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Design of ventilated helmets: computational fluid and impact dynamics studies

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The existing motorcycle helmets are thermally uncomfortable as there is no provision for air flow inside the helmet. A new design of helmet, with grooves in the liner foam and slot in the outer shell and liner foam to improve the ventilation, is proposed. Computational fluid dynamics studies show considerable improvement in air velocities inside the helmet in the presence of grooves and slot. Impact dynamics and biomechanics studies on various motorcycle helmets with deformable and rigid head show that the proposed design meets the requirements of the standards in the drop test. The optimum size of the groove and number of grooves for a motorcycle helmet are decided on the basis of the above studies.

Keywords: helmets; design; fluid flow; impact; finite element; biomechanics

1. Introduction

A well-designed motorcycle crash helmet has proved to be a very good protection device for the rider to prevent or minimise the head injuries in road accidents. If a helmet is not worn, the head impact with any object would cause localised high pressure on the skull, which leads to brain injury. The helmet design can be divided into functional (like shock-absorbing capability, penetration resistance, retention and reliability) and non-functional (like low cost, good aesthetics, comfort, light weight and good thermal characteristics) categories. Though a helmet is well-designed for functional characteristics, because of weak non-functional characteristics drivers sometimes dislike wearing it while riding. In South Asia, excessive sweating and resulting discomfort due to hot and humid weather conditions discourage motorcycle riders from using helmets unless it is mandatory by law. The space between the head and helmet is small, and both mass flow and air velocities in this gap are also low; as a result, the sweat is unable to evaporate making the rider uncomfortable. The discomfort caused by sweating can be reduced by increasing the air velocities inside the helmet so as to enhance the sweat evaporation rate. Air flow in helmet can be improved by large ventilation openings as in bicycle helmets, but unfortunately such ventilation openings may be detrimental to the safety and structural integrity of the helmet. Most of the studies on motorcycle helmets are based on the material and biomechanics aspects, and few studies exist which investigate the effect of ventilation on air flow inside the helmet or effect of this (or ventilation openings) on the dynamic performance of helmet. It is possible that helmets with ventilation are available in the market, but systematic studies on these are not available in the literature. In first part of the paper, we investigate air velocities inside the helmet, with and without ventilation using computational fluid dynamics (CFD) techniques. The fluid flow study was carried out to examine the possibility of improving the ventilation in motorcycle helmets. In second part of the paper, the biomechanics characteristics of head impact were studied for helmets with and without ventilation using finite element (FE) analysis.

In a motorcycle helmet, the comfort foam apparently helps in fitting the helmet on heads of different sizes, although it is rarely used in bicycle helmets. Because the comfort foam always rests on the head and gives resistance to air flow, it has not been included in the helmet designs studied here. We found that, without comfort foam and if tied properly, the helmet sits on the head and does not move. Even without comfort foam, however, there are regions in the central plane of the head, where this helmet rests on the head, and there is no space for air to circulate. It was decided to support the helmet on the head by comfort foam of 2 mm thickness provided on the sides of the helmet only (but not on the top). A groove was made in the central plane to provide space for air to flow, and a slot was provided in front of the helmet for air to enter. The groove and slot in the helmet are shown in Figure 1. Flow velocity inside the helmet was determined by varying the depth and width of the groove keeping slot dimensions fixed. Four different sizes of groove, listed in Table 1, were investigated. The dimensions of the slot present in the outer shell and liner foam were fixed at 48 mm × 7 mm. These helmets did not have

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