L-transition from right- to left-handed helical vortices

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Abstract This study is devoted to analysing changes in the helical symmetry of axial vortex structures. The aim is to provide an improved understanding of the appearance of recirculating bubbles in swirl flows. The bubble generation is usually referred to as vortex breakdown, see e.g. Leibovich 1978 or Escudier 1988. The study concerns a viscous, incompressible, axisymmetric flow in a closed cylinder with co-rotation of the end-covers in the regime where the appearance of the first bubble takes place, see Brøns et al. 1999. For the investigated flow regime only one type of change in helical symmetry, denoted L-transition, was observed. The change of helical symmetry provides a possible explanation for the appearance of bubble structures in the vortex breakdown problem.

1. Introduction

Recent progress in the understanding of vortex breakdown (Okulov 1996) shows that the phenomenon may be considered as a spontaneous transition from right- to left-handed helical vortices that both may exist under the same integral flow parameters. The difference between vortex structures with right- and left-handed helical symmetry (Alekseenko et al. 1999) is governed by the sign of the helical pitch of the vortex lines (a positive pitch denotes a right-handed helical vortex and a negative pitch a left-handed one). Although the theory (Okulov 1996) connects the flow before and after breakdown, it does not explain how the helical symmetry of the flow changes. As shown in figure 1, a continuous transition from a right-handed helical vortex to a left-handed one may take place in two different ways. Either the pitch goes through infinity or it goes through zero. The first (regular) case we refer to as L (linear)-transition (figure 1*a*) and the second (singular) one we refer to as R (ring)-transition (figure 1*b*). If the vortex ring appearing in the R-transition was added to the swirl flow, without changing input and output conditions, it would