A Numerical Approach for the Optimisation of a Composite Chin Bar for Protection against Basilar Skull Fracture

Siamak Farajzadeh Khosroshahi, Mazdak Ghajari, Ugo Galvanetto *

I. INTRODUCTION

According to clinical and statistical surveys Basilar Skull Fracture (BSF) is one of the most common types of injury in motorcycle accidents in which the riders use full-face helmets [1-2]. It is known that facial impacts, especially impacts on the chin bar of full-face helmets can lead to BSF [3-4]. The induced neck axial load can be considered as the most important cause of BSF [5]. It is revealed that the chin bar of the helmet must not be too stiff [6] in order to absorb the impact energy and mitigate the transmitted force to the base of the skull. Since relevant standards [7-8] assess the chin bar of the helmet according to brain injury, there is no clear criterion to design the helmet's chin bar with respect to brain injury and BSF simultaneously. Therefore, the present work proposes a numerical approach to modify the chin bar of a helmet with the aim of reducing the risk of BSF and of satisfying the requirements of the current standards.

II. METHODS

Finite Element (FE) Simulations

Two types of FE simulations were carried out in the present work by means of LS-Dyna software. The first one involved a helmeted HYBRID III head and neck which was hit by a cylindrical impactor on the chin bar of the helmet at a velocity of 3.5 m/s. This simulation was adopted from the test method in [8] for the chin bar in order to measure the induced neck force due to the impact on the chin bar. The second type of FE simulation was the virtual impact test for the chin bar of the full-face helmet according to ECE 22.05 [7]. Figure 1 illustrates the mentioned FE models. The main parts of the helmet, which were considered in the models, were the external shell, which was made of composite laminates with different thicknesses and ply configurations for different parts of the helmet, the foam liner, which was made of expanded polystyrene and the chin strap [9]. The orientation of the fibres of the composite chin bar was considered as the variable parameters. The chin bar of the studied helmet was made of an angle ply laminate by the configuration of [$\pm\theta_1$, $\pm\theta_2$, $\pm\theta_3$] (Figure 1).

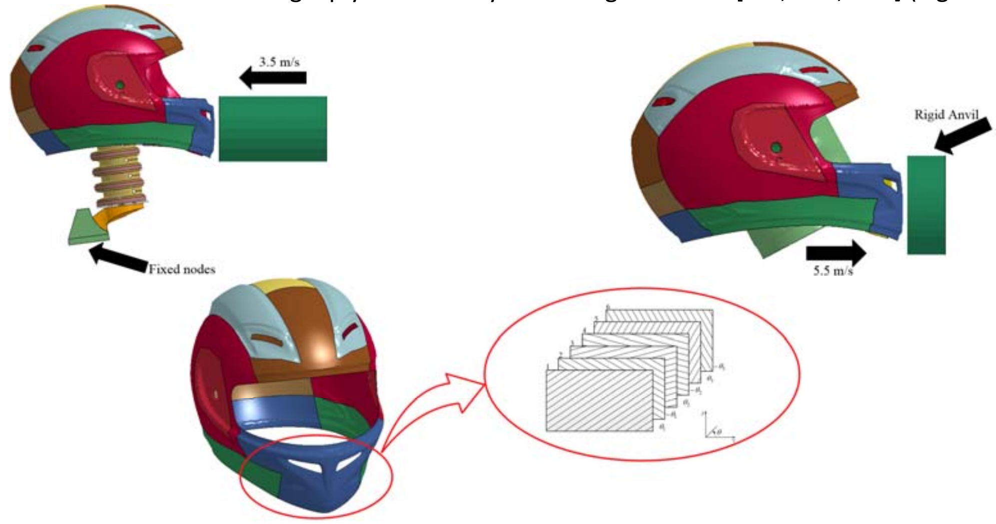

Fig. 1. Helmeted HYBRID III head-neck FE model (upper and left), FE model of the virtual impact test for validation of the chin bar of the helmet according to ECE 22.05 (upper and right), and the schematic view of the chin bar's ply configuration (lower).

* S. F. Khosroshahi is a PhD student of Aerospace Engineering in the department of Industrial Engineering of Padova University in Padova, Italy (+393440641676, siamak.farajzadehkhosroshai@unipd.it). M. Ghajari is a Lecturer in the Dyson School of Design Engineering at Imperial College London, UK. U.Galvanetto is Professor in the department of Industrial Engineering at University of Padova, Italy.

Iterative Computational Approach

A code has been developed in MATLAB, to modify the LS-Dyna input files, run the software and read the output, automatically. A database was generated for different ply configurations of the chin bar by considering θ_1, θ_2 and θ_3 as the variables, and the corresponding neck axial force as the output. Then all available triplets (θ_1, θ_2, θ_3) were listed in the order of increasing neck-force. Starting from the triplet providing the lowest neck force the ECE 22.05 test was virtually carried out: the optimal triplet was chosen as the one passing the ECE test with minimum neck force. The adopted methodology is shown in Figure 2.

