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Impact attenuation of customized user-centered bicycle helmet design

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Abstract

Bicycle helmets are currently available to cater to general head sizes, ranging from S/M and L/XL, but there is also a universal model that can fit all sizes through adjustable helmet strap. Numerous surveys addressed that wearing helmet is not comfortable and the current sizing did not accommodate various range of users, because the human head shapes and dimensions are different according to ethnic groups, age and gender. This paper describes impact attenuation of user-centred design approach, i.e by modifying the shape of the liner to improve fit of bicycle helmet in accordance to AS/NZS 2063:2008. Head scans of 15 participants from a selected control group were captured using Artec3D portable scanner, while bicycle helmets and J headform were scanned using Flexscan 3D scanning equipment. These participants were selected based on a grouping method referring to selected 37 landmarks on human head shape. A new headform for the control group was developed by aligning and combining all the involved head scans in Geomagic Studio 12. Several new helmets with different liner thickness were designed based on the new headform. A validated drop impact simulation model, developed using Abaqus FEA software, was used to conduct drop impact simulation of each customized helmet design. Thickness of each user-centred helmet models at 37 landmarks was also recorded and the peak linear acceleration (PLA) of the helmet at impact locations such as top, side and front area were measured. Results revealed that the PLA increases as the thickness of helmet liner decreases. The rate of increase of PLA as the helmet liner thickness decreases is different at each impact location; it was greater at front and side location compared to top impact location.

Keywords: Bicycle helmet; Impact test; User centered

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1. Introduction

Most bicycle helmets that are currently available on the market have been designed to cater for general head sizes, ranging from S/M and L/XL. There are also universal models that can fit all users' head sizes through adjustable helmet strap. However, based on the human anthropometric studies, the human head shape and dimension are different according to ethnic groups, age and gender [1-3]. For example, it was found out from the anthropometric survey that Asian heads were rounder than Caucasian counterparts; Asian heads also generally flatter at the back and forehead. Furthermore, numerous surveys have addressed that wearing helmet is uncomfortable and the current sizing do not accommodate the wide range of the user's head shape, size and dimension [4-7]. Exclusively, it was also reported that Asian users experience poor fit because most helmet are designed according to the anthropometric geometry of Western heads [2, 8].

In order to overcome these helmet fit related problems, several investigations of bicycle helmet have been carried out aiming to improve fit and comfort for a diverse range of user groups. For example, adjustable strap has been introduced by manufacturers to improve fit for all head sizes into one helmet; it has not addressed the gap and fit between the liner and the head. Chang et al. (2001) acknowledged the fit problem in regards to helmet safety, but different sizes of head form instead of different shape of liner were used to demonstrate different fit conditions [9]. Therefore, the effect of helmet fit on impact performance of helmet by using improvised helmet liner shape is still unclear.

One possible solution to overcome helmet fit problem for each individual is user-centred customization of helmet design approach. The key to facilitate user-centred design approach to bicycle helmet is to change the shape of liner to follow the shape and geometry of the user's head. However, changing liner design and thickness to improve fit would alter the impact performance of helmet. The impact performance of bicycle helmet is indicated by the peak linear acceleration during impact test; the peak deceleration according to Australian Standards cannot exceed 250g to be deemed safe for use. Therefore the objective of this research is to investigate the impact performance of user-customized helmet liner and to determine the minimum allowable thickness at three impact locations that still comply with the Australian Standards.

2. Material and methods

2.1. 3D scanning of helmet and participant head shape

Head shapes from 50 participants volunteered for the study were scanned using portable Artec3D scanner. The participants were given one S/M size and another one L size Netti Lightning helmet model, and they were asked to test which helmet size fit them best. All the participants had chosen the size S/M helmet. During scanning, the participants were asked to sit straight and to avoid any movement, and maintain their usual facial expression. They were also required to wear a thin hair cap to compress their hair. The scans of the participants wearing bicycle helmet were also taken afterwards.

A S/M size Netti Lightning bicycle helmet model was scanned using the Flexscan 3D scanner. The strap, velcro stickers, visor and paddings were removed from the helmet before the scanning. The whole helmet was scanned and assumed as helmet liner because the shell cannot be easily removed from the helmet due to glue application and in-mould bonding. The helmet was placed onto a rotating table and scanned using projector and camera setup of Flexscan 3D scanner. The helmet was scanned from 8 different positions in order to capture its entire profile and geometry, in particular the ventilation holes area. All scans from different positions of helmet were aligned and combined using the Flexscan 3D software. General post-processing job to remove the background scans was also conducted.