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COMPUTATIONAL STUDIES ON THERMAL COMFORT OF HELMET

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Abstract— In this competitive era of sports, bicycle Helmet based game gaining popularity and everybody want to win so the knowledge of sports engineering become very important. We either do not know about science behind it or very less information is available in open domain. Even a very little information can play crucial role to win the game. In every game like volleyball, football, golf, cricket, rugby, baseball, tennis and bicycle racing aerodynamic and thermal comfort play an important role; Most of the bicycle helmet is elliptical shape with maximum vents for the thermal comfort. To study the computational performance aerodynamics and thermal performance studied at 30 to 70 kph speed and at 45^o and 90^o pitch angle, It has been found that at 45^o pitch angle is the more efficient for thermal comfort than 90^o pitch angle, at 30 kph velocity temperature drop is more but at 60 to 70 kph temperature drop is very less. Variation of temperature have been studied and found the little difference in temperature at different pitch angle.

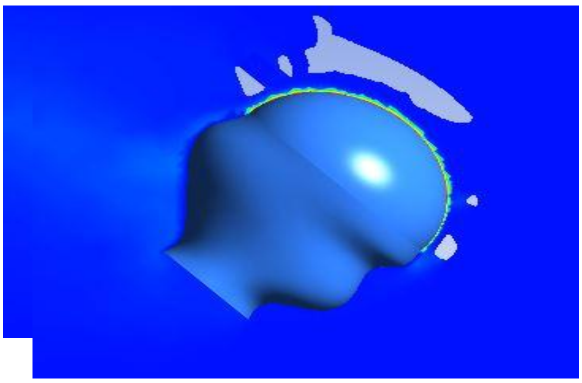
Keywords— CFD, bicycle helmet, Modelled mannequin, thermal comfort, variable speed, pitch angle.

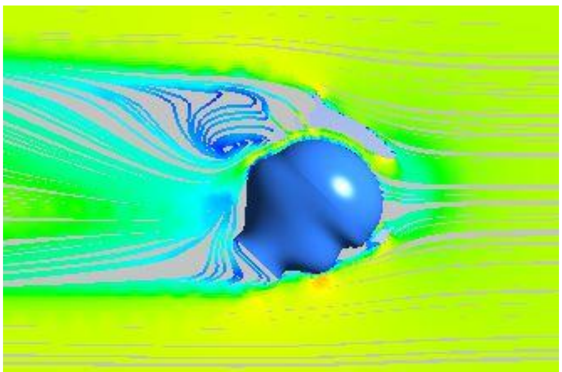
I. INTRODUCTION

Accident is major problem in India. Today, road injuries are one of the leading causes of the death. Most of people are injured in accident due to not wearing the helmet and not wearing the seat belt. Speed is biggest problem and use of mobile is also one of the issue for accident in India. They survey reveals that the major cause of not wearing of the helmet is its thermal discomfort. The thermal comfort can be improved by adding the vents but more vents reduce the strength of the helmet. Thus there is need to redesign and optimize the performance of the helmet so that acceptability to wear it increases leading to saving of life of two wheeler riders in case of accidents.

II. THERMAL PRINCIPAL

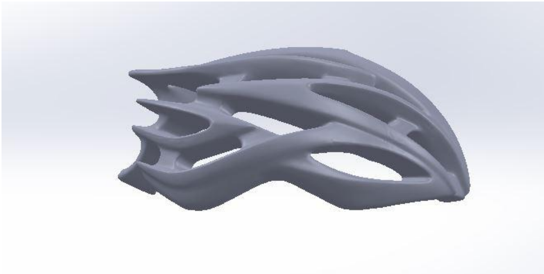
The main assumption of flow field is continuum. The equations of conservation of mass, momentum and energy are used for computational study of the helmet performance. In addition thermal performance depends upon the second law of thermodynamics and convection of heat. And the performance is characterized by the properties as flow velocity, pressure, temperature may be the function of position and time to understand the flow field and the temperature. The air flow between head and helmet temperature decreases due to the effect of inner surface, vents and holes.



