COMPARATIVE STUDY OF THE DECAY OF GRID GENERATED TURBULENCE BETWEEN EXPERIMENTS AND RANS SIMULATIONS

Torrano Ivan[1], Tutar Mustafa[1], Martinez-Agirre Manex[1],
Rouquier Anthony[2], Mordant Nicolas[2] & Bourgoin Mickael[2]
[1]*Laboratory of Fluid Mechanics, Mondragon Unibertsitatea, Mondragon, Spain*
[2]*Laboratoire des Ecoulements Géophysiques et Industriels, University of Grenoble, Grenoble, France*

Abstract We investigate the turbulence generated by a conventional planar grid in a wind tunnel. The aim of the presented work is to investigate the capacity of simple RANS simulations to capture some basic features of the turbulence generated downstream a grid. Experiments are performed in the wind tunnel facility available at the LEGI (Laboratoire des Ecoulements Géophysiques et Industriels) of the Grenoble University, where a moderate turbulence with Reynolds number of order 100 (based on Taylor microscale) is obtained. RANS simulations are run using a k-epsilon model, while several boundary conditions are considered. We probe the capability of these numerical techniques to capture the turbulence intensity and the energy decay of turbulence as measured experimentally downstream a grid with the same geometry.

INTRODUCTION

Decaying isotropic turbulence has been a classical research issue since the work done by Batchelor [1] and Saffman [2]. It is known that in grid generated turbulence, the decay of the turbulent kinetic energy evolve according to power laws [3], as follows:

$$\frac{k}{U_0^2} = A\left(\frac{x - x_0}{M}\right)^{-n}$$

Depending on the value of n exponent, different types of turbulence exist, Saffman ($n=6/5$) and Batchelor ($n=10/7$), as discussed by Krogstad [4]. It has been shown repeatedly that it is very difficult to obtain reliable values from experimental data for the constants A, x_0 and n in the decay law. In recent years, numerous wind tunnel experiments have been focused on homogeneous turbulence generated by grids, as for example Ishida *et al*. [5]. Other authors have tried to simulate the grid generated turbulence decay by computational simulations, such as DNS [6], or LES [7]. The DNS numerical techniques directly compute all the scales present in the turbulent flow, while in the LES simulations only the small scales of eddies are modeled. The inconvenient of these simulations is that they have high computational cost. RANS simulations, in contrast, all scales of turbulence are modeled, the cost of the computation is decreased but with a lost in accuracy. The objective is to verify if RANS simulations are able to capture the energy decay with good agreement to the experimental results.

DESCRIPTION OF THE EXPERIMENTAL SET-UP

The wind tunnel employed is fully described in [8]. It is composed of several sections made of 1 cm thick plywood. Four 37 W fans (EBMPAPST model DV6224) suck the air into the tunnel. The next section narrows because the fans are too big to fit in the 25 cm width of the tunnel. The next section is 1 m long and ends with an 8 cm thick honeycomb for damping the vortices generated by the fans. After this section the flow is rather homogeneous with fluctuations of the order of 2% of the mean velocity, which can reach 7.5 m/ s at the full speed of the fans. Air then flows through the grid system followed by a 2 m test section with a free exit. The test section has Altuglas windows on one side with a slit at mid height to enable the positioning of the hot wire probe inside the wind tunnel. Hot wire anemometers are the classical tool for velocity measurements in wind tunnel facilities. It is used to record the velocity fluctuations at different distances from the grid along the length of the test section. An image of the grid employed is given in Figure 1.

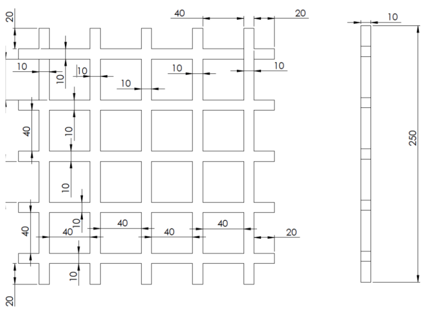

Figure 1. Dimensions of the grid.

