SLOW DYNAMICS IN TURBULENT VON KÁRMÁN HELIUM FLOWS

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Abstract The presence of slow dynamics is a recurrent feature of many turbulent flows. This behaviour can be created by instabilities of the mean flow or by other mechanisms. In this work we analyze the behavior of a highly turbulent Helium flow (maximum Reynolds number $Re = 10^8$, with a Reynolds based on the Taylor microscale $Re_\lambda = 2000$). We have performed velocity measurements using home-made Pitot tubes. The analysis of the data series reveals that below the injection frequencies there are different dynamical regimes with time scales two orders of magnitude below the injection scale.

EXPERIMENTAL SETUP.— We have analyzed the slow behaviour that may appear in closed flows for very high Reynolds numbers. The experimental cell consists on a closed cavity filled with liquid Helium (330 liters) close to the lambda point (between 1.8 and 2.5 K) where two inhomogeneous and strongly turbulent flows collide in a thin region. The cylindrical cavity has a diameter of 78cm and two impellers rotate in opposite directions with rotation frequencies up to 2Hz. The distance between the propellers is 70cm. The experimental setup has been described in detail in [4]. The maximum Reynolds number reached on this setup has been $Re = 10^8$. The first results concerning the evolution of the applied torque was published in a recent paper [5]. A detailed description of classical von Kármán flows can be found in [1].

Here we present the first velocity series that have been acquired on this experimental setup. Different velocity probes were placed on the setup (see figure 1), but here we will focus on a set of four Pitot tubes that were placed in the middle plane. These tubes allow the determination of the axial and azimuthal components of the velocity close to the wall.

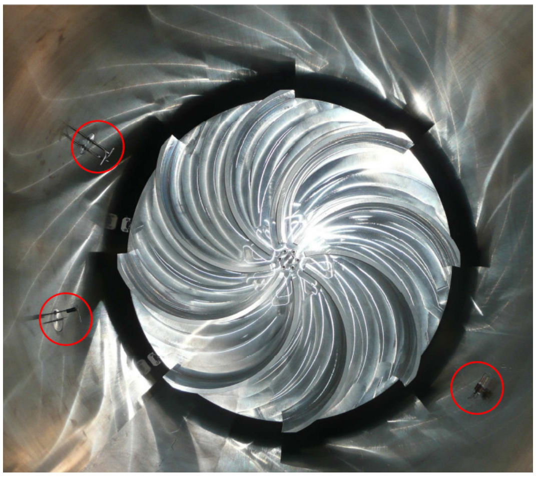

Figure 1. Top view of the experimental cell: the bottom propeller (the top propeller has been removed) and the different velocity probes (marked with red circles) around the middle plane of the cylindrical wall are visible. In this contribution we present the results corresponding to the Pitot tubes on the top left. See the text for a detailed explanation.

RESULTS.— We have analyzed different regimes. When the propellers rotate in positive direction (counterclockwise direction, see figure 1) they push the fluid with the convex side of the blade. Alternatively, they can rotate in the negative direction (clockwise direction) and then they push with the concave side. Each one of these regimes will produce an average flow with slightly different characteristics, as they will have a different intensity of the azimuthal, radial and axial components. The final effect is that each one of the propellers produces a toroidal recirculation close to them, and these torus collide in the middle plane where different instabilities may appear. The velocity probes were located in this region to observe the slow behaviour created in this layer as it was observed in similar configurations for smaller Reynolds numbers [2, 3].

The spectra obtained in this experiment present a similar slow behavior (see figure 2). We observe a slow dynamics up to two decades below the injection frequency. The data presented here correspond to the exact counter-rotation regime (same velocity in both propellers) with a positive rotation frequency. All the data series collapse, no matter we consider the case of normal fluid (Helium temperature over the lambda point) or with a superfluid component.

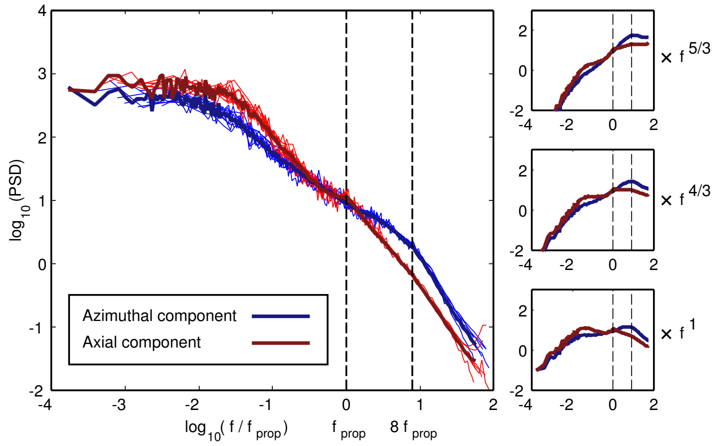

Figure 2. Left: Spectral density for all the considered experimental runs. Right, the same data compensated by different powers of the frequency (indicated in the pictures).

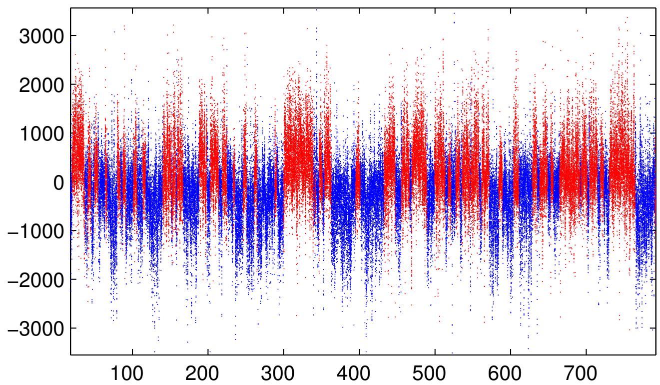

Figure 3. Slow evolution of the velocity series. The data have been splitted on two regions, associated with positive (red) and negative (blue) velocities. See explanation in the text.

This slow behaviour is associated with a bistability on the dynamics of the velocity series, as it can be observed in figure 3. The data have been splitted on two sets, one of them labeled with a red color and the other with blue color to emphasize both regimes. The system remains on each one of these states for random periods of time. We have computed the statistics of these data and we have verified that they follow a Kramer's law.

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