How sensitive are different headform design parameters in oblique helmeted impacts?

Peter Halldin and Madelen Fahlstedt

I. INTRODUCTION

There are several initiatives around the world to design a new helmet test method mimicking a realistic angled/oblique accident situation [1-3]. A new test method for oblique impacts might need a new headform as the existing experimental headforms on the market were not designed for measurements of rotational kinematics. The aim of this study is to understand the influence of different parameters that effect the measured head kinematics in oblique helmet impacts.

II. METHODS

FE model of helmet and headform

LSDYNA is used for the simulations (Version 7.12). The helmet model is the same as used by Fahlstedt *et al*. [4]. The shell is modeled as linear elastic material using triangular elements. The EPS liner is modeled with crushable foam material MAT_BILKHU/DUBOIS_FOAM.

The FE model of the 50% Hybrid III (HIII) headform was based on a 2005 version from LSTC. The reason for using the old version of the HIII head was that the helmet was validated using that version of the headform.

Parametric study

The parameters altered in this study were:

- Rubber skin material – linear viscoelastic or rigid.
- Head Centre of Gravity (CG) – the X and Z CG position were altered ±1 cm from original positions.
- The mass was reduced and increased by 20% from the original mass of 4.38 kg.
- The MOI (I_{xx}=0.0198, I_{yy}=0.0187, and I_{zz}=0.0194) were all increased by 20% from the original values.
- The COF was altered 0.5–0.7 for the helmet-anvil contact and 0.15–0.5 for the head-helmet contact.
- The initial position was altered by rotating the head and helmet by ±10° around the X- and Y-axis.

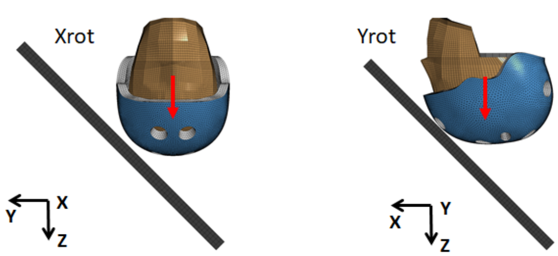


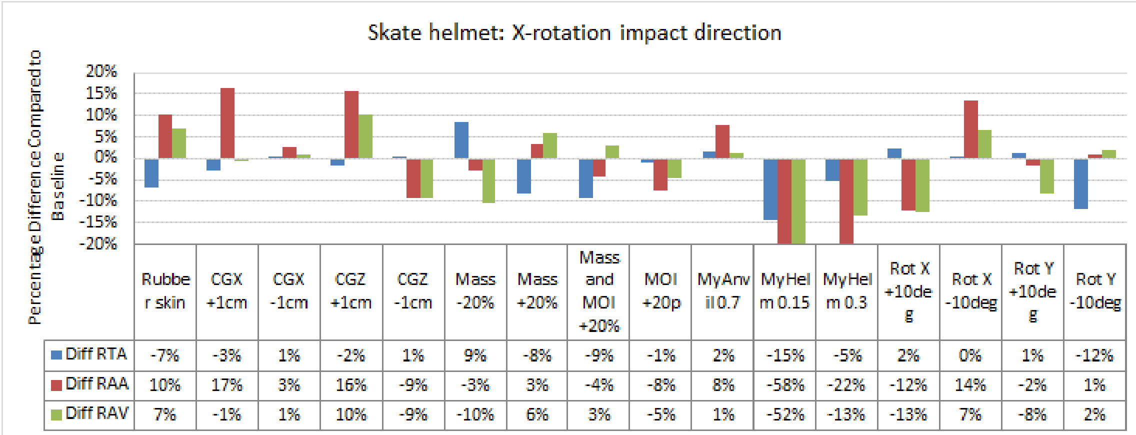
Fig. 1. Left: X rotation impact direction. Middle: Y rotation impact direction. Right: Maximum Resultant values computed for the basline models in Xrot and Yrot directions.

All simulations were performed for two impact situations (Xrot and Yrot) (Fig. 1). In total, 17 simulations were performed for each impact direction. The resultant translational acceleration (RTA), resultant angular acceleration (RAA) and resultant angular velocity (RAV) of the head were compared for each simulation. The baseline simulation had a COF between both head-helmet and helmet-anvil of 0.5, rigid scalp and unchanged CG, MOI and mass.

