FORMATION AND DECAY OF VORTICITY IN IMPULSIVELY STOPPED INFINITE CYLINDERS

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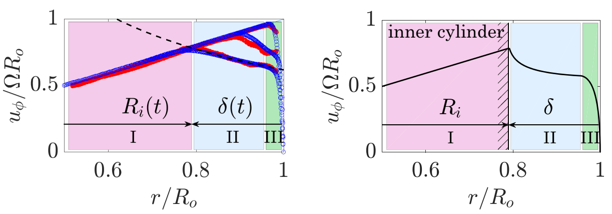
Spinning cylinders and the co-occurring vortical structures have been extensively studied over the last decades. Particularly the Taylor-Couette (TC) flow enjoys great attention as comprehensively illustrated by Fardin et al. [2]. More recently, the turbulent character of high-Re TC flow scenarios was explicitly addressed in the review by Grossmann et al. [3]. However, investigations on the unsteady behavior of such flows are fairly limited (e.g. [1, 7]). Furthermore, Morton [6] comprehensively outlines how development and/or decay of vorticity builds upon spatial and/or temporal changes of boundary conditions.

The present study centers around the investigation of vorticity and boundary-layer (BL) formation off of an outer cylinder wall after impulsively changed angular velocity Ω. The comparison between spin-up (SU) and spin-down (SD) cases allows to identify how the inboard propagation of both BL and vorticity interface is influenced by the presence of pre-existing vorticity fields, i.e. 2Ω, and the different (in)stability conditions. Direct numerical simulations (DNS) were carried out with a pseudo-spectral parallel solver for incompressible Navier-Stokes equation in cylindrical coordinates [5]. An infinite pipe with outer radius R_o in solid body rotation was simulated, where the side wall was impulsively stopped. Data for various Reynolds numbers $Re_o = \Omega R_o^2/\nu$, and correspondingly combinations of initial rotational speeds Ω and radii R_o, were obtained. The simulations are complemented with additional PIV experiments that expand the Reynolds number range of the present investigation [4].

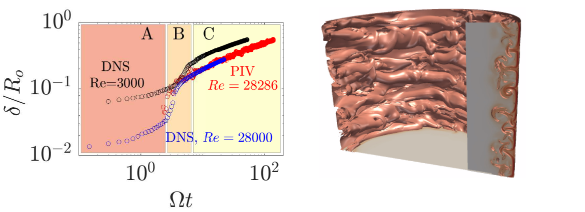
In accordance with Rayleigh's stability criterion the SU motions turned out to mimic an inverse Oseen vortex $\delta(t) \sim \sqrt{\nu t}$, which consists of an undisturbed solid body core I and an outer shear layer III. For the SD, in contrast, the initially laminar BL (A) develops an additional buffer layer II early on (see Fig. 1(a)), which is consecutively contains instabilities (A→B), coherent structures (B), eventually followed by turbulence and its decay (C), and re-laminarization towards ultimately quiescent fluid across the entire cylinder (D); see Fig. 2. At the conference, we intend to discuss the features of this spatial and temporal flow field evolution in detail.

Interestingly, the fully developed TC flow with continuously spinning inner cylinder reveals similarities to the SD velocity profile (see Fig. 1(b)), if the inner cylinder with radius $R_i = R_o - \delta$) were considered as the solid-body-rotation core region. Based on this apparent analogy we will complement our analysis with a comparison of the SD case with steady and decaying TC flows (cp. e.g. Verschoof et al. [7]). At the present stage, it is hypothesized that the turbulent decay will exhibit distinct similarities between the buffer region II of the SD case and the TC case once the inner cylinder stopped.



(a) SD [4]; ○ DNS, ○ PIV, - - $1/r$ (b) TC (adapted from [3])

Figure 1. Velocity profiles during SD and for fully developed turbulent TC flow. Three similar zones I-III can be recognized.



(a) BL growth $\delta(t)$ (b) FTLE of Görtler-vortices

Figure 2. (a) temporal BL evolution and (b) structure formation (Görtler-vortex break-down (B→ C)).

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