XX Polish Fluid Mechanics Conference,
Gliwice, 17-20 September 2012

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF THE NATURAL CONVECTION IN THE LABORATORY DRYING OVEN

Zbigniew BULIŃSKI[1], Marek ROJCZYK[1], Wojciech ADAMCZYK[1], Jacek SMOŁKA[1]
[1]*Institute of Thermal Technology, Silesian University of Technology, Gliwice, Poland;*
E-mail: zbigniew.bulinski@polsl.pl

Abstract

The paper presents experimental and computational investigation of the natural convection inside the laboratory drying oven. The time-resolved particle image velocimetry (PIV) technique was employed to capture instantaneous velocity field in the selected cross-sections of the oven. The digital infrared camera was used to measure temperature field at the outer wall surfaces of the oven and at the surfaces of the electric heaters. Simultaneously, the numerical model of the oven was built using commercial computational fluid dynamics (CFD) package Ansys Fluent. Calculations were carried out with different turbulence models. The measurement data were compared with the computations results allowing us to assess accuracy of each turbulence model in prediction of this type of flows.
Key words: natural convection, laboratory oven, particle image velocimetry, flow visualisation, validation

INTRODUCTION

Natural convection is one of the most commonly encountered heat transfer mechanism in nature. Most often this phenomena by his nature is strongly three-dimensional and non-stationary, moreover it is accompanied by intensive turbulence effects. Hence, it is very difficult to model numerically this kind of flows, especially, due to turbulence modelling issues. There are many research articles covering experimental investigation of the natural convection in closed cavity. However, most of them concentrates on the so called closed cavity benchmark (Leong et al. (1998, 1999)). In this paper an experimental and numerical investigation of the natural convection inside the real-life laboratory oven are presented. Time-resolved particle image velocimetry (PIV) technique was used to capture unsteady velocity field inside the analysed device. This technique allowed us to capture huge number of data which are well suited for the purpose of mathematical model validation.

EXPERIMENTAL SETUP

The investigated device is a laboratory drying oven with natural air circulation in the storage chamber. The dimensions of the working chamber are following: width 0.32 m, depth 0.24 m, and height 0.18 m. The air temperature is controlled by four electric heaters placed at the bottom of the storage chamber. In normal operating conditions heaters are covered by the steel wall with rectangular holes. However, the heaters were uncovered during measurements. A schematic view of the experimental setup is shown in figure 1a. As it is seen in figure 1b PIV measurements were carried out on the specially prepared drying oven, particularly part of the side and front walls were replaced with the glass. The high power constant wave laser supplying 18W at 532 nm (middle of the green band) was used in the experiment to highlight the flow. The seeding pictures were recorded with Optronis CamRecord 600 CMOS digital camera with the frame rate 500 frames per second at resolution 1280x1024 pixels. This camera has 4 GB of the internal memory in which pictures are stored and later transferred to the computer hard drive. It allows to store about 3200 picture at resolution 1280x1024 pixels.

An aluminium powder with average size around 1μm was used to seed the flow. PIV pictures were processed with the MatPIV version 1.61 open software. This software is written as a toolbox for MatLab and can be used only in this environment. Velocity fields at each time instance was calculated using adaptive cross-correlation together with Fast Fourier Transform (Raffel et al (2007), Sveen and Cowen (2004)).

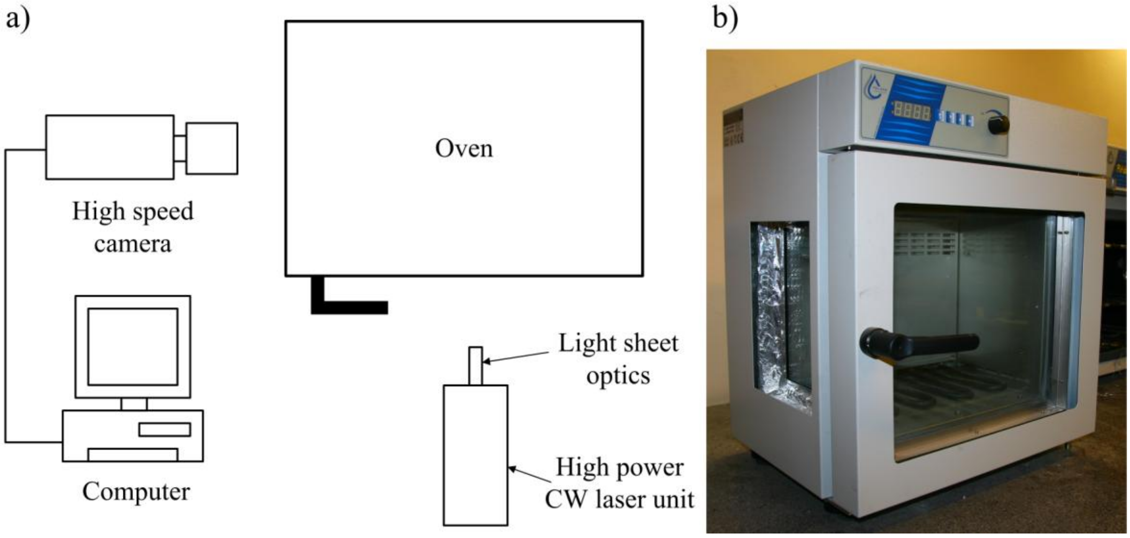

Fig. 1 Laboratory oven: a – schema of the experimental rig, b – picture of the device.

NUMERICAL MODEL

Computational domain comprised the whole oven. The boundary conditions at the outer oven walls and at the heaters surfaces were assumed based on the measurements with infrared camera. Air was treated as an ideal gas, with transport properties i.e. viscosity and thermal conductivity calculated according to accurate REFPROP 8.0 libraries. Following equations were considered in the model:

- continuity equation,
- Navier-Stokes equation,
- Energy equation,
- turbulence model equations.

Performance and accuracy of all basic RANS (Reynolds Averaged Navier-Stokes) type turbulence models were considered. Assessment were carried out in terms of the velocity, kinetic turbulent energy and Reynolds stresses fields at the selected measurement planes.

REFERENCES

Leong, W.H., Hollands, K.G.T., Brunger ,A.P. (1998): *On a physically- realizable benchmark problem in internal natural convection.* International Journal of Heat and Mass Transfer, vol. 41, 3817-3828.

Leong, W.H., Hollands, K.G.T., Brunger ,A.P. (1999): *Experimantal Nusselt numbers for a cubical-cavity benchmark problem in natural convection*, International Journal of Heat and Mass Transfer, vol. 42, 1979-1989.

Raffel M., Willert C., Wereley S., Kompenhans J., (2007): *Particle image velocimetry. A practical guide,* Springer-Verlag, Berlin, 2nd edition.

Sveen J. K., Cowen E. A., (2004): *Quantitative Imaging Techniques and their application to wavy flows*, Advances in Coastal and Ocean Engineering, vol. 9, World Scientific Publishing Co. Pte. Ltd., Singapore, edited by J. Grue, P. L-F Liu&G. K. Pedersen.