EXPERIMENTAL AND NUMERICAL INVESTIGATION OF COUPLED HEAT AND MASS TRANSPORT IN A PARTICIPATING MEDIUM

Ozgur Isik, Orkun Temel, Seyhan Uygur Onbasioglu

*Istanbul Technical University Department of Mechanical Engineering, 34437 Istanbul, Turkey

A turbulent natural convection flow in a confined cavity interacting with gas radiation was experimentally and numerically investigated. Experiments and numerical studies have been carried out with varying local mass fraction of H_2O as initial conditions. Effect of specific humidity to the heat and mass transport within the cavity has been investigated. Two different approaches for the modeling of radiation (Radiosity- Irradiosity and Discrete Ordinates Model) have been compared for various initial conditions. Schematic of the experimental setup is given in Figure 1. The experimental setup is an enclosure with aluminum walls. The dimensions of enclosure are L=370 mm, W=430 mm, B=470 mm and aluminum plates of 3 mm thickness having 0.2 emissivity are constituting the walls. Bottom and upper walls are heated by an electrical heater with a constant heat generation rate. For upper wall 2000 W and for bottom wall 1200 W electrical heaters are being used. The electrical heaters are being regulated by a PID controller to set the center temperature for a certain value.

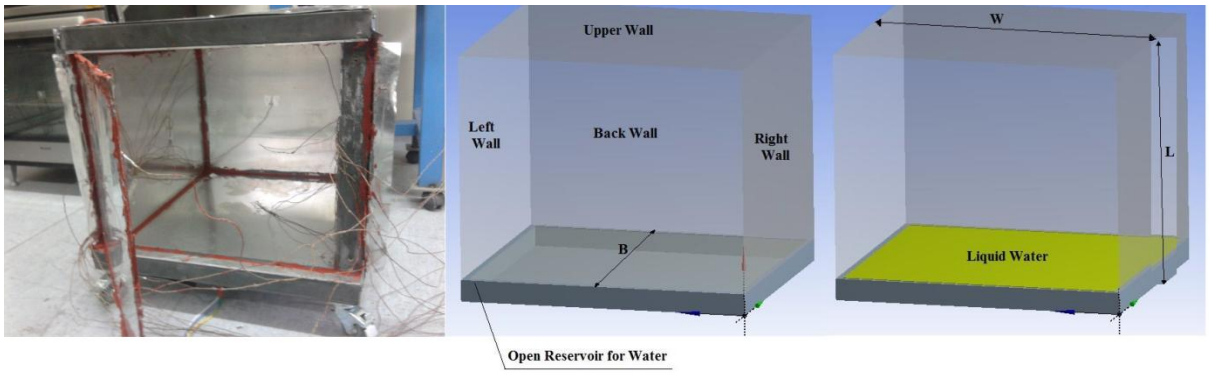

Figure 1. Schematics of Experimental Setup

In order to provide a participating medium, water has been used to be vaporized. The water initially has been set in the cavity as a liquid. Experimental study has been carried out not only for the time period that all liquid water has been vaporized but also for an additional time interval that only water vapor exists in cavity.

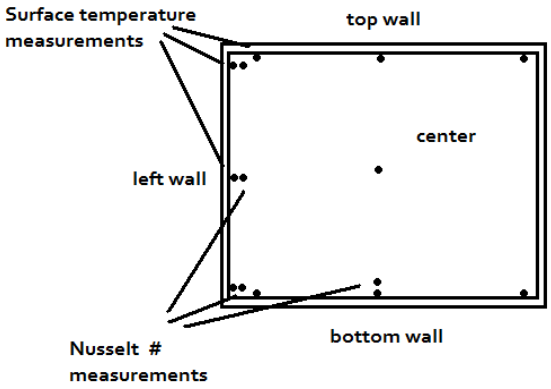

Figure 2. Positions of the thermocouples

The center of the cavity is heated up to 190 C and after a while, it has decreased to make an oscillation around 165 C average temperature. Temperature measurements on each surface of experimental setup have been conducted by using thermocouples (Omega J type with glass insulation). The voltage of the system has been regulated for 230 V ± 1 %. In addition to voltage, power and current have also been measured during the experiments. The position of the thermocouples are being chosen to measure both surface temperatures of the walls and air temperature as shown in Figure 2. Therefore, the center temperature of the cavity is measured and for vertical and bottom walls and Nusselt numbers are calculated from experimental results.
In contrast to experimental study, numerical study has been carried out for the time period that begins from the instant time that all water has been vaporized. Experiments and numerical studies will be conducted for various mole fractions of water vapour and air shown in Table 1. The experimental and numerical study has been completed for 10 and 30 % of mole fractions and the other cases are in progress.

