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Computational studies on thermal comfort of helmet– A review

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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 the science behind it or very less information is available in the open domain. Even very little information can play a 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 an 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 45º and 90º pitch angle, It has been found that at 45º pitch angle is the more efficient for thermal comfort than 90º pitch angle, at 30 kph velocity temperature drop is more but at 60 to 70 kph temperature drop is very less. Variation of temperature has 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*

1. INTRODUCTION

The accident is a major problem in India. Today, road injuries are one of the leading causes of death. Most of the people are injured in an accident due to not wearing the helmet and not wearing the seat belt. Speed is the biggest problem and use of mobile is also one of the issues for an accident in India. The 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 a need to redesign and optimize the performance of the helmet so that acceptability to wear it increases leading to saving of the life of two-wheeler riders in case of accidents.

2. LITERATURE SURVEY

This research targets computational study on the thermal comfort of the helmet. Thus, the previous work related to this topic are presented in this chapter.

2.1 Empa and St Gallen (2005): They had done experimental work on the principle of bicycle helmet ventilation. A thermal head form mounted in a climate-regulated wind tunnel was used to study the ventilation efficiency of 24 bicycle helmet in wind tunnel with 6 km/hr and 22 km/hr at 0˚ and 30˚, they had used the forced convection technique to transfer from head to environment. They had investigated the roles of vents in a bicycle helmet, experiment without vents and blocking the vents. The wide variability in helmet performance indicates the combination of relevant factors reduces the ventilation of most helmet. They had observed that difference in heat transfer among the helmet of up to 10 % face and 30% scalp.

2.2 Brecht et al. (2007): They performed an experiment to study the ventilation characteristics of the helmet. They reported that many cyclists refuse to wear a helmet because of the thermal discomfort. In this paper, a method is described that quantifies the ventilation characteristics of a helmet using tracer gas experiments. A DBM (database mechanics) model used to improve the thermal efficiency. It is found that ventilation at side zone has poor thermal efficiency, Thermal efficiency also depends on the distance between helmet and head.

2.3 Alam et al. (2010): They had performed experiment on six different bicycle helmets (ex. Giro, Giro Atoms, Prowls F22-Raptor, LG Rocket, Modified Giro Helmets) in wind tunnel dimension (3m×2m×9m) with air velocity 30 km/hr to 70 km/hr at different angle 0˚, 45˚ 90˚ but they presented the result in this paper at only 45˚, They have tested aerodynamic efficiency and thermal efficiency and found the Giro Prowll helmet has the highest C_D and Giro advantage has lowest C_D, Initially temperature was 56˚c at 0 km/hr. When the velocities (30 km/hr to 70 km/hr) increases temperature decreases, However, a further increase in wind speed did not cause a drop in temp. but stays relatively constant. They finally concluded that Giro advantage is a good helmet for aerodynamic efficiency and Prowell is worst. And Giro Ionos is the most optimum helmet for both aerodynamic efficiency and thermal comfort.

2.4 Pang et al. (2011): An experimental study of heat distribution for four types of cricket helmets (ex. NXT, Elite, Premiere, Masuri) was carried out in the laboratory. The model consists of an aluminum mannequin head, water boilers insulated pipes and water pump, The head was heated around 36˚C (normal body temperature) through pumping system that was used to supply warm water from boilers to the mannequin head through insulated pipe, 8k type thermocouple was attached to mannequin head for measuring the temperature between the helmet shell and liner at different locations. The temperature was recorded three different times 1.used Infrared camera used for the surface temperature of the helmets 8 k-type thermocouples was attached to mannequin head measure the temperature between the helmet shell and liner thermocouple taken at three different times 1. 0-2 minutes where no helmet was attached 2.with helmet when a steady state condition was reached after 30 minutes 3. After removing the helmet from mannequin head each test performed 45 minutes and each repeated 5 times. Used Infrared camera for measuring the surface temperature of the helmets. The results show that the temperature of mannequin increases by 1.4 ^{o}C, the temperature varies according to the position of the head. The recorded high temperature at rear side as compared to the side of the helmet.

2.5 Soubic et al. (2013): They performed an experiment to investigate, thermal properties of five different type of cricket helmets (NXT, Elite, Premiere, Masuri, and Ultimate). These helmets have a different shape with some modification in circular holes with small cross crown, Thermal comfort was evaluated at 23±0.5˚C maintained in the laboratory and wind velocities 0.8±0.05 m/s. The temperature was measured with a K-type thermocouple.

2.6 Pang et al. (2014): They investigated experimentally five different cricket helmets to evaluate thermal and evaporative resistance with a sweating mannequin. They mannequin was used in two stages: dry test and wet test. Naked test means test without a helmet in the wet test, skin suit is pre-wetted with water to measure evaporating resistance at 35˚C skin temperature and 40% relative humidity.

