A motion tracking technique to assess the kinematics of oblique impact

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1 INTRODUCTION

Oblique impact may cause of head trauma like diffuse axonal injuries and acute subdural hematoma. This paper focuses on the effect of oblique impact when wearing a bicycle helmet. Current helmet testing procedures only focus on measurements at the center of gravity of the headform. This information might help in predicting the expected injuries in the brain but it does not give any information about the kinematics of the head and the helmet that lead to those results. Such information could help in improving helmet designing and testing thus to reduce the magnitude of the variables that lead to traumatic brain injuries. Experiments with cadavers and dummies still leave the effect of the neck as an open subject while the strength that straps are tightened on the headform has been considered to increase its rotational acceleration. Furthermore, the concept against rotational acceleration that currently dominates the market is internal sliding technologies.

The questions that this paper addresses are: 1) How can we use motion tracking techniques to assess the kinematics of a helmeted head impacting an oblique anvil? 2) Does the presence of a neck affect the functionality of the straps during testing? 3) Should a neckform be added to emerge the technology of straps during tests against rotational acceleration? 4) How do internal sliding technologies affect the kinematics of the head during impact?

2 METHOD

During motion tracking, predefined patterns or signals are detected in a series of video frames using image analysis techniques. The derived data can give information about the kinematics of that object. In our case the freeware “Tracker” was used to track the motion of certain patterns on the head and helmets. All patterns on the head were on the same plane as well as the patterns on the helmet with some deviations during the impact due to the slide rotation of the system. These deviations can be considered neglectable since the impact is almost perfectly symmetrical during the 10 ms of its duration as shown by the graph of the angular velocity measured around X and Z axes during the impact (Figure 1). Furthermore for rotation of less than 15 degrees around any random axis on the XZ plane, the error in measurement is also neglectable as shown in the graphs of figures 2-3 for error between the seen angle for rotation and the initial angle of the tracked line.

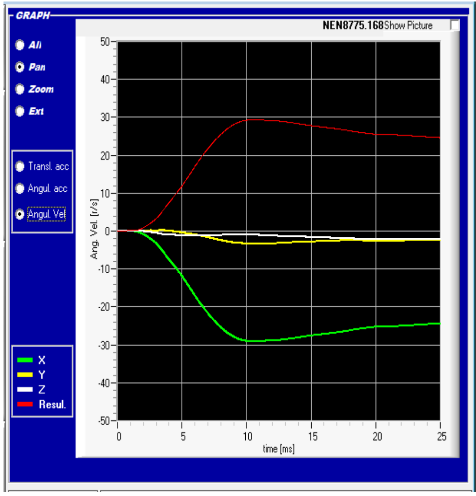

Figure 1: Angular velocity measured during the impact. Neglectable in Y and Z axes

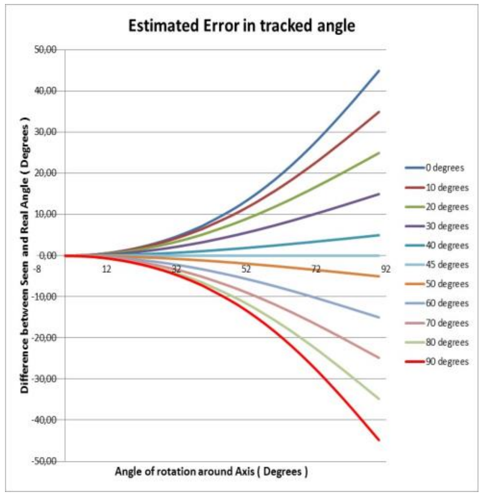

Figure 2: Error in seen angle of a horizontal tracking line if 0°-90° inclination of axis of rotation is assumed

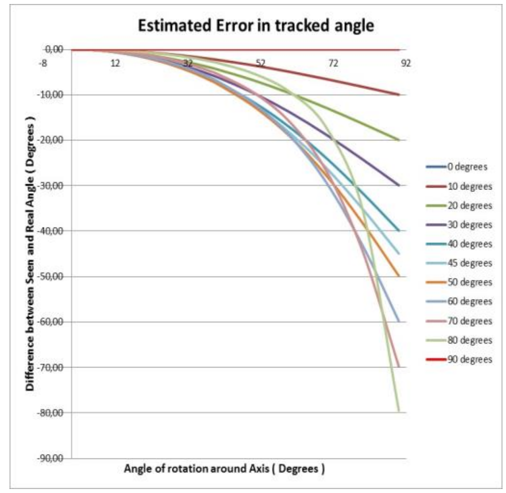

Figure 3: Error in seen angle of a 45° inclined tracking line if 0°-90° inclination of axis of rotation is assumed

The technique is not limited to the pattern that will be used. The outputs of the technique were the relative angle between the head and the helmet, the rotation and the angular velocity of the head and the helmet. A series of fifteen (15) experiments were performed to examine the kinematics of a helmeted head during impact. The set-up and testing process that were used were aligned with the work of [[1]]. HIII was chosen for its biofidelic moment of inertia around the tested axis of rotation [[2]]. A system of nine accelerometers was mounted inside the test head according to the 3-2-2-2 method described by Padgaonkar et al [**Error! Reference source not found.**]. To assess the effect of the neck on the kinematics of the headform due to the straps, a cylindrical, lightweight cylinder was added to the headform's base to simulate a simple neckform. To assess the effect of a mechanisms against rotational acceleration on the kinematics of the headform, a commercially available product was used (MIPS). Three different LAZER helmet models were tested. All experiments were recorded by a Photron Fastcam Mini AX 100 high speed camera with a frame rate of 3600 fps.

