ISFV15-151-S20

15th International Symposium on Flow Visualization
June 25-28, 2012, Minsk, Belarus

DIRECT NUMERICAL SIMULATION OF THE HYDRODYNAMICAL PERTURBATIONS EVOLUTION

M.F. IVANOV, A.D. KIVERIN[c]

Joint Institute for High Temperatures of RAS, Moscow, 125412, Russia

[c]Corresponding author: Tel.: +79265335989; Email: alexeykiverin@gmail.com

KEYWORDS:
hydrodynamical perturbations, flow synchronization, 3D numerical modeling, correlation analysis

ABSTRACT: Nowadays contemporary experimental and numerical methods allow us to study a large-scale flows with high degree of accuracy. Meanwhile the dynamics of small scales against the background of the primary flow remains less studied. In turn, the small-scale perturbations of the flow may play a significant role in the whole process evolution (e.g. it may influence on the burning kinetics and contaminants formation in the combustors). The main numerical approach for hydrodynamical modeling is based on utilizing of the sub-grid models for the evolution of the flows on the unresolved scales. In this case the small-scale flows are forced to evolve according to the laws of isotropic turbulence. Thus such an approach may cause confusing results when the small-scale flows evolution differs from the one predicted by isotropic laws. The paper discusses a problem of the evolution of hydrodynamical perturbations in closed volume with non-slip walls using the results of 2D and 3D direct numerical simulations. It is shown that initially random flow field evolves into regular structure with integral length-scale comparable with the dimensions of the volume. In 3D case the randomness of the initial velocity field causes anisotropy of the generated structure along one of the directions (the direction is random). One can observe a cone vortex belted with a transverse toroidal flow. Here it is advisable to treat such a flow as an axisymmetric one described e.g. in [1]. In [2] the flows within combustor were analyzed utilizing the approach of so-called "axisymmetric turbulence". The numerical simulation of the experiment from [2] was performed using axisymmetric setup. Correlation analysis was implemented for the numerical results averaged over the set of computations and gave a good agreement with data for correlations growth during the compression stroke obtained in [2]. The formation of the stable microstructures against the background of the primary flow was according to the cascade scenario: small vortices were born out from the random perturbations and evolve into vortices with scales comparable with combustors dimensions. The results show that correlation characteristics of the velocity deviations can be reproduced by the basic transport model for viscous compressible gas without additional turbulent model. The perturbations evolve according to the axisymmetric scenario.

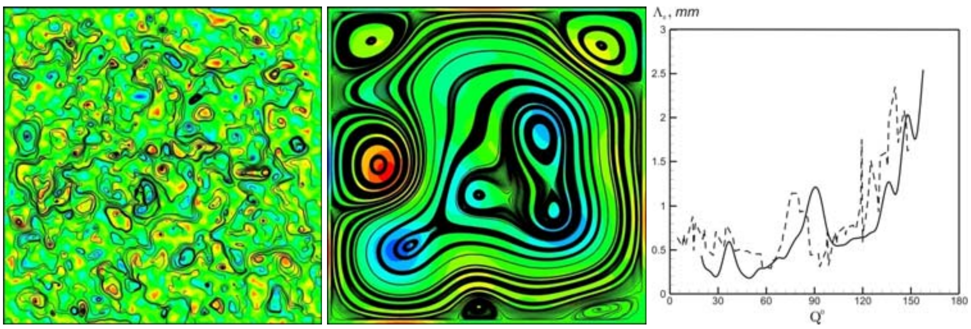

Fig. 1 Early phase of small-scale vortices birth (left). Late phase of large-scale regular structure (center). Numerical (solid) and experimental (dashed) axial component of integral length scale Λ_z during compression stroke, Q - cranc angle (right).

References

1. Batchelor G.K. *The theory of axisymmetric turbulence*. Proc. Roy. Soc. A. 1946, 186, p. 480
2. Breuer S. et. al. *Non-isotropic length scales during the compression stroke of a motored piston engine*. Flow, Turbulence and Combustion. 2005, 74, p. 145