Development of Innovative 6aω Head Instrumentation Fixture for the Hybrid III 50th Percentile Male

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In motor vehicle crash conditions it is important to assess head-neck loads as well as potential for Traumatic Brain Injury (TBI) to understand specific kinematics that result in injury. Specifically, the ability to accurately measure six degrees of freedom (6 DOF) head kinematics leading to insights about the causes of debilitating or fatal head and brain injuries in car crash scenarios. This study utilized a measurement system consisting of six accelerometers and three angular rate sensors in a coplanar configuration (6aω) to accurately measure 6 DOF kinematics in high-magnitude head impacts. The 6aω coplanar configuration offers advantages of computational speed and accuracy, as it allows angular acceleration to be calculated with algebraic equations, angular velocity to be measured directly, and angular displacement to be obtained with single numerical integration. This methodology minimizes the use of error-producing numerical integration and differentiation that is seen in traditional methods.

During impact scenarios an anthropomorphic test device (ATD) collects essential data to determine possible injuries. Unfortunately, vibrational content also seen by the instrumentation can result in data analysis error. 86 hammer and pneumatic ram impact tests in several locations of the Hybrid III 50th Male standard and nine accelerometers array package (NAAP) heads were completed to record natural frequency response. The developed fixture required a first natural frequency not within the range of frequency responses seen by the ATD to avoid vibrational noise in data collection. From testing, the heads did not have frequency content in the 4000-level Hz range defining the fixture design constraint.

Applying the ATD frequency results, a 6aω coplanar fixture for the Hybrid III 50th Male standard head was developed to eliminate the use of expensive NAAP heads that possibly violate rigid body kinematic theory due to skull deformation. Frequency content of the proposed design was determined via ANSYS modal analysis simulations. Natural frequencies for initial designs were greater for aluminum compared to steel, due to lower material density, suggesting production feasibility of an aluminum fixture to also obtain reduced fixture weight. The finalized design presents a first natural frequency of 4246.3 Hz, which met fixture design requirements. The proposed fixture also met design constraints, such as low fixture mass (61.025 grams), fixture center of gravity (CG) alignment with head CG, ease of fastening and a modular design that incorporates standard instrumentation blocks.

This fixture was tested against nine accelerometers installed on a previously validated tetrahedron fixture (tNAAP) during severe impact scenarios. Repetitive tests were conducted using combinations of neck fixture, angle and impact speed for a comprehensive test matrix. The average normalized root mean square deviation (NRMSD) between angular acceleration calculated from the 6aω coplanar configuration and tNAAP was less than 5% for all impact tests, indicating the proposed 6aω coplanar fixture is capable of accurately mimicking the accuracy of the angular acceleration in the tNAAP scheme. Furthermore, the 6aω coplanar configuration has the additional ability to minimize vibrational noise and the use of error-producing numerical methods, thus providing potential improvement in the assessment of TBI and head-neck injuries.