2.7 I. Mustary et al. (2014): They carried out his experiment on four type of bicycle helmets (ex. Giro, Blast, Nitro, and Zenith) at three different pitch angle (0˚, 45˚, 90˚) with velocities (20 to 40 km/hr.) in RMIT industrial wind tunnel. On the basis of the thermal and aerodynamic of every helmet was ranked. Giro is the most smoothly competent helmet and the performance of Nitro was the poorest quality and in terms of thermal comfort Giro is the most optimal helmet. Blast and Nitro were poorest performing helmet 45^{o} degree position is best for thermal and aerodynamically performance.

2.8 Vigneswaran and Arulmrugan (2014): They performed an experiment on safety helmets using Phase Change Material (PCM), they performed an experiment in a closed box, and they used K type thermocouple and DAQ card for temperature measurement and experiment done on the left side of the helmet. The helmet is kept in a closed container and three bulbs used for heating and maintaining the temperature of the head and 8 thermocouples are used for temperature measurement. The experiment was performed with no airstream and performed the experiment with PCM and without PCM, paraffin wax is used for PCM, Paraffin wax has excellent heat storing capacity and it changes phase from solid to liquid on heating, and molted PCM can be resolidified by dissipating heat to the surrounding when helmet is not in used. They made PCM pouch of dimension (9×5×5cm) in aluminum foil and the only ¾ of paraffin wax is filled in each pouch and remaining space for expansion of PCM. The average temperature underneath of the helmet in warmer days is 45˚C and decreased to 35˚C in the PCM based helmet, this paper presents the design of a helmet cooling system using PCM to absorb and store the heat to achieve comfort cooling.

2.8 Martinez et al. (2015): They performed an experiment on bicycle helmet to evaluate local heat transfer variation in nine zones on mannequin head (face, forehead, neck, right temple, left the temple, lower head back, upper head back, crown, occipital). This study presents two tests: convective and radiation tests, Two zone mannequin (facial and cranial section) at 25˚C environment temperature and 60% relative humidity at different velocities 1.6 m/s to 6.26 m/s were studied and found that the variation of heat flux is lower for 9Zone Mannequin than for 2Zone Mannequin .

2.9 Pang et al. (2015): They performed an experiment with four different cricket helmets for ventilation, The main objective is to design vent for ventilation and thermal comfort and perform the experiment at RMIT wind tunnel at 2.3 m/s constant velocity and the temperature is measured by k- type thermocouple. They performed four cricket helmet M1 has one circular hole, N1 has several vent hole, A1 has three circular holes with cross-shaped and E1 has radial vents with small cross-shaped, More temp. Increases in M1 type helmet.

2.10 Gisolfi et al. (2016): They published a paper on the effect of wearing a helmet on thermal balance while cycling in the heat, the purpose of this study is to implement two basic concepts of heat transfer for the cooling of the human head beneath bicycle helmet. They had arranged the geometry with vents. The heat pipe is used as the integrated structure of helmet, they used the copper disk as heat coupling element and aluminum mesh pipe used to transfer heat from copper to heat sink then heat is transferred heat sink to the environment by the convective process.

2.11 Ghani et al. (2016): They performed experiment and simulation both in this paper to study the effect of forced convection and PCM on helmets thermal performance in hot and arid environment, They performed the study on an industrial helmet in close space (1m×1m×1m) in four cases. They studied the thermal performance with different velocities (0 to 3 m/s), with the use of PCM (paraffin wax) and Solar Fan in rear side of helmet and tested for 15 minutes and 30 minutes the result of experiment and simulation are compared, In simulation they used K-Ɛ model and fan velocity was 4 m/s. The conclusion of this paper is when fan and PCM are used in the helmet, it gives more comfort in thermal performance.

2.12 Cao et al. (2017): They designed helmet by thermoelectric refrigeration system with combination of water, cooling of air and simultaneously cooling of man head and neck, are cool the new helmet It is working on two modules, ARM (air refrigeration module) and LRM (liquid refrigeration module) and micro water pump. Helmet working follows these steps. By using micro fans air from the arm is passed to air cooler to make cool and follows the helmet and cool the head. The thermoelectric cooler concept is used to cool liquid by circulating micro pump into cooling tubes of the liquid to get absorb the heat from neck and liquid move back into the cooler and cools down to whole the cycle.

3. RESEARCH GAP

After going through different researches on thermal comfort on the helmets, it has been found that there is still scope of works in this field.

- No extensive computational work on thermal comfort of racing bicycle helmets exists.
- Computational studied on different pitch angle (0°, 90°).
- Inserting the grooves into the vents of the helmet.
- Inserting additional pads added inside surface of the helmet to provide a gap between helmet and wearer to provide ventilation.

- Inserts suspension straps system to enhance the air gap and indorse air flow between wearer head and helmet to improve thermal comfort.
- Insert forced convection (Ex. Fan) to increase the thermal comfort in a bicycle helmet.

4. AIMS AND RESEARCH OBJECTIVES

Objectives are specified as follows:

- Validation of the present computational study with the established experimental studies on thermal comfort of a bicycle helmet.
- To study the effect of pitch angle (θ=45°) and relative velocity (30 kph to 70 kph) of the fluid flow on the thermal comfort of the bicycle helmet.

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