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EVALUATION OF CONVECTIVE HEAT TRANSFER COEFFICIENT AT DIFFERENT ALTITUDES IN ATMOSPHERIC REGIME USING FORCED CONVECTION

Swajot Singh *, Raji N. Mishra

Department of Mechanical Engineering, SORT, Peoples University, Bhopal, (M.P.), India

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ABSTRACT

This article is present for a detailed investigation of the design Of solar air heater having difference size of rib on the absorber plate by using the application of computational fluid dynamics (CFD).In this Solar air heater an absorber plate is made of 'Aluminium' and Roughened with difference size ribs due which creates the turbulence in the flow of fluid (air) and increase the heat transfer from the absorber plate to the fluid. The commercial finite-volume based CFD code ANSYS FLUENT 14.5 is used to simulate turbulent airflow through artificially roughened solar air heater. The results predicted by the present CFD investigation are much closer to experimental results. It can, therefore be concluded that the present numerical results have demonstrated the validity of the proposed system. Thus it is possible to establish a validated model for the prediction of heat transfer and fluid flow phenomena in artificially roughened solar air heater. In order to predict performance of the system, Nusselt number and friction factor correlations have been developed by using the data generated under CFD based investigation.

KEYWORDS: CFD, FORCED CONVECTION, HEAT TRANSFER COEFFICIENT.

INTRODUCTION

Heat transfer is one of the prevalent concepts with many usages in different fields of science, industry and so on. In different application we need more or less to know about this phenomenon. Control of this phenomenon is too important in some cases and we should be aware how to control it. Convection mode of heat transfer is very much effective for the component or devices which are exposed to air. Natural convection heat transfer phenomenon is responsible for the cooling of the airborne payloads. In following section, the importance of heat transfer and its modes are described. Heat transfer is related to the Rayleigh number (Ra) which is the product of the Prandtl number (Pr) and Grashof number (Gr). Small values of Ra indicate small amount of heat transfer and vice-versa. The effect of convection on heat transfer is indicated in terms of Nusselt number (Nu). With the variation of surrounding pressure, the role of convection in overall heat transfer changes greatly. Low pressure results in small share of convection in heat transfer phenomenon while at high pressures the share of convection is more but again on increasing pressure it leads to a saturation curve.

Convection

Convective heat transfer is one of the most important way to lose heat for the equipment exposed to air or any fluid. Convective heat and mass transfer take place both by diffusion – the random Brownian motion of individual particles in the fluid – and by advection, in which matter or heat is transported by the larger-scale motion of currents in the fluid. Convection can be qualified in terms of being natural, forced, gravitational, granular, or thermo magnetic. It may also be said to be due to combustion, capillary action. Heat transfer by natural convection plays a role in the structure of Earth's atmosphere, its oceans, and its mantle. Discrete convective cells in the atmosphere can be seen as clouds, with stronger convection resulting in thunderstorms. Natural convection also plays a role in stellar physics.

Air pressure dependence of convection

It is obvious that convection is caused by density variation of fluid molecules. Surrounded air of a specimen has a molecular density that relates to its pressure. So, it's clear that various pressure causes various convective heat transfer. Air pressure varies in different places due to altitude and other things like latitude, weather condition and temperature difference. It is possible that air pressure increases or decreases in a container in which heat transfer rate from an internal part of it is important.

Computational Fluid Dynamics

Computational fluid dynamics (CFD) is a computer-based simulation method for analyzing flow of fluid, transfer of heat, and related phenomena such as reactions carried out in chemicals. This project is using CFD for analysis of fluid flow and heat transfer. Some examples of application areas are: aerodynamic lift and drag (i.e. aerofoils or windmill wings), power plant combustion, chemical processes, heating/ventilation, and even biomedical engineering (simulating blood flow through arteries and veins). CFD analysis carried out in the various industries is used in R&D and manufacture of aircraft, combustion systems, as well as many other industrial products.

Problem-Solving with CFD

There are many decisions to be made before setting up the problem in the CFD code. Some of the decisions to be made can include: whether the problem should be 2D or 3D, which type of boundary conditions to use, whether or not to calculate pressure/temperature variations based on the air flow density, which turbulence model to use, etc. The assumptions made should be reduced to a level as simple as possible, yet still retaining the most important features of the problem to be solved in order to reach an accurate solution.