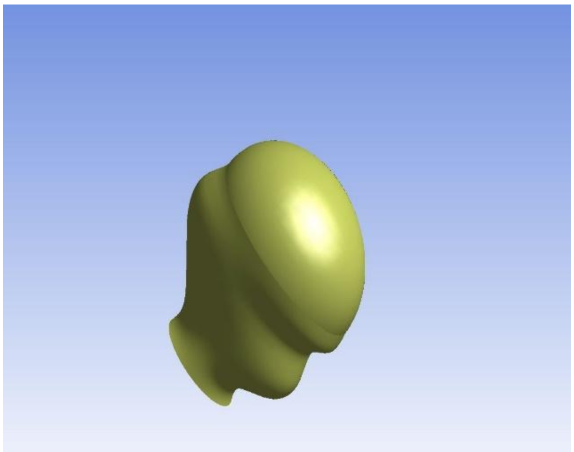


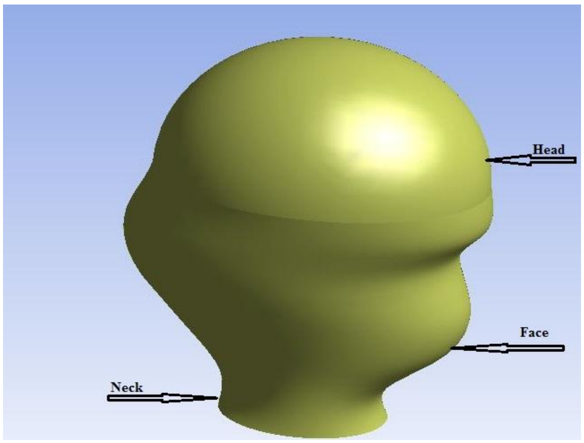
III GEOMETRY

Geometry of the helmet in the present study is downloaded from the grab cad website which is similar to the Almas et al.(2010) experimental helmet as shown in Fig. The geometry is in IGES format and it is imported in the workbench ANSYS software, the geometry in workbench Design Modeller of ANSYS 16.0 shown in the Figure.



Mannequin is a dummy human figure which is used for the computer simulation, To model the human body in this study,a mannequin of human face was modelled in SOLID WORK software and then imported in the workbench .





iv GOVERINING EQUATIONS AND BOUNDARY CONDITIONS

The main assumptions which are associated in the computational solution: (i) flow analysis in 3D, (ii) flow throughout in the domain is unsteady, (iii) viscous dissipation neglected, and (iv) Thermo physical properties independent on temperature. From above approximations, the governing conservation equations such as mass and momentum and energy are defined below.

Continuity equation

$$div(\vec{V}) = 0$$

Momentum equations

In x direction

$$\rho \frac{Du}{Dt} = \frac{\partial(-p+\tau_{xx})}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + S_{Mx}$$

In y direction

$$\rho \frac{Dv}{Dt} = \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial(-p+\tau_{yy})}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + S_{My}$$

In z direction

$$\rho \frac{Dw}{Dt} = \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial(-p+\tau_{zz})}{\partial z} + S_{Mz}$$

Energy equations

$$\frac{\partial}{\partial x_i}(\rho u_i T) = \frac{\partial}{\partial x_i}(\frac{k\partial T}{C_p \partial x_i})$$

Where u_i, u_j and are the average velocity, μ is dynamic viscosity, ρ is the density, C_p and k are heat capacity and thermal conductivity of fluid respectively. Turbulence model is used for momentum equation that contains Reynolds stresses.

Turbulence model

The airflow analysis in a fluid flow is taken an account as turbulent this is due to the dimensions and velocities, and also buoyancy effect were considered. The standard k-Ɛ model is used as ,

***k* -equation**

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\in-Y_M+S_k$$

***Ɛ* -equation:**

$$\frac{\partial}{\partial t}(\rho\in)+\frac{\partial}{\partial x_i}(\rho\in u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\in}\right)\frac{\partial\in}{\partial x_j}\right]+C_{1\in}\frac{\in}{k}(G_k+C_{3\in}C_b)-C_{2\in\rho}\frac{\in^2}{k}+S_\in$$

G_k = generation of turbulent kinetic energy due to mean velocity G_b = generation of turbulent kinetic energy due to buoyancy Y_M = contribution of fluctuation dilatation in compressible turbulence to the overall dissipation rate , $C_{1\in}$, $C_{2\in}$ and $C_{3\in}$ are constant, σ_k and $\sigma_\in$ are the turbulent Prandtl number for k and ε respectively , S_k and $S_\in$ are user-defined source terms.

Boundary condition is important parameter for the computational simulation which is shows the tabulated below.

Table 3. 1 Boundary conditions

Zone	Type	Boundary condition
Inlet	Velocity Inlet	Velocity magnitude= (30 to 70 km/hr.) Inlet Pressure : 101325 Pa (atmospheric)
Outlet	Pressure Outlet	Outlet Pressure : 101325 Pa (atmospheric)
Head	WALL	Temperature : 56 ˚C(329K)

v RESULTS AND DISCISSION

Validation

The current simulation results were validated with the experimental results of Alam et al (2010). In this paper An Experimental Study of Thermal Comfort and Aerodynamic Efficiency of Recreational and Racing Bicycle Helmets has been discussed. Fig. Shows the variation of temperature with respect to wind speed. The experimental results of Alam et al (2010) and presented computational result were plotted together in this Fig. Both the results are tabulated in Table. The trend of both the results are same, however, there magnitude differs by 40 to 44%. The reason for this is attributed to the geometry of the helmet used in the simulation was not the same but similar to that used by Alam et al(2010).

