Large-scale motion in a baffled von Kármán tank

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Large-scale motions (LSMs) are recognized in a variety of turbulent flows, e.g. boundary layer flows, Taylor-Couette flows. Recent studies on a baffled von Kármán flow (VK flow, i.e. a flow within a baffled cylinder closed at both ends with counter-rotating impellers that drive the flow) revealed the appearance of such a structure in its central region. Since a baffled VK flow can be seen as a model flow for flows within industrial stirred vessels, it is of significant importance to investigate this phenomenon thoroughly.

The present work provides a characterisation of an LSM within the baffled VK flow based on experimental data. Particle Image Velocimetry (PIV) measurements were executed in two rigs, the Gottingen Turbulence Facility #3 (GTF) and Warsaw University of Technology VK Facility (WUT VK, fig. 1a), both having a similar design (radius R=250mm, height H=580mm) and at similar Reynolds numbers $Re=2\times10^4$.

The velocity field measured in the proximity of the tank centre exhibits a clear peak in its power spectral density (PSD) function. It is located at a relatively low frequency of $0.1f_{imp}$, where f_{imp} is the stirring frequency (fig. 1b). Proper Orthogonal Decomposition (POD) allows extraction of the associated mode of motion. The first two POD modes can be directly linked to the spectral peak. Their energy share is roughly equal and cumulatively accounts for more than 65% of the total velocity fluctuations energy in the vicinity of the tank centre (fig. 1c). The topology of the first POD mode can be described as a radially-oriented velocity field whose amplitude decays parabolically as moving away from the tank's centre (fig. 1d). The second mode is similar, except it is rotated by 90° about the tank axis. The characteristic length of the structure is as large as 0.4R, thus it can be described as an LSM phenomenon. Further insight into the nature of the structure is gained through the consideration of its associated evolution equations.

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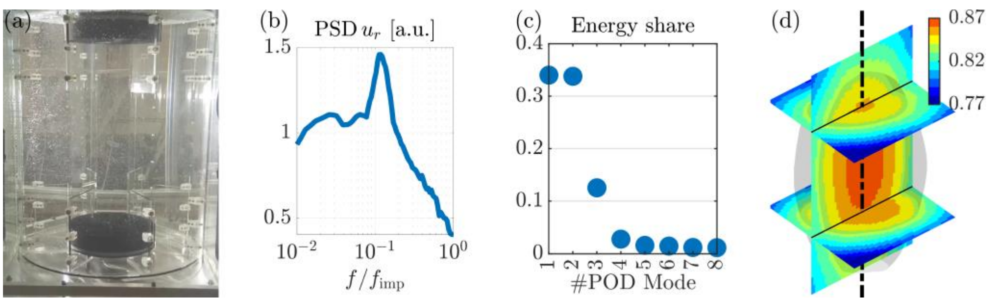

Figure 1: (a) WUT VK Facility. (b) PSD of the radial velocity component measured in the tank centre. (c) Energy contribution from initial POD modes. (d) Topology of the first POD mode (contours of the mode amplitude normalised with velocity fluctuations r.m.s. value).