MATERIALS AND METHODS

Convection coefficient of heat transfer is the factor which shows the extent of convection. Its value is an indication of how fast the convection heat transfer can occur. It depends upon a large number of parameters and its determination is quite difficult. There are some classical methods to calculate it but nowadays due to advancement in technology and availability many CFD software, it is readily calculated using these. In this section various factors affecting the convection coefficient and its dependency on different parameters are discussed.

Methods to calculate

A simple way to calculate h is to define it through the classical formula for convection, and compare it with a different definition of h, through dimensionless parameters. The classic approach to calculate convective heat transfer coefficient is by dimensional analysis. This method is quite easy to use; however, it has the disadvantage that it doesn't allow an understanding of underlying physics of this complex phenomenon. Unfortunately, even if defined by means of different parameters, both the environment and the heat sink temperature are important to estimate convective heat transfer coefficient. An iterative method to calculate convective heat transfer coefficient at atmospheric pressure is also given by D. Roncati.

Another way to calculate convective heat transfer coefficient is by the use of empirical correlation. There are many correlations which provide solution for convection coefficient but they are case specific and there is no generalized equation by which convection coefficient can be determined for all problems. At the same time solving these correlations is also a tedious problem.

On the other hand, Computational Fluid Dynamics can be used to determine the convective heat transfer coefficients. The laminar and turbulent convective heat transfer models for CFD have been shown to calculate the convective heat transfer coefficients with good agreement with experimental and analytical values. As a result, the CFD models can be used with confidence for cases similar to the ones described here.

Practical significance

The demands for airborne applications have increased in recent years. It serves the purpose of all types of surveillance. And with the increased demand the quantity and complexity of electronic equipment installed aboard has increased. This is brought about mainly by the rapid development of new electronic system, and the trends toward more sophisticated aircraft and engine electronic control system. Airborne payloads which works in upper atmosphere below 15 km can be helpful in many ways, some of them are listed below:

Air surveillance, Homeland security system, Night vision surveillance, Port/ harbour security, Coastal surveillance, Agricultural and flood surveillance.

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RESULTS AND DISCUSSION

The results obtained from CFD simulations as well as from experiments are presented here. The various graphs between dimensionless number like Nu, Gr, and Pr etc. for both cases are prepared and described in this section.

Formulae:

$Re = \frac{\rho V L}{\mu}$.........(1)

$Pr = \frac{\mu C_p}{K}$..........(2)

$Gr = \frac{(\beta g \Delta T)\rho^2 l^3}{\mu^2}$......(3)

$Nu = 0.54(Gr \times Pr)^{0.25}$.........(4)

$Nu = \frac{hl}{K}$...........(5)

Tables:1

All Parameters

P(mbar)	v(m/s)	Tp(K)	Tw(K)	Re	Pr	Gr	Nu	h(w/m2-K)
100	0.1	384	300	347.1	0.744	1.40E+06	17.4	8.35
200	0.2	376	300	694.2	0.744	1.32E+06	17.02	8.24
300	0.3	368	300	1041	0.744	1.20E+06	16.6	8.039
400	0.4	360	300	1339	0.744	1.18E+06	16.38	7.92
500	0.5	352	300	1686	0.744	1.06E+06	15.93	7.71

