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"TWO DIMENSIONAL CFD ANALYSIS WITH DIFFERENT TURBULENCE MODEL TO STUDY ABOUT CONVECTION AIR FLOW WITH MIXED CONVECTION IN A SQUARE CAVITY"

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Abstract

CFD simulations employ RANS equations in conjunction with a turbulence model to perfectly predict the mixed convection within square cavity. The work presented is carried out on a 2-D square cavity for mixed convection analysis in ANSYS Fluent 14.5. Variable effects and Turbulence effects are studied and compared with six different turbulent models namely k-epsilon, k-epsilon Realizable, k-omega, Transition k-kl-omega, Transition SST and Reynolds Stress Model. Prandlt Number obtained by different models is compared with molecular Prandlt number of air.

***Keywords**-Square cavity, Turbulent models, Mixed convection, Prandlt number*

INTRODUCTION

There are three basic mechanism of heat transfer: conduction, convection, and radiation [1]. A convection situation involving both natural and force convection (both are of comparable magnitude) is commonly referred as mixed convection. Mixed convection occurs if the effect of buoyancy force on a forced flow on a buoyant flow is significant [2].

CASE: 1

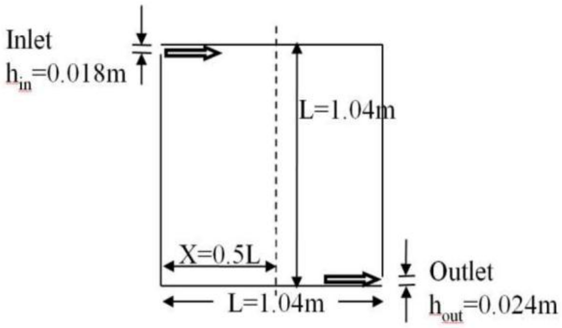

Figure 1: Geometry of a Square Room

BOUNDARY CONDITIONS

Temperature: Left side wall - 288.15 k, Top side wall – 288.15 k, Right side wall – 288.15 k, Bottom side wall – 308.65 k, Inlet port – 288.15 k, Outlet port (Back flow Total Temperature) – 300 k

Inlet port: Velocity Magnitude - 0.455 (m/s), Initial gauge pressure – 0 (pascal), Turbulent Intensity – 5 (%), Turbulent Viscosity Ratio - 10

Outlet port: Back flows Turbulent Intensity – 5 (%)**,** Department of Mechanical Engineering**,** Back flow Turbulent Viscosity Ratio – 10**,** Gauge Pressure – 0 (pascal)

Momentum: Wall motion – Stationary wall**,** Shear condition – No Slip**,** Wall Roughness Constant – 0.5

NUMERICAL SOLUTION METHOD

The RANS equations and turbulence models create a system of six equations that need to be solved numerically. An analytical solution for these equations is impossible; therefore, an iterative numerical solution method is used on a mesh to approximate the partial differential equations into of approximate algebraic equations. Linearize algebraic equations iteratively converge to the nonlinear solutions by employing a suitable algorithm built in FLUENT. A convergence criterion is specified to achieve an acceptable accuracy. When all the flow properties in all cells of the mesh reach the convergence criteria, the solution is considered "converged" and the iterative process ends.

