Initial Evaluation of ATDs for Testing of Obliquely Oriented Seats

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Transport category passenger seats continue to evolve, with the latest development being a partially enclosed (pod) seat that is oriented obliquely with respect to the aircraft centerline in what is commonly referred to as a “herringbone” arrangement. This orientation exceeds the standard 18 degrees of a forward facing seat, but is not purely side facing. The Anthropomorphic Test Devices (ATDs) used in aviation impact testing are designed to perform in a relatively confined environment i.e. automotive interiors, and be loaded in forward, sideward, and rearward directions. Oblique seats present a novel loading environment that may permit significant flailing and have an off-axis loading direction. An ATD capable of evaluating injury risks due to combined forward and lateral loading is necessary.

The Civil Aerospace Medical Institute (CAMI) conducted a project to evaluate some of the current ATD’s for potential use in oblique seat testing. The ATDs evaluated were those used in aviation crash testing, including the Hybrid II, FAA-Hybrid III, and ES-2re, as well as the THOR ATD, an advanced research dummy. The evaluation methods included impact tests, detailed structural examination, and computer modeling. The ES-2re, a dummy designed for lateral loading, was excluded from the impact tests due to concerns over permanent damage to rib sliders and abdomen during forward flailing. Its performance instead was evaluated numerically in a separate project. The THOR ATD is under development in the automotive community as a potential replacement for the Hybrid III for frontal crash tests. It has an extensive array of instrumentation, particularly in the thoracic and abdominal regions. While this instrumentation would greatly increase the types of injuries which could be predicted, it was excluded after visual inspection of the internal structures revealed that extensive damage to the instrumentation and the lumbar spine element would likely occur during any test that induced lateral or forward flexion at the lumbar. The Hybrid II was selected for the initial tests to bound the likely occupant kinematics. For the second phase of tests, the FAA-Hybrid III was selected because of its expanded set of instrumentation which allows a greater ability to measure potential injury risks.

At CAMI’s request, the SAE Seat Committee conducted an industry survey to determine typical oblique seat configurations. Based on the information received, a rigid couch was configured to reflect two seat configurations and permit orientation at thirty and forty-five degrees with respect to the aircraft center line. The first configuration emulates a scenario where an occupant is seated next to an interior feature that restricts the motion of the legs and the pelvis but not the upper torso. The second configuration emulates a scenario where an occupant is seated next to an interior feature that is rigid below the armrest level and very flexible above it. Tests were completed using the deceleration sled with the 16 G, 44 feet per second impact severity defined in 14 CFR 25.562. Specialized instrumentation was employed in the FAA Hybrid III to measure the angular velocity of each major body segment, and derive the relative orientation for each segment throughout the impact. Current side facing research findings indicate that spinal mis-alignment can lead to a lowered tolerance for spinal loading, so the ability to quantify this mis-alignment may be necessary to predict injuries.

This test series demonstrated that there are many potential injury risks that can occur when an occupant flails in an oblique orientation. Potential injuries include fractures to the sternum, pelvis, and ribs due to contact with a structure, leg fractures due to inertial loading, and head and neck injuries due to either direct contact or inertial loading. This is essentially a combination of the risks of both a purely side facing occupant and a purely forward facing occupant. The fully instrumented FAA Hybrid III was able to measure parameters that can be used to predict some of the potential injuries and of the available dummies is the best choice for oblique seat research tests. A follow-on study funded by the FAA is being conducted by the Medical College of Wisconsin (MCW) in order to determine what specific injuries occur in these oblique orientations and develop injury criteria.