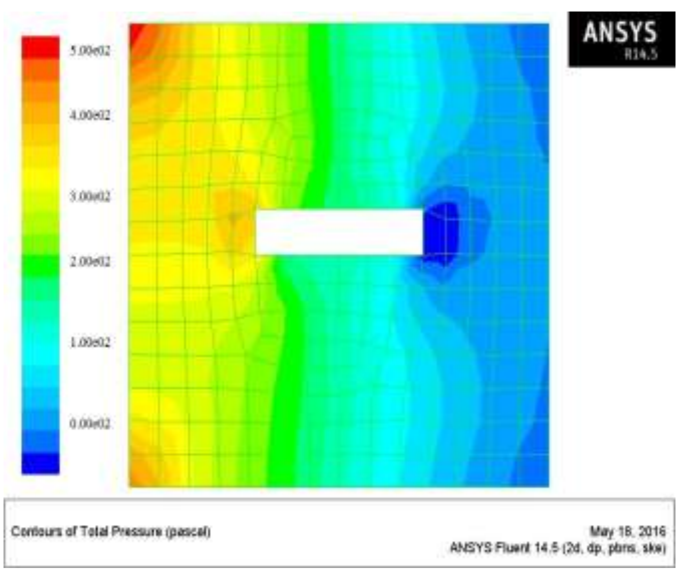

Fig. 1 Total Pressure

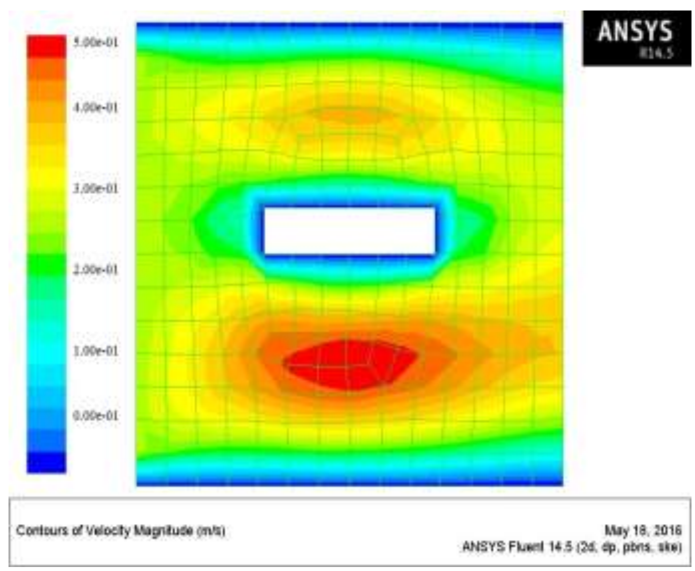

Fig. 2 Velocity Magnitude

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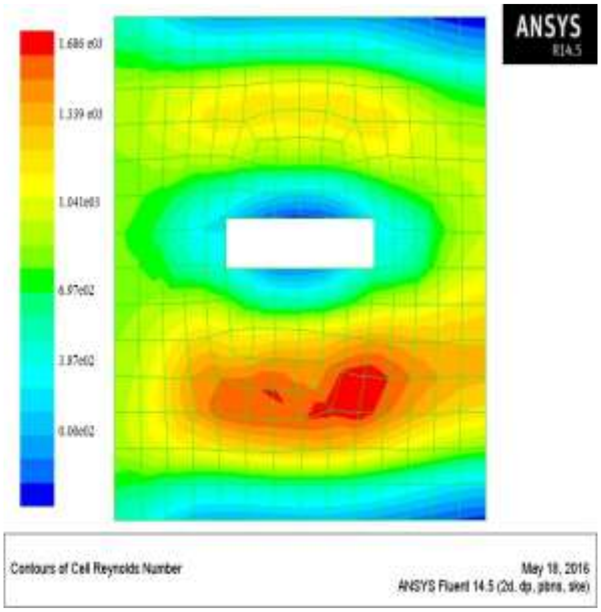

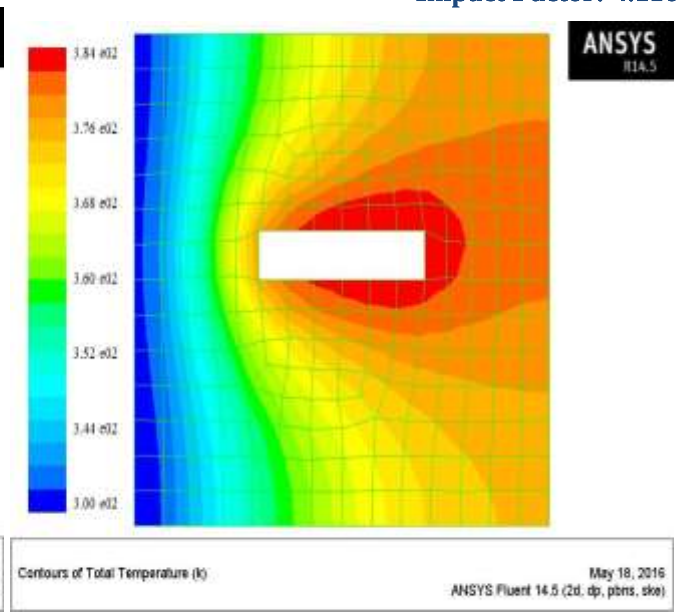

Fig. 3 Reynolds number(Re)

Fig. 4 Total temperature(Tp& Tw)

CONCLUSION

From the above table it can be concluded that with the decrease in the domain pressure the maximum temperature of the plate increases. This is due to the fact that density is directly proportional to the pressure and with the decrease in the pressure the number of air molecules in the domain decreases. As the pressure increases the Reynolds number increases with increasing velocity which results in decreasing Nusselt number from equation number 4. As we know tha Heat transfer coefficient is directly proportional to Nusselt number from equation 5.

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