Numerical Analysis of Bicycle Helmet Impacts using Biomechanical Metrics

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1) ABSTRACT

This study evaluates various safety aspects of standardized impacts that cyclist may suffer while wearing a bicycle helmet, by combining a partially validated finite element model of the cranio-cervical region and a newly developed commercial bicycle helmet model.

2) OBJECTIVES OF RESEARCH

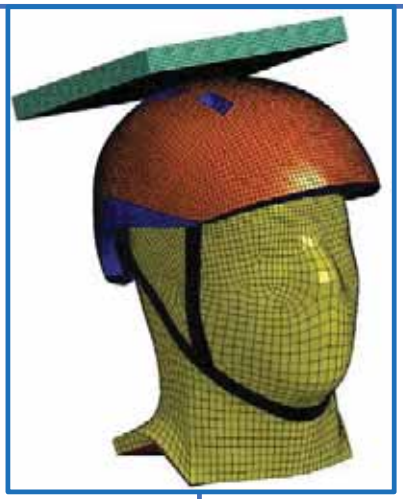
The objective of the research is to develop a Numerical Impact Model of bicycle helmets including a partially validated human FEA head in LS-DYNA to analyze the following parameters:

Biomechanical Metrics

- Peak Linear Acceleration (PLA)
- Gadd Severity Index (GSI)
- Head Injury Criterion (HIC15)
- 3 Ms Criterion (A3MS)
- 5 Ms Criterion (A5MS)
- Skull Fracture Probability

FEA Analyses on the head-helmet Biomechanical system

- Energy absorbed by the helmet
- Importance of the EPS Foam density
- Curves to assess the probability of injury based on impact speed



3) FEA DEVELOPMENT

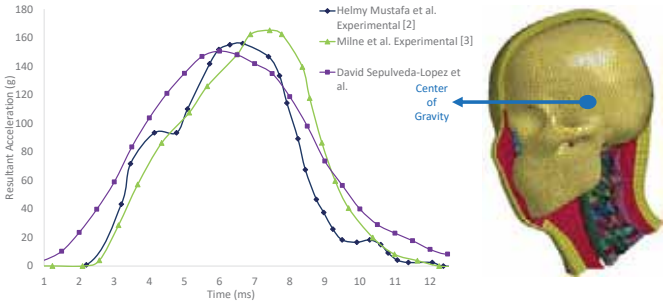
All the elements involved in an experimental impact are included in the simulation; the mesh includes the padding, chin strap, rear strap, shell, and EPS foam of the bicycle helmet, which is based on a helmet available on market.

Partially validated finite element model of the cranio-cervical region [1] developed the Japan Automobile Research Institute which includes brain, skull, skin, grey matter, brainstem….

Hexahedral and quadrilateral elements in the Helmet Mesh for convergence purposes.

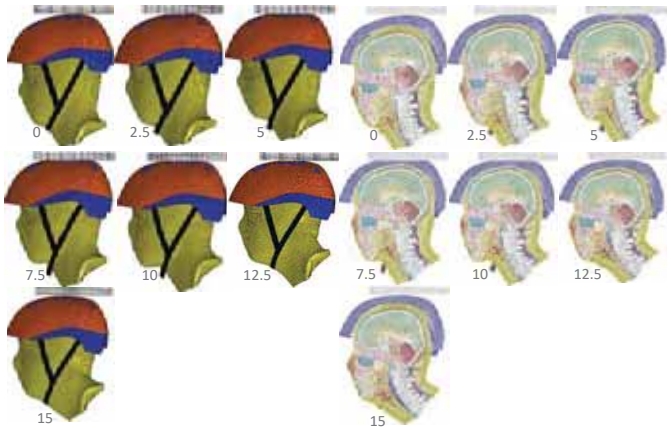
4) VALIDATION OF FEM MODEL

The results of this research and previous experimental studies was validated comparing the resultant acceleration of the Center of Gravity of the head with experimental studies:



EN 1078 Resultant Acceleration Comparison on Flat Anvil.