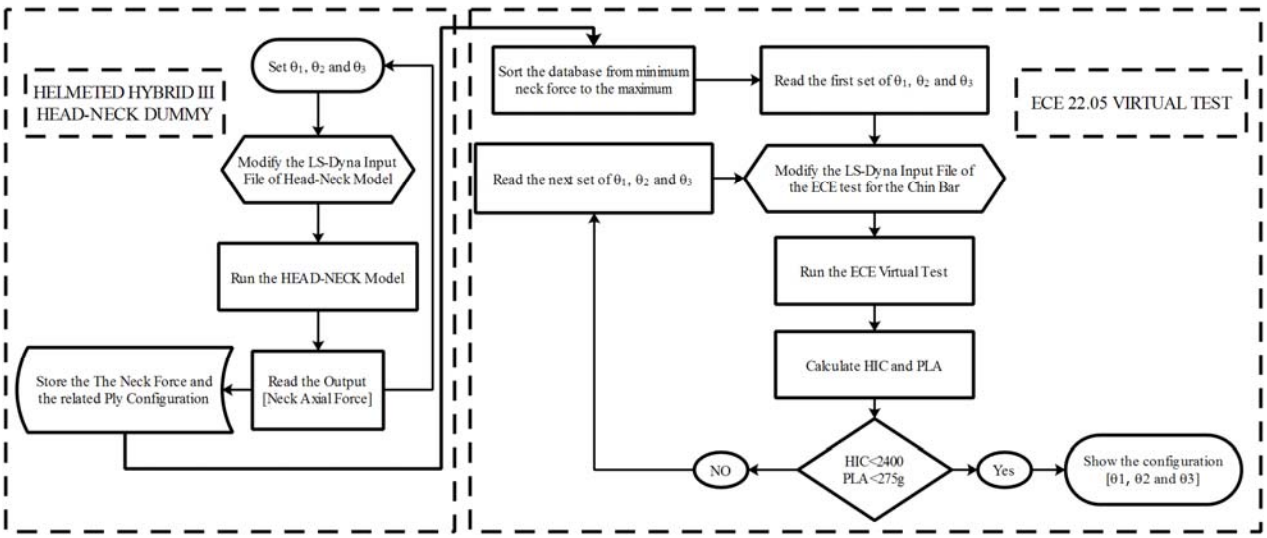

Fig. 2. The flowchart of the methodology which was used in the present work.

III. INITIAL FINDINGS

The developed code reported that the composite chin bar with configuration of *[(0)$_2$, (0)$_2$, (90)$_2$]* induced the lowest possible neck force but could not pass the ECE 22.05 requirements. The configuration which could pass the ECE 22.05 and induced the lowest possible neck force was *[(90)$_2$, (90)$_2$, (0)$_2$]*. Table I illustrates the output of the iterative approach for three cases of ply configuration.

TABLE I
RESULTS OF THE ITERATIVE SIMULATIONS FOR THREE DIFFERENT PLY CONFIGURATIONS

Ply Configuration	Neck Axial Force [N]	HIC	Peak Linear Acceleration [g]	ECE 22.05 Criterion
[(0)$_2$, (0)$_2$, (90)$_2$]	713.8 [Minimum]	936.8	290.4	Not passed
[(90)$_2$, (90)$_2$, (0)$_2$]	746.7	842.5	274.4	Passed
[±15, ±60, ±15]	1029.3 [Maximum]	Not Calculated	Not Calculated	Not checked

IV. DISCUSSION

The proposed approach was developed to optimise the composite chin bar of a full-face helmet to reduce the risk of BSF, which is one of the most common types of injury among motorcycle accidents but is not clearly addressed in standards [6]. Our results show that the developed approach could be successfully used to include the neck axial force, the main mechanism of BSF [5], in the design of a composite helmet's chin bar.

V. REFERENCES

[1] Chee C.P et al, ANZ JSurgery, 1991.
[2] Whyte T et al, JNeurotrauma, 2015.
[3] Cooter R.D et al, Proc. of Int. Motorcycle Safety Conference , 1990.
[4] Thibault L.E et al, Central Nervous System Trauma Research Status Report, 1985.
[5] McElhaney J.H et al, JNeurotrauma,1995.
[6] Gibson T.J et al, Australian Transport Safety Bureau Research and Analysis Report, 2007.
[7] ECE 22.05, E/ECE/324 & E/ECE/TRANS/505 Addendum 21, Regulation No. 22, Revision 4, 2002.
[8] Snell 2015, Snell Memorial Foundation, 2015.
[9] Ghajari M et al, J Crashwothiness, 2011.