Table 1 : Mole fraction of water vapour / air used in experiments

Initial water mass (g)	Mole Fraction (mole of water vapour / mole of air) %
5,60	10
8,40	15
11,20	20
14,00	25
16,80	30

Discrete Ordinates Method has been implemented without using DO/Energy Coupling approach and non-gray model. Angular discretization has been performed for θ and ϕ with double divisions and single pixels. For RIM method (S2S model), view factors have been obtained by ray tracing. The governing equations are solved by means of finite-volume approach with a commercial CFD program (Fluent). All equations are temporally discretized by first order implicit time integration method.Standard $k-\epsilon$ model has been chosen. Absorption coefficient of mixture in cavity, has been defined by Weighted Sum of Gray Gases Model. Convective terms are discretized by FOU and SOU (First/Second Order Upwind).

Table 2: Numerical Study vs Experimental Results for Center Temperature

Mesh		Mole Fraction of Water Vapour : % 10				Mole Fraction of Water Vapour : % 30			
		RIM		DO		RIM		DO	
		Mean Error	Max Error	Mean Error	Max Error	Mean Error	Max Error	Mean Error	Max Error
250K		4.24	4.85	3.58	4.45	-	-	-	-
460K	FOU	3.81	4.56	3.26	4.12	4.17	6.15	3.39	4.38
	SOU	-	-	-	-	3.84	4.78	2.82	3.21
800K		3.84	4.47	3.18	4.06	-	-	-	-
1.2M		3.81	4.54	3.28	4.14	-	-	-	-

Table 3: Numerical Study vs Experimental Results for Side Wall Temperature

Mesh		Mole Fraction of Water Vapour : % 10				Mole Fraction of Water Vapour : % 30			
		RIM		DO		RIM		DO	
		Mean Error	Max Error	Mean Error	Max Error	Mean Error	Max Error	Mean Error	Max Error
250K		5.98	7.39	5.69	7.24	-	-	-	-
460K	FOU	5.79	7.31	5.56	7.1	8.02	11.04	6.57	7.96
	SOU	-	-	-	-	6.91	8.26	5.46	5.91
800K		5.96	7.32	5.53	7.03	-	-	-	-
1.2M		5.96	7.36	5.66	7.09	-	-	-	-

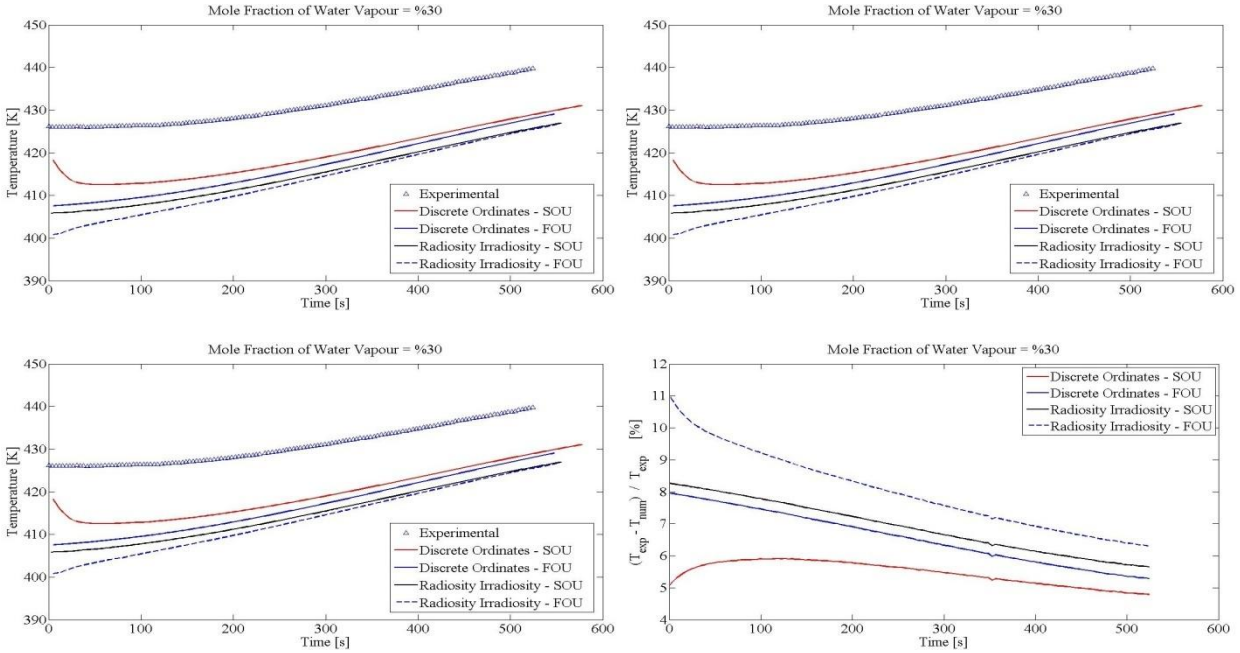

Figure 3. Numerical Study vs Experimental Results for Center Temperatures