TEMPERATURE CONTOURS

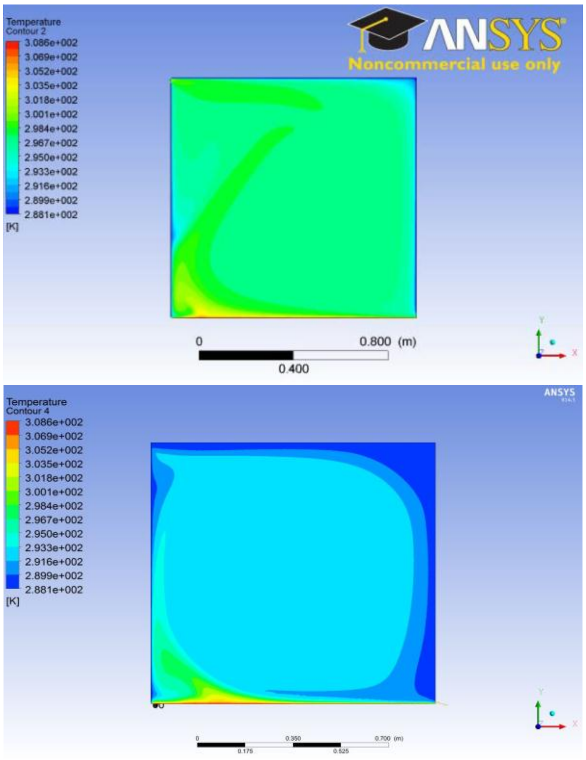

Figure2. Comparison of Alexander Kayne Temperature Contours (Upper) with Present Computed Temperature Contours (below) using the K-epsilon Realizable Model

Figure 2 shows the compute temperature contour using the k-epsilon Realizable modal. Both figure present 11 number of Contour, each Contour presented temperature. These contours indicate that the k-e Realizable modal is more accurate near the wall.

There are six number of Viscous Model presented:

Table 1: Result on Different Model

Sr. no.	Prandlt Number			Air Prandlt No.	Different	% of Error
1	k-epsilon			0.758	0.0491	4.91
	Min.	Max.	Avg.			
	0.7702	0.8458	0.8080			
2	k-epsilon Realizable			0.758	0.0441	4.41
	Min.	Max.	Avg.			
	0.7610	0.8451	0.8031			
3	k-omega			0.758	0.0431	4.31
	Min.	Max.	Avg.			
	0.7589	0.8450	0.8020			
4	Transition k-kl-omega			0.758	0.0455	4.55
	Min.	Max.	Avg.			
	0.7595	0.8494	0.8044			
5	Transition SST			0.758	0.0453	4.53
	Min.	Max.	Avg.			
	0.7597	0.8487	0.8042			
6	Reynolds Stress			0.758	0.0469	4.69
	Min.	Max.	Avg.			
	0.7624	0.8493	0.8058			

Table 1 shows the results of different Model based on the Prandlt Number. Here Molecular Prandalt Number for all Models is constant at 0.758912. There are all model has minimum and maximum values of Prandlt Number, so derived average value of Prandlt Number. Comparison of Average Model Prandalt Number with Molecular Prandlt Number and it shows the difference between them; also found the % of Error. Transition SST Model is much more sophisticated than the other Model under a situation of room region.

TRANSITION SST MODEL

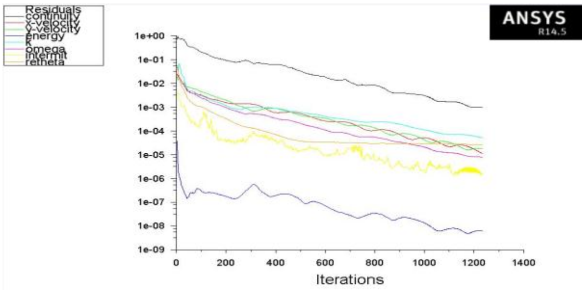

Figure 3: Iteration of Transition SST Model

In the figure 3 the convergence history for calculations Transition SST model is presented. The Transition SST model have solution is converged at 1232 number of iteration. The converged of the present numerical result was again re-calculated, but no change in the result. After the calculation of the iteration the converged result can be changed approximately within 4-5 minute. For the evolution of continuity equation we have been using two equations for solving the iteration of Transition SST the value of the iteration has been converged at the point of 10^{-4}.

Table 2 shows the result of different variables at inlet, outlet and surface for Transition SST Model and Table 3 shows the results, Turbulence Effects of minimum and maximum for Transition SST Model.