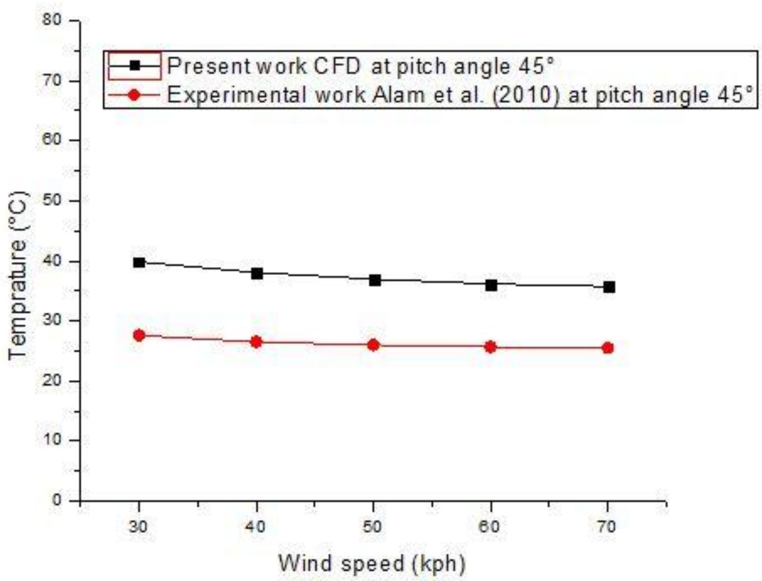


Fig.4. 1Validation with experimental data

Table Comparison of validation result for Temperature

Velocity (Kph)	Alam et al. (2010) Temperature(°C)	CFD simulation Temperature (°C)	Error (%)
30	27.6	39.85	44.38
40	26.5	38.07	43.66
50	26.0	36.97	42.19
60	25.7	36.17	40.07
70	25.5	35.76	40.23

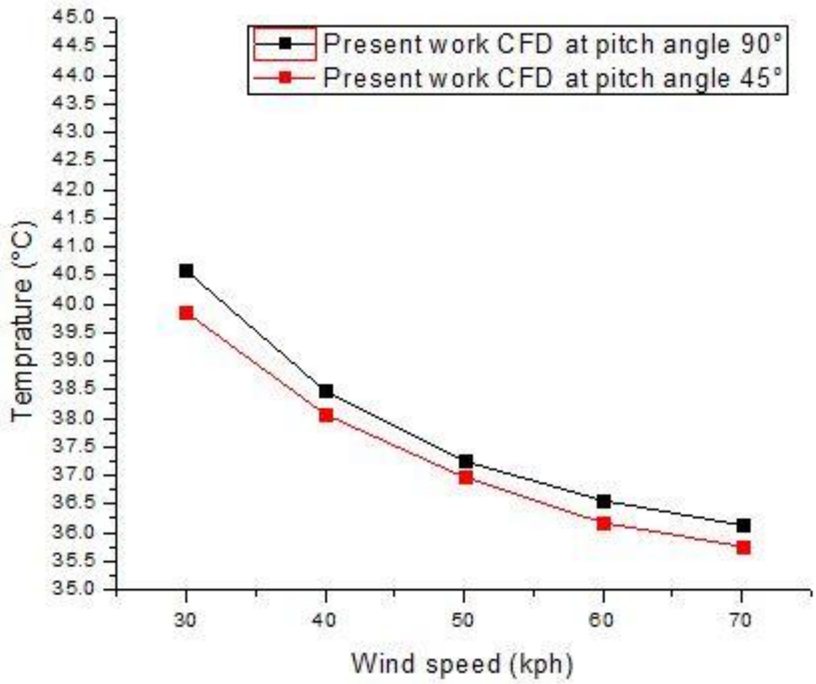
Comparison of the temperature between $at\ \theta = 45^{\circ}$ ***and*** $\theta = 90^{\circ}$

Result compare

Velocity (kph)	Temperature (°C) at $\theta = 45^{\circ}$	Temperature (°C) at $\theta = 90^{\circ}$
30	39.85	40.58
40	38.07	38.48
50	36.97	37.25
60	36.17	36.56
70	35.76	36.13

Compare the result at 45° and 90 °

Fig shows the variation of temperature for 45° and 90°pitch angles at 30 kph to70 kph wind velocities .The simulation reveals that there is the less thermal comfort in 90° pitch angles as compared to 45° pitch angle.



VI CONCLUSIONS

Simulations are performing on helmet, with velocities (30 kph to 70 kph) at two different pitch angles (45° and 90°).

- Temperature of the head decreases rate of reduction as the wind speed increase.
- It was found that Pitch angle has prominent effect on heat transfer characteristics of helmet. The results specify that at 45º pitch angle helmets show lower head temperature corresponding to pitch angle 90°.
- The design and position of venting need to be selected on heat dissipation characteristics while keeping thermal comfort intact.
- The vent of the helmet permits air to pass and carry away the heat. Thus to maintain thermal comfort of the helmet that is to cool.

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