Turbulent flow measurements in a new hydrodynamic rotating tank

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Abstract – Preliminary results of laboratory experiments carried out in a new rotating tank are presented. A neutral shear driven boundary layer is generated and both the mean flow and turbulence are measured by means of Particle Image Velocimetry. The vertical profiles of the turbulent quantities are shown and discussed.

Key words – *Turbulence, Laboratory Experiments, Rotating fluids*

1 Introduction

Recently the Department of Fisica Generale of the University of Turin (Italy) has realized an important experimental facility for fluid-dynamics studies. It is composed by a large rotating platform of 5 m diameter above which a cylindrical tank is placed. This latter can be filled by water layers, whose depth can reach as far as about 1 m in order to simulate stratified and homogeneous fluid flows under the action of the apparent forces due to the rotation.

This facility has been built in close cooperation with the LEGI-Coriolis laboratory (Grenoble). As a matter of fact, we have got a long lasting scientific collaboration (since the 70’s) with the Grenoble group. Thus our rotating tank is designed to analyze in greater detail particular aspect of large-scale flows studied in the Coriolis laboratory, as for example the boundary layer turbulence at low Rossby number.

The laboratory has been equipped with measurement instruments based on the most modern technologies based on image processing principles[1] to obtain the motion fields generated inside the tank. These measurements instruments are able to resolve the flow structure even on small scales and at higher sampling rates.

The work presented here is aimed at studying the turbulent structures which arise in rotating fluids; it is a development of a experiment on the neutral boundary layer (NBL) previously conducted at the Coriolis Laboratory [2]. Experiments in different conditions can be carried out by varying the wall roughness and the water density profile. The results of the experiments are analyzed in term of statistical moments of the turbulent fluctuations of the velocity, namely fluxes of mean turbulent kinetic energy, momentum and variance (third order moments).

2 Experimental facility

The Turin facility, of very recent construction and upgraded conception, has a working section of 5 m (diameter in the horizontal plane) x 80 cm (maximum water filling height). The rotating speed of the tank can be continuously adjusted from rest up to 20 rotations per minute.

In order to generate a regular mean flow, both spin-up and spin-down techniques [2] can be adopted by varying the rotation period of the tank, allowing to achieve small Rossby numbers typical of mesoscale and synoptic circulations. More precisely, low Rossby numbers can be attained in the Torino facility thanks to its high rotation speed even for its relatively small horizontal scale.

Figure 1: The experimental facility

The hydrodynamic laboratory is equipped with:

A)- LASER-PIV (Particle Image Velocimetry) system, allowing the quantitative detection of Eulerian flow mean characteristics, such as velocity, vorticity and divergence fields together with their turbulent properties, represented by the statistical moments of the velocity fluctuations. This detection is accomplished by spreading in the water a microscopic seeding and lightening it by means of a light sheet produced by a diode laser, coupled with a beam expanding optical device. High resolution digital cameras record sequences of snapshots of the flow at adjustable time rates and, through cross- correlation techniques, can identify the displacements of clusters of elements of seeding, and then the velocity of flow at any point and time of the monitored region [1,3].

B)- LIF (Laser Induced Fluorescence) system, allowing to reconstruct the average and fluctuating 3-D field of concentration of a particular dye (fluorescine) excited by suitable frequencies of laser light.

3 Simulations and Results

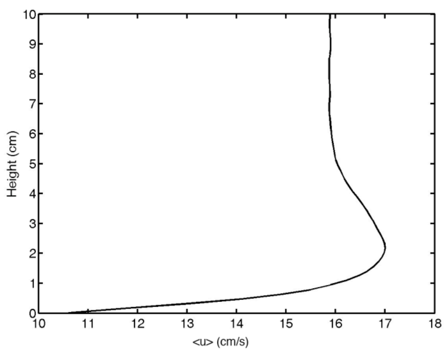

Figure 2: Vertical profile of horizontal mean velocity

A neutral shear driven boundary layer was simulated in the tank filled with 40 cm of water. The mean flow was created by means of the spin-down techniques changing the rotation period of the platform from about 40 s to 120 s.

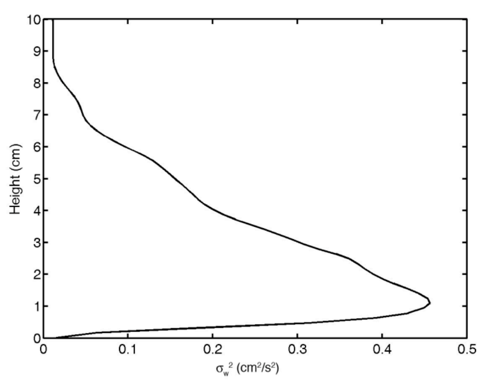

Figure 3: Vertical profile of the velocity vertical component variance

After about 165 s a horizontal velocity of roughly 16 cm/s was attains far from the tank walls (Figure 2) while the typical neutral boundary layer overshooting appears at about 2 cm. A boundary layer develops up to about 8 cm above the tank bottom, as can be seen in Figure 3 where the vertical profile of the vertical velocity variance is depicted.

Looking at Figure 4 it can be observed that the vertical profile of the momentum flux shows the typical behavior for the neutral boundary layer.

4 Conclusions

The preliminary results presented here show the ability of the new rotating tank to reproduce a well developed turbulent boundary layer. These results encourage planning of future work for deeper studies of the structure of the turbulent boundary layer in different conditions, taking advantage of the special characteristics of this facility such as the high rotation period and the advanced measurement techniques.

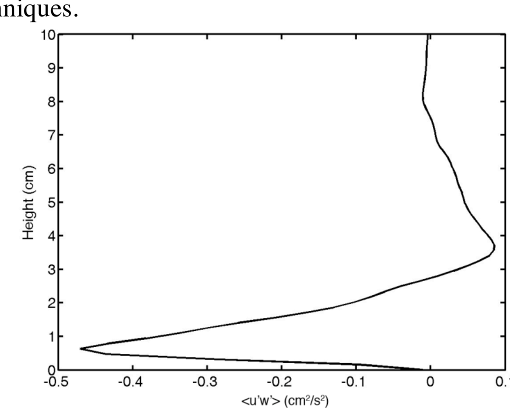

Figure 4: Momentum flux vertical profile

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