Table 2: Variable Effects on Transition SST Model

Sr. no	Variable	Transition SST Model		
		Inlet	Outlet	Surface
1	Boundary Heat Flux (w/m^2)	1653.64	-2395.53	-
2	Density (kg/m^3)	1.204	1.204	1.204
3	Eddy Viscosity (Pa. s)	$4.421*10^{-5}$	$5.616*10^{-6}$	0.00054682
4	Pressure (Pa)	0.0905223	0	0.07823871
5	Temperature (k)	301.15	303.627	304.789
6	Turbulence Eddy Frequency (m^2/s^3)	5.12174	66.514	5.09026
7	Turbulence Kinetic Energy (J/kg)	0.00077634	0.000498533	0.000754775
8	Velocity (m/s)	0.455	0.391174	0.0990621

Table 3: Turbulence Effects on Transition SST Model

Sr. no	Turbulence	SST Model	
		Minimum	Maximum
1	Turbulent Kinetic Energy (k) (m^2/s^2)	$6.694096*10^{-5}$	0.01303679
2	Turbulent Intensity (%)	0.4643123	20.32137
3	Turbulent Dissipation Rate (epsilon) (m^2/s^2)	$2.746067*10^{-5}$	0.06045709
4	Intermittency	0.0417259	1
5	Momentum Thickness Re	88.81451	122.0311
6	Specific Dissipation Rate (omega)	0.5319225	505.9149
7	Turbulent Viscosity (kg/m-s)	$1.768589*10^{-7}$	0.001489269
8	Effective Viscosity (kg/m-s)	$1.842686*10^{-5}$	0.001597519
9	Turbulent Viscosity Ratio	0.009690897	81.60379
10	Effective Thermal Conductivity (W/m-k)	0.02440941	1.787547
11	Effective Prandlt Number	0.7597622	0.8487678