DESCRIPTION OF THE NUMERICAL SIMULATIONS

First, the flow domain of the test section with the grid inside has been reproduced with a CAD program. After importing the geometry to the Ansys environment, a computational mesh is created to discretize the governing flow equations for computationally model. The mesh presents over 4 million quadrilateral elements for the final mesh system and the cut cell assembly method is employed for a faster convergence and stability for flow simulations. The mesh is also checked and revised for its skewness and aspect ratio criteria. An image of the performed global mesh is shown in Figure 2.

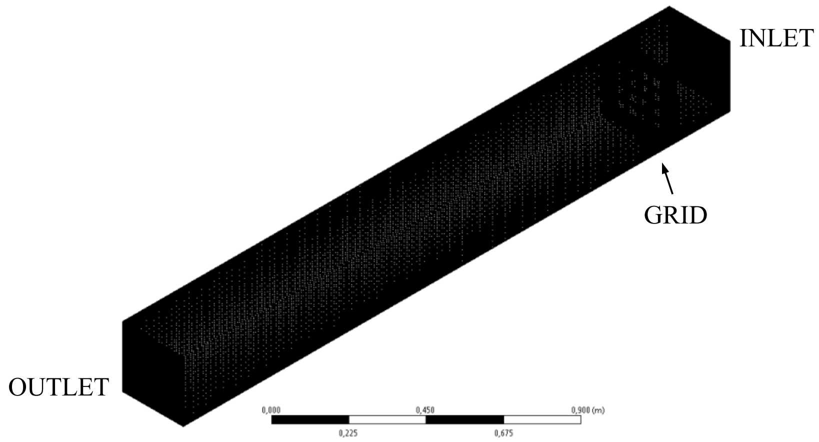

Figure 2. Computational domain.

Velocity inlet and outflow boundary conditions are defined. Zero shear condition is assumed in the test section walls while no slip treatment is performed in the grid walls. Regarding the RANS calculations a finite volume method is used for solving the incompressible Navier-Stokes equations within steady and unsteady state assumptions. The SIMPLE pressure velocity coupling scheme based on the high degree of approximate relation between pressure and velocity is used for the present numerical solver. In addition to this, a RNG k-ε turbulence model is tested for vortex shedding flow. An enhanced wall function is employed for boundary layer resolution in the close vicinity of the wall surfaces.

RESULTS AND DISCUSSION

Once both experimental and numerical results are obtained, the treatment of the recorded data is performed. Different variables will be presented, such as velocity profiles of velocity fluctuations, anisotropy, decay of the turbulent kinetic energy, etc. as a function of the model length.

References

[1] P. G. Saffman. The large-scale structure of homogeneous turbulence. *Journal of Fluid Mechanics* **27**: 581-593, 1967.
[2] G. K. Batchelor. The theory of homogeneous turbulence, *Cambridge University Press*.1953.
[3] M.S. Mohamed and J.C. La Rue. The decay power law in grid-generated turbulence. *Journal of Fluid Mechanics* **219**: 195-214, 1990.
[4] P. - A. Krogstad and P.A. Davidson. Is grid turbulence Saffman turbulence? *Journal of Fluid Mechanics* **642**: 373–394, 2009.
[5] T. Ishida, P.A. Davidson and Y. Kaneda. On the decay of isotropic turbulence. *Journal of Fluid Mechanics* **564**: 455-475, 2006.
[6] S. Laizet and J.C. Vassilicos. Direct Numercial Simulation of fractal-generated turbulence. *Flow turbulence Combust* **87**: 673-705, 2011.
[7] H.S. Kang, S. Chester and C. Meneveau. Decaying turbulence in an active-grid-generated flow and comparisons with large-eddy simulation. *Journal of Fluid Mechanics* **480:** 129-160, 2003.
[8] N. Mordant. Experimetal high Reynolds number turbulence with an active grid. *American Journal of Physics* **76**: 1092, 2008.