5) IMPACT SEQUENCE OF RESULTS

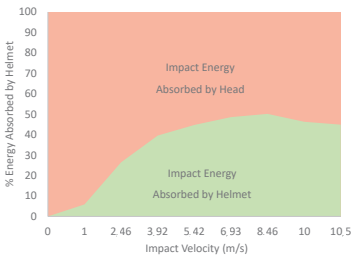


EN 1078 Flat Anvil Graphical Sequence Results (ms).

6) RESULTS OF BIOMECHANICAL METRICS (EN 1078 STANDARD)

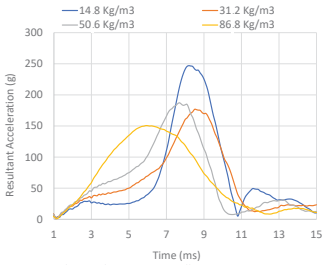
	FLAT ANVIL	CURBSTONE ANVIL
Peak Linear Acceleration (PLA)	75 % Concussion	50 % Concussion
Gadd Severity Index (GSI)	Serious Internal Head Injuries	NO Serious Internal Head Injuries
Head Injury Criterion (HIC15)	100 % Minor Injury 88 % Moderate Injury 49 % Serious Injury 15 % Severe Injury 2 % Critical Injury 0 % Maximum Injury	20 % Minor Injury 7 % Moderate Injury 3 % Serious Injury 0 % Severe Injury 0 % Critical Injury 0 % Maximum Injury
3 Ms Criterion (A3MS)	Does NOT Meet Requirements	Meets Requirements
5 Ms Criterion (A5MS)	Meets Requirements	Meets Requirements
Skull Fracture Probability	14.04 %	0.13 %

7) ENERGY ABSORBED BASED ON IMPACT SPEED



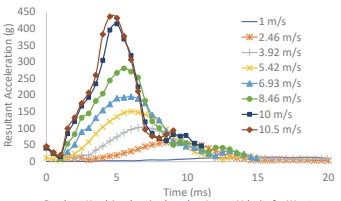
Energy Absorbed by Helmet and Head in Worst-Case Impacts.

8) INFLUENCE OF EPS FOAM DENSITY

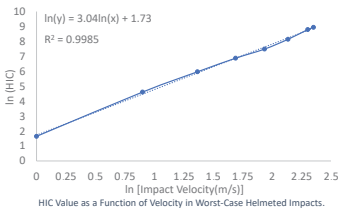


Influence of EPS Foams with different Densities in the Resultant Acceleration of the Head.

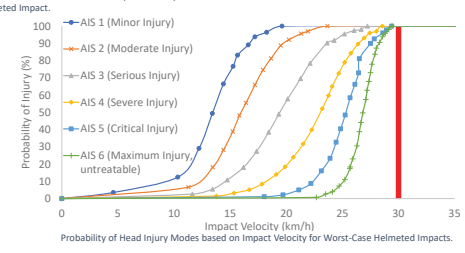
9) PROBABILITY OF INJURY BASED ON IMPACT SPEED



Resultant Head Acceleration based on Impact Velocity for Worst-Case Helmeted Impact.



HIC Value as a Function of Velocity in Worst-Case Helmeted Impacts.



Probability of Head Injury Modes based on Impact Velocity for Worst-Case Helmeted Impacts.

10) CONCLUSIONS

- Under European standard impact conditions (EN 1078) cyclists can suffer head injuries
- Under EN 1078 impact conditions the helmet can absorb 40 to 50 % of the total impact energy at speeds above 4 m/s
- A larger EPS foam density achieves a more distributed impact, with a lower HIC value and a lower maximum acceleration
- Minor injuries may occur at impact velocities of 10 km/h, serious injuries at 15 km/h, and severe injuries at 20 km/h. Fatal Injuries will very likely occur at impact speeds of 30 km/h and higher

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