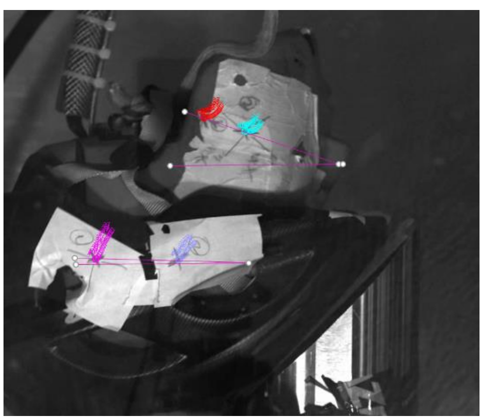

Figure 6: Impact without neckform

Figure 7: Impact with neckform

3 FINDINGS

Results showed that the observed impacts can be broken down into four (4) different stages (Figures 8-9). During the first stage the helmet impacts the anvil but the head keeps its tranlational motion. During stage 2 the head impacts the internal surface of the helmet and starts rotating. At stage 3 we reach the maximum angle between the helmet and the head after which the helmet decelerates and the head keeps rotating with an almost constant pace. As far as the neckform is concerned, results showed that its existence did not affect the kinematics of the headform due to the restrictions created by the straps. This is probably a result of the first stage of the impact during which enough space between the neck and the straps is created for the head to move freely as if straps do not exist. Finally, the existence of MIPS reduced the rotation of the headform up to 65%. The angular velocity of the headform measured using the motion tracking technique was validated by comparing it with the angular velocity measured by the accelerometers of the headform. As shown by the graphs the results match and thus the technique can also be used to measure the angular velocity of the helmet.

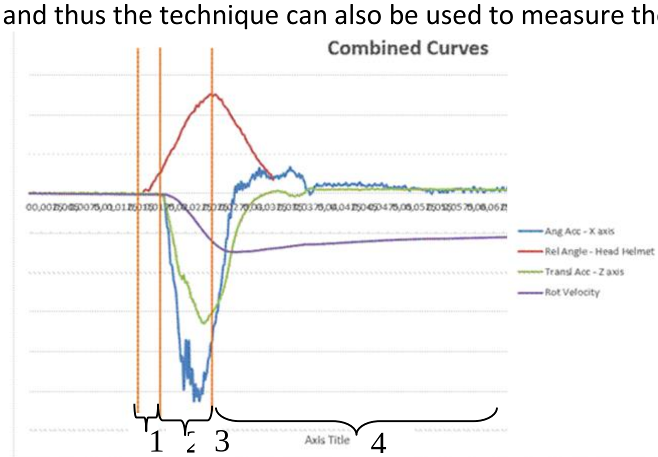

Figure 8: Example of motion profile pattern stages. Y axis' scaled to ease the comparison between curves

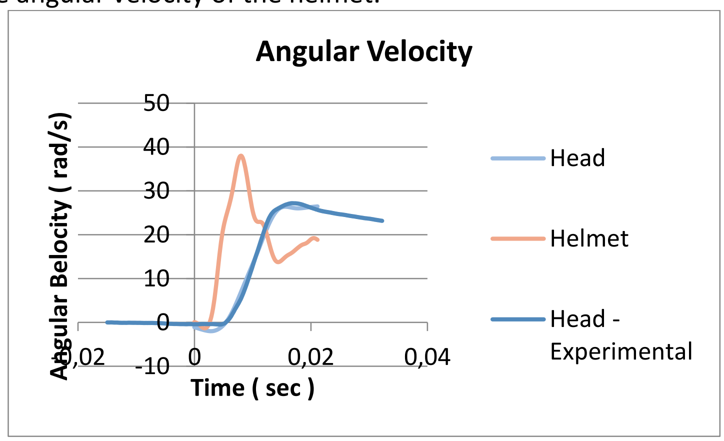

Figure 9: Example of angular velocity as measured using motion tracking and the accelerometers

4 CONCLUSIONS

This research examined the use of 2D motion tracking to gain insight in head and helmet kinematics during oblique impact. The technique is accurate and can give valuable information towards assessing the kinematics of an impacting helmet on an anvil. A pattern was defined for a helmet impacting an anvil that seems to be repeated throughout all impacts. The existence of a neck on a headform has a neglectable, if any, influence to the functionality of the straps as part of the helmet's technology against rotational acceleration. MIPS technology contributed to reduce the relative motion between the head and the helmet and rotational acceleration.

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