the opposite case of co-rotation the swirl velocity is nonzero in the middle cross-section, and vortex tubes pass through the plane in the central part of the cylinder (inside the dashed-lines in Fig. 1*d*). In the present study only the vortex tubes will be analysed. Those tubes consist of helical vortex lines and the middle plane ($z = 0$) is a boundary between zones with different helical symmetry of the vorticity field.

In the study various L-transitions in the helical symmetry of a vortex were established for flows with different topology (with and without bubble). We consider the flow in a cavity with co-rotating end covers as a unique model for investigating changes in helical symmetry and further studies on this phenomenon for a wider range of parameters will be carried out and presented.

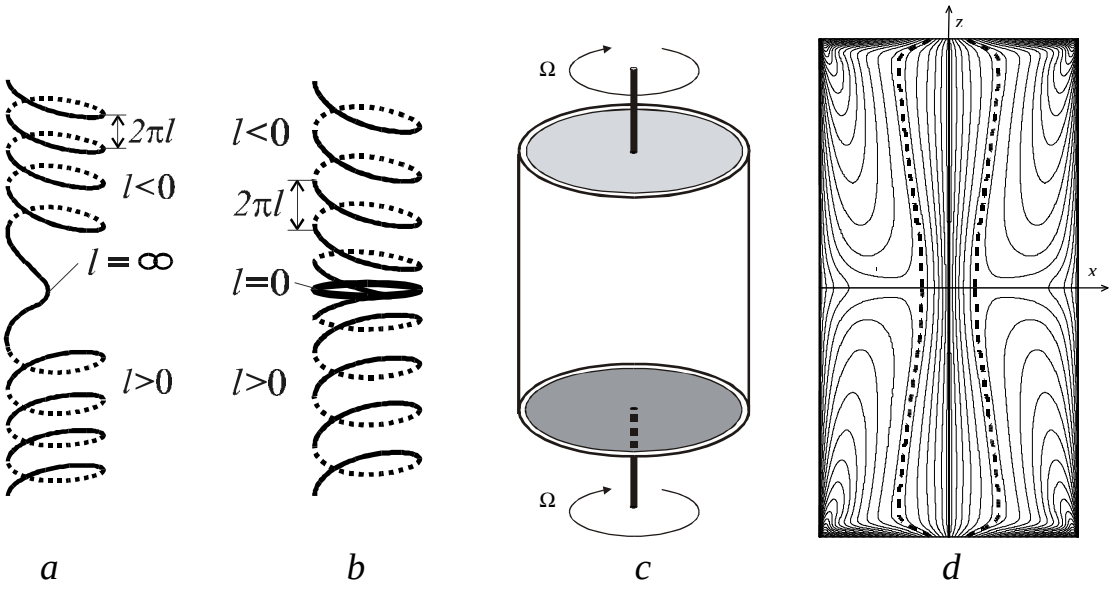

Figure 1: Types of transitions (*a, b*); flow domain (*c*); and cross-section of vortex tubes (*d*)

References

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