12	Turbulent Reynolds Number (Re)	0.5292886	867.258

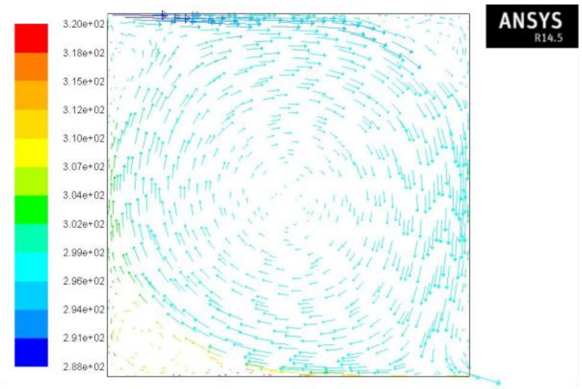

Figure 4: Velocity Vector of Temperature

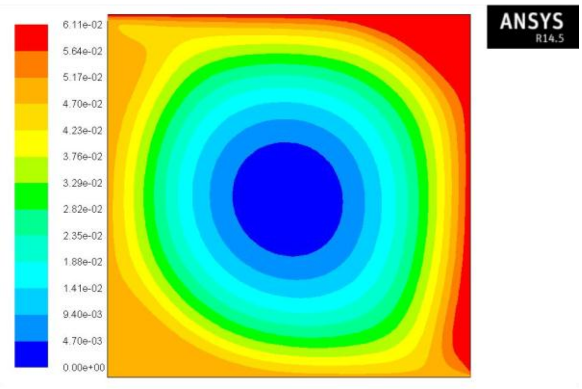

Figure 5: Stream function Contours

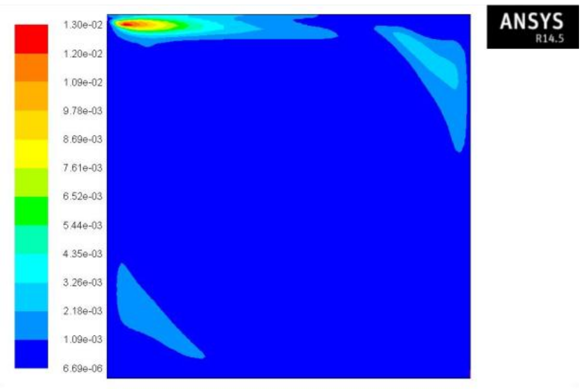

Figure 6: Turbulent Kinetic Energy Contours

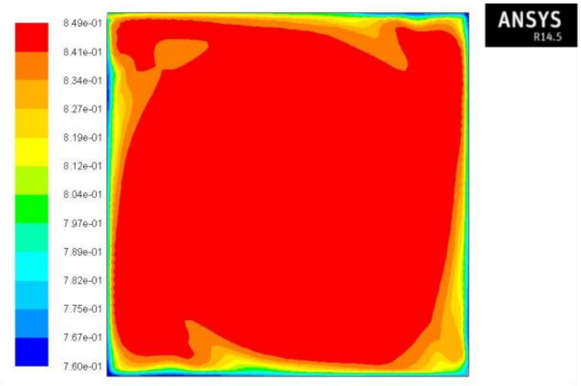

Figure 7: Effective Prandlt Number

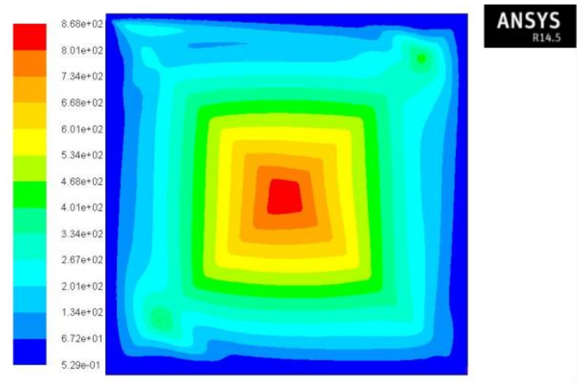

Figure 8: Turbulent Reynolds Number

Figure 4 shows Vector presented the temperature profile flows direction, and clock wise direction represented positive value of temperature which indicates effective area. The floor has generated small region of temperature contours, remain area have only air is flow.

Figure 5 Contours indicating a period of stagnation near the center of room which is surrounded by the circulating air. Furthermore, the ceiling to right side wall has a considerable accumulation of cold air near the wall, possibly due to the impingement of the cool supply air on this wall.

Figure 6 shows the turbulent air flow is generated near the inlet port, maximum turbulent air flow contours linearly decreasing along the ceiling, and turbulent kinetic Energy is high in this region. Many number of turbulent kinetic energy contours are generated in the room. One of them is at inlet, other is at ceiling right corner, at a floor left side corner and floor center to room center.

Figure 7 shows the Effective Prandlt Number Contours of Transition SST Model. There is maximum area of the room affected by a Prandlt number. Affective areas represent the room geometry again the kinetic viscosity to the thermal diffusivity. Only small region of ceiling right side corner and floor left side corner has minimum affected region.

Figure 8 shows the Turbulent Reynolds Number (Re_y) Contours of Transition SST Model. Turbulent Reynolds Number presented turbulent inertia force to the viscous force. Contour indicated a period of maximum effects near the center of room which is surrounded by the circulating air Turbulent Viscosity. The wall surface has a negative turbulent Reynolds Number.

CONCLUSION

The accuracy of the different six turbulence models was examined for mixed convection flow in a square cavity. Variable effects and Turbulence effects are studied and compared between six different turbulent models. Also Prandlt Number obtained by different models is compared with molecular Prandlt number of air. It was discovered that out of these six models used, The Transition SST Model gives more accurate result.

FUTURE WORK

1. Additional simulation should be conducted using turbulent Transition SST Model for 3-D analysis.
2. This can be solved by varying Air velocity based on different zone of Indian environment.

3. More work can be performed to study and optimize port location and port size for mixed convection.

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