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Development and Simulation of Calibration tests of Multibody Head-neck Models for the Hybrid-II and Hybrid-III ATDs

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EXTENDED ABSTRACT

1 Introduction

Anthropomorphic test devices (ATDs) have been relevant tools in certification tests and research for the transportation systems, and consequent reduction of accident's fatalities and improvements of transport safety. These devices, which simulate the human body in terms of mass, dimensions and kinematic response, are equipped with instrumentation that allows obtaining the necessary data to assess the crashworthiness of seats and occupants responses in specific test scenarios and thus determine their compliance with the safety requirements. Hybrid-II and Hybrid-III are two of the most widely used ATDs. Hybrid-III was developed in the 1970s by General Motors in the version of the 50th percentile adult male [1]. The major improvements of Hybrid-III regarding its predecessor, Hybrid-II, are the more accurate biomechanical responses of several body parts, especially the neck, that has become equipped with a transducer that allows the evaluation of axial and shear loads, and moment about the occipital condyle, while with Hybrid-II the risk of injury in the neck cannot be assessed [2]. However, Hybrid-II has a better instrumentation for measuring compressive loads of the lumbar spine, being therefore frequently used in aerospace safety applications [3]. The lumbar spine of the Hybrid-III has been modified in the development of newer FAA-Hybrid-III ATD, viable for aerospace testing.

In order to ensure that the ATD produce the expected biomechanical response, the US code of Federal Regulations requires calibration tests to be carried out on various components of the crash test dummies approved for transport safety assessment tests [4]. In this work are developed multibody (MBD) numerical models of the head-neck assembly of the Hybrid-II and Hybrid-III ATDs, depicted respectively in figures 1a and 1c. The validation of the numerical models is verified through the correlation between the values stated in the standards and the values obtained in the simulation of head and neck calibration tests.

2 Numerical model and calibration tests

In this study, numerical models have been developed and analyzed using the commercial MSC Adams software. The head model of each dummy consists of a rigid body with the mass and inertia properties of the corresponding ATD [5, 6].

The neck of the Hybrid-II MBD model is composed of two rigid bodies connected to the head by a torsional spring, and linked together by a second torsional spring, located in the center of the neck, equidistant between the two rigid bodies, as depicted in figure 1b. The damping and stiffness values were adjusted in order to present the neck kinematic response defined by the standard. The neck of the Hybrid-III, depicted in figures 1c and 1d, is made up of five rigid bodies with the mass and inertia properties of the three aluminum disks and two mounting plates that compose this part of the dummy. Between the discs, non-linear torsion springs were introduced to simulate the bending characteristics of the elastomer in which the aluminum discs are molded. These springs are not centered with the neck, but displaced in the anterior posterior direction, in order to simulate the uneven behavior of the neck in flexion and extension. A fifth torsional spring was introduced at the location of the occipital condyle.

a) b) c) d)

Figure 1: Head-neck assemblies: a) Hybrid-II ATD; b) Hybrid-II MBD model; c) Hybrid-III ATD; d) Hybrid-III MBD model

The head calibration of ATD consists of a drop test in which the head falls from a defined height with the aim of measuring its acceleration when the head impacts a rigid plane. In the case of the Hybrid-II, the standard defines that the head is dropped from a height of 254 mm, and the measured acceleration must lie between 210 and 260 G. In the case of the Hybrid-III, the dropping height must be 376 mm, as represented in figure 2a, and the acceleration peak should be between 225 and 275 G.

The neck calibration test consists of evaluating the rotation of the head relative to a fixed plane of the neck after the impact of a pendulum on an energy-absorbing structure, as depicted in figure 2b. The maximum velocity that the pendulum must reach in each test, as well as the pendulum deceleration profile after impact, are specified in the standard. During the Hybrid-II calibration, only neck flexion is evaluated, while for the calibration of Hybrid-III, both flexion and extension are tested. In the case of the Hybrid-III, the standard also provides specifications for the calibration of the maximum moment measured at the occipital condyle.

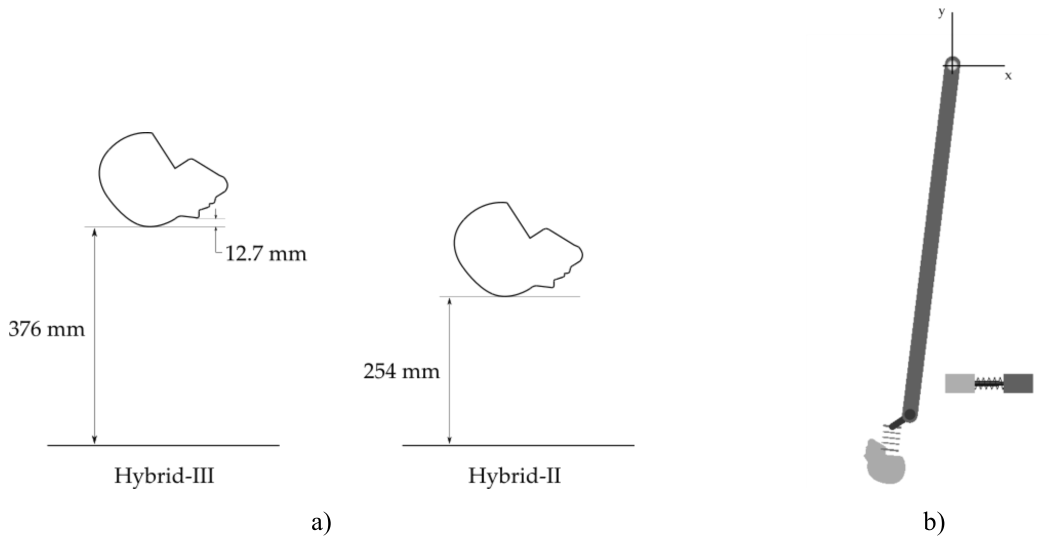

Figure 2: Calibration tests: a) Head drop test; b) Head-neck assembly for flexion/extension pendulum test

3 Results and Discussion

The numerical analysis have been performed to simulate the calibration tests for the head and neck assemblies of Hybrid II and Hybrid III presented a good agreement between the computed results and the values specified in Part 572, Subpart B and Subpart E. The computed acceleration for the Hybrid III head was 259 G, while obtained the peak acceleration of the Hybrid II head was close the upper limit of 260 G. The neck maximum flexion of the Hybrid-III neck was within the 64° and 78° range defined by the performance specifications. The simulation of the Hybrid III extension pendulum test was also in compliance with the requirements, as the maximum rotation of the head was within the 81° and 106° range .With both numerical MBD models of the Hybrid-III and Hybrid-II head and neck assembly developed, and the models calibrated by the regulatory certification for approval testing, the models can now be utilized for reconstruction of aircraft occupant impact responses, such as the row-to-row or bulkhead seating, as well as a tool for certification-by-analysis procedure related to aircraft cabin crashworthiness.

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