Dynamical behavior of the cylindrical wall boundary layer in a co-rotating split-cylinder flow

Jesús O. Rodríguez-García and Javier Burguete
Departamento de Física y Matemática Aplicada, Universidad de Navarra, c. Irunlarrea 1, 31008 Pamplona, Spain

Rotating and turbulent systems are present in many natural and industrial processes. In geophysical flows, rotation is present in many scales creating different instabilities. This kind of behavior is observed in industrial flows too like in liquid mixing processes. The importance of this kind of phenomena has provoked much research to better understand the different processes involved in turbulence and rotation.

To have a better knowledge of these systems, different experiments have been carried out in our group using a von Kármán flow driven by propellers [1, 2, 3] finding very rich phenomena. Now, we have developed a new experimental device motivated by different numerical simulations [4, 5, 6] to continue analyzing rotating flows.

The new experimental setup is a horizontal split-cylinder in which each half is moved independently by two shafts (see Fig. 1). All the split-cylinder set is enclosed in an aluminum cell fulfilled by the working fluid (water for this work). Shafts are moved by two servomotors which allow a co-rotation or counter-rotation regimen which different velocities in each half. The radius R of the cylinder is fixed but the internal length of the halves L can be changed using different bases, so the aspect ratio of the cylinder $\Gamma = 2L/R$, can be modified. In this work Γ is fixed and equal to 2.

Using this setup we can study the different regimes of the flow created inside the split-cylinder and the symmetry-breaking that should appear according to [4] and [5]. To measure the experimental velocity field of the flow an LDV system has been used with silver coated hollow glass spheres as tracers.

First results have been obtained in co-rotation using a differential velocity between halves. We set a main rotation velocity in both sides Ω, and we add or subtract a differential velocity ω, depending on the side, achieving an asymmetric rotation. Assuming that ν is the kinematic viscosity of our working fluid, the flow developed inside the split-cylinder is characterized by two dimensionless parameters, the Reynolds Re and the Rossby Ro numbers defined as

$$\mathrm{Re} = \frac{\Omega R^2}{\nu}, \tag{1a}$$

$$\mathrm{Ro} = \frac{\omega}{\Omega}. \tag{1b}$$

The basic state (BS) described in [5] has been found experimentally. A complex behavior of the cylindrical wall boundary layer is also found with dependence on the Re and the Ro. In addition, the flow presents different azimuthal instabilities depending on the experimental parameters.

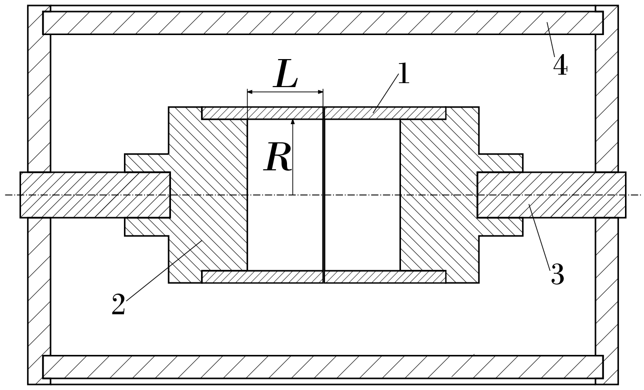

Fig. 1. Cross section of the experimental setup: 1, methacrylate semi-cylinders; 2, aluminum bases; 3, shafts; 4, external cell.

[1] A. de la Torre, J. Burguete, Slow dynamics in a turbulent von Kármán swirling flow, Phys. Rev. Lett. **99**, 054101 (2007).

[2] M. López-Caballero, J. Burguete, Inverse cascades sustained by the transfer rate of angular momentum in a 3D turbulent flow, Phys. Rev. Lett. **110**, 124501 (2013).

[3] O. Liot, J. Burguete, Bifurcation induced by the aspect ratio in a turbulent von Kármán swirling flow, Phys. Rev. E **9**, 013101 (2017).

[4] P. Gutierrez-Castillo, J. M. Lopez, Instabilities of the sidewall boundary layer in a rapidly rotating split cylinder, Eur. J. Mech. B **52**, 76-84 (2015).

[5] J. M. Lopez, P. Gutierrez-Castillo, Three-dimensional instabilities and inertial waves in a rapidly rotating split-cylinder flow, J. Fluid Mech. **800**, 666-687 (2016).

[6] P. Gutierrez-Castillo, J. M. Lopez, Nonlinear mode interactions in a counter-rotating split-cylinder flow, J. Fluid Mech. **816**, 719-745 (2017).