World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:15, No:06, 2021

Correlation of Unsuited and Suited 5th Female Hybrid III Anthropometric Test Device Model under Multi-Axial Simulated Orion Abort and Landing Conditions

Authors : Christian J. Kennett, Mark A. Baldwin

Abstract : As several companies are working towards returning American astronauts back to space on US-made spacecraft, NASA developed a human flight certification-by-test and analysis approach due to the cost-prohibitive nature of extensive testing. This process relies heavily on the quality of analytical models to accurately predict crew injury potential specific to each spacecraft and under dynamic environments not tested. As the prime contractor on the Orion spacecraft, Lockheed Martin was tasked with quantifying the correlation of analytical anthropometric test devices (ATDs), also known as crash test dummies, against test measurements under representative impact conditions. Multiple dynamic impact sled tests were conducted to characterize Hybrid III 5th ATD lumbar, head, and neck responses with and without a modified shuttle-era advanced crew escape suit (ACES) under simulated Orion landing and abort conditions. Each ATD was restrained via a 5-point harness in a mockup Orion seat fixed to a dynamic impact sled at the Wright Patterson Air Force Base (WPAFB) Biodynamics Laboratory in the horizontal impact accelerator (HIA). ATDs were subject to multiple impact magnitudes, half-sine pulse rise times, and XZ - 'eyeballs out/down' or Z-axis 'eyeballs down' orientations for landing or an X-axis 'eyeballs in' orientation for abort. Several helmet constraint devices were evaluated during suited testing. Unique finite element models (FEMs) were developed of the unsuited and suited sled test configurations using an analytical 5th ATD model developed by LSTC (Livermore, CA) and deformable representations of the seat, suit, helmet constraint countermeasures, and body restraints. Explicit FE analyses were conducted using the non-linear solver LS-DYNA. Head linear and rotational acceleration, head rotational velocity, upper neck force and moment, and lumbar force time histories were compared between test and analysis using the enhanced error assessment of response time histories (EEARTH) composite score index. The EEARTH rating paired with the correlation and analysis (CORA) corridor rating provided a composite ISO score that was used to asses model correlation accuracy. NASA occupant protection subject matter experts established an ISO score of 0.5 or greater as the minimum expectation for correlating analytical and experimental ATD responses. Unsuited 5th ATD head X, Z, and resultant linear accelerations, head Y rotational accelerations and velocities, neck X and Z forces, and lumbar Z forces all showed consistent ISO scores above 0.5 in the XZ impact orientation, regardless of peak g-level or rise time. Upper neck Y moments were near or above the 0.5 score for most of the XZ cases. Similar trends were found in the XZ and Z-axis suited tests despite the addition of several different countermeasures for restraining the helmet. For the X-axis 'eyeballs in' loading direction, only resultant head linear acceleration and lumbar Z-axis force produced ISO scores above 0.5 whether unsuited or suited. The analytical LSTC 5th ATD model showed good correlation across multiple head, neck, and lumbar responses in both the unsuited and suited configurations when loaded in the XZ 'eyeballs out/down' direction. Upper neck moments were consistently the most difficult to predict, regardless of impact direction or test configuration.

Keywords : impact biomechanics, manned spaceflight, model correlation, multi-axial loading
Conference Title : ICCB 2021 : International Conference on Computational Biomechanics
Conference Location : New York, United States
Conference Dates : June 03-04, 2021