III. INITIAL FINDINGS

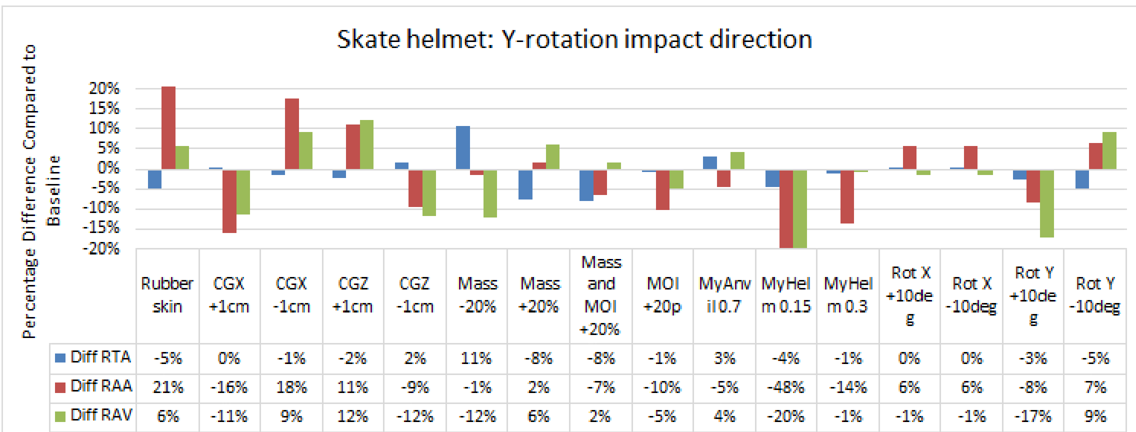
Figure 2 and Figure 3 show the percentage difference for each parameter compared to the baseline simulation for Xrot (peak RTA=180.9 g , RAA 7.7 krad/s, 28.0 rad/s) and Yrot (peak RTA=168.5 g , RAA 9.2 krad/s, 29.3 rad/s), respectively. The Rigid/rubber skin showed a minor change of the RTA and the RAV. The RAA showed a 21% change for the Yrot simulation, but this was mainly oscillations due to the elastic rubber. The shift of the CG in the X- and Z-direction did not affect the RTA. The shift in the X-direction affected the RAV by 9–11 % for the Yrot impacts. This is due to the fact that the moment arm from the CG and the impact point is changed. The shift in the Z-direction affected the RAV for both the Xrot and Yrot impacts by 9–12%. Reducing the mass of the head-form by 20% increased the RTA by 9–11% and reduced the RAV by 10–12%. Increasing the mass resulted in an opposite effect. Increasing the MOI by 20% did not affect the RTA, but reduced the RAA by 8–10% and the RAV by 5%. A decrease of the COF from 0.5 to 0.15 between the headform and the helmet changed the RAA and RAV significantly. Rotations of the head and helmet, by 10°, around the same axes as the main rotation in the impact resulted in the largest variations in the computed results.

P. Halldin (e-mail: peterh@kth.se; tel: +46739850061) is CSO at MIPS AB, Stockholm, Sweden, and also Assistant Professor at Division Neuronic Engineering, KTH Royal Institute of Technology, Stockholm, Sweden, where M. Fahlstedt is a Post Doc.



	Rubber skin	CGX +1cm	CGX -1cm	CGZ +1cm	CGZ -1cm	Mass -20%	Mass +20%	Mass and MOI +20%	MOI +20p	MyAnvil 0.7	MyHelm 0.15	MyHelm 0.3	Rot X +10deg	Rot X -10deg	Rot Y +10deg	Rot Y -10deg
Diff RTA	-7%	-3%	1%	-2%	1%	9%	-8%	-9%	-1%	2%	-15%	-5%	2%	0%	1%	-12%
Diff RAA	10%	17%	3%	16%	-9%	-3%	3%	-4%	-8%	8%	-58%	-22%	-12%	14%	-2%	1%
Diff RAV	7%	-1%	1%	10%	-9%	-10%	6%	3%	-5%	1%	-52%	-13%	-13%	7%	-8%	2%

Fig. 2. Simulation results fro the X-rotational impact. Results are the difference compared to the baseline results.



	Rubber skin	CGX +1cm	CGX -1cm	CGZ +1cm	CGZ -1cm	Mass -20%	Mass +20%	Mass and MOI +20%	MOI +20p	MyAnvil 0.7	MyHelm 0.15	MyHelm 0.3	Rot X +10deg	Rot X -10deg	Rot Y +10deg	Rot Y -10deg
Diff RTA	-5%	0%	-1%	-2%	2%	11%	-8%	-8%	-1%	3%	-4%	-1%	0%	0%	-3%	-5%
Diff RAA	21%	-16%	18%	11%	-9%	-1%	2%	-7%	-10%	-5%	-48%	-14%	6%	6%	-8%	7%
Diff RAV	6%	-11%	9%	12%	-12%	-12%	6%	2%	-5%	4%	-20%	-1%	-1%	-1%	-17%	9%

Fig. 3. Simulation results fro the Y-rotational impact. Results are the difference compared to the baseline results.

IV. DISCUSSION

This study was performed to give insight into the importance of different parameters that affect the measured headform kinematics in 45° oblique impacts. The main finding from this study is that all parameters studied seem to be of about the same importance. Therefore, when designing a test method for oblique impacts the headform inertia and CG are of the same importance as defining the COF and initial position of the headform in the test. The results presented here are limited to one impact velocity, one helmet model and two impact locations. These factors could influence the results and should be further investigated.

V. REFERENCES

[1] Bourdet, N., *et al.*, *Int J crashworthiness*, 2012.

[2] FIM Racing Homologation Programme for Helmets, 2017.

[3] Pang, T. Y., et al., *Int J Crashworthiness*, 2011.

[4] Fahlstedt, M., *et al.*, IRCOBI, 2016.

P. Halldin (e-mail: peterh@kth.se; tel: +46739850061) is CSO at MIPS AB, Stockholm, Sweden, and also Assistant Professor at Division Neuronic Engineering, KTH Royal Institute of Technology, Stockholm, Sweden, where M. Fahlstedt is a Post Doc.