BioRID FE model positioning without predefined physical reference points

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I. INTRODUCTION

Advanced simulation techniques (e.g. Finite Element (FE) modelling) offer an unparalleled opportunity for vehicle safety assessment. Vehicle manufacturers have long embraced simulation techniques in the vehicle design process. The maturity of these tools opens up the possibility of expanding vehicle assessment scenarios via simulation in a manner that complements physical crash tests. However, this step requires the development of tools and procedures needed for appropriate model setup. Since there is the possibility that future virtual assessment efforts may involve occupant models that don't have a physical analog (e.g. occupant models of various anthropometries), there is a need for a robust and repeatable occupant model positioning procedure that does not rely on a-priori positioning measurements from a physical experiment.

This study uses the BioRID positioning procedure from the Insurance Institute for Highway Safety's (IIHS) rear impact tests as a test case to develop a model positioning procedure that can be used when the target H-point location is unknown. The main positioning steps in IIHS's physical tests with the BioRID are: adapt the vehicle seat to the mounting requirements for the test; position a H-Point machine and a Head Restraint Measuring Device (HRMD) on the seat to take reference measurements and to establish the angle of the seatback for the test; and then position the BioRID dummy using the reference points from those previous devices [1]. Commercial tools to replicate this process in a simulated environment are available, however they mostly focus on importing the reference points obtained from a physical measurement and forcing the dummy model into that position [2-3]. Typically, the goal is to position the BioRID computational model by prescribing its motion to match the H-Point location and the distance between the head and head restraint, as these reference measurements have the potential to affect the results in a rear impact simulation.

The goal of this short communication is to describe a novel procedure to position a BioRID FE dummy into a vehicle seat without using a predefined known location for the dummy's reference points. This method was refined and validated against positioning measurements from IIHS's rear impact BioRID tests.

II. METHODS

For this endeavour, a BioRID FE model, together with a collection of FE seats with physical counterparts, was exercised in multiple positioning trials with the LS-DYNA solver in order to achieve the procedure that resulted in the positioning location closest to the matching seats from the IIHS tests. The seats came from publicly available projects, vehicle manufacturers and professional FE development houses. The chosen reference coordinate system was the Orientation System 2 defined in SAE J211-1, with X pointing backwards with respect to the seat.

Pre-position - Since this positioning process seeks to achieve a consistent position without known reference, a series of trial positioning simulations was conducted with the BioRID starting at various positions to check the sensitivity to pre-position. The final results showed a sensitivity to dummy's initial position, thus a method for having a uniform starting location was developed. This was based on an iterative de-penetration without shape deformation of the dummy with respect to the seat structure using the preprocessor PRIMER from the Oasys software suite. This starts with the dummy's H-Point located at the seat recliner point and then iteratively displacing the dummy, employing PRIMER's commands *orient* and *contact* while selecting the dummy and seat parts.

Position - The positioning procedure was inspired by the IIHS's physical method where the dummy is settled on the seat and iteratively pushed into it until the desired location and equilibrium are reached. After several trial iterations, the final version of the procedure involved applying a 0.5 G acceleration in the horizontal direction

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using the keyword *BOUNDARY_PRESCRIBED_MOTION_RIGID on the head centre of gravity (CG), the first thoracic vertebra (T1) and the H-Point of the BioRID model. Additionally, it was connected to a *SENSOR set of keywords that tracked the contact force between the dummy and the seatback foam, and it was disconnected when the measurement reached the threshold of 50 N. The dummy was consecutively allowed to reach equilibrium. Some other conditions applied to the model were *LOAD_BODY_Z representing gravity, the head, T1, H-Point, and knees' displacement was constrained in the Y-axis and a 0.02 constant global damping coefficient was added. The simulation process lasted 400 ms, which was sufficient time for the model to reach equilibrium.

Comparison to IIHS positioning results - To evaluate the simulation results, the final dummy position was compared with the IIHS reference data obtained for the specific makes and models of the simulated seats. In IIHS's tests the H-Point machine and the HRMD were positioned, and the reference points were adopted to position the BioRID physical dummy [1]. Those physical positioning results were then compared to the simulation positions, via the following measurements: the X and Z location of the head CG and H-Point; the knee-to-knee Y-axis distance; and the Y-axis angle of the head, pelvis and femurs.

III. INITIAL FINDINGS

After several iterations, and varying the threshold values for the contact force sensor, the optimal one was chosen. The final simulation parameters were selected when the differences between the simulation and experimental results were minimised in absolute terms across the collection of seats. This comparison can be seen in Fig. 1. In addition to the physical position reference data, some of these seats had a H-Point location specified on the model. This was also compared to the H-point location achieved in the unguided positioning simulations, noted as (FEM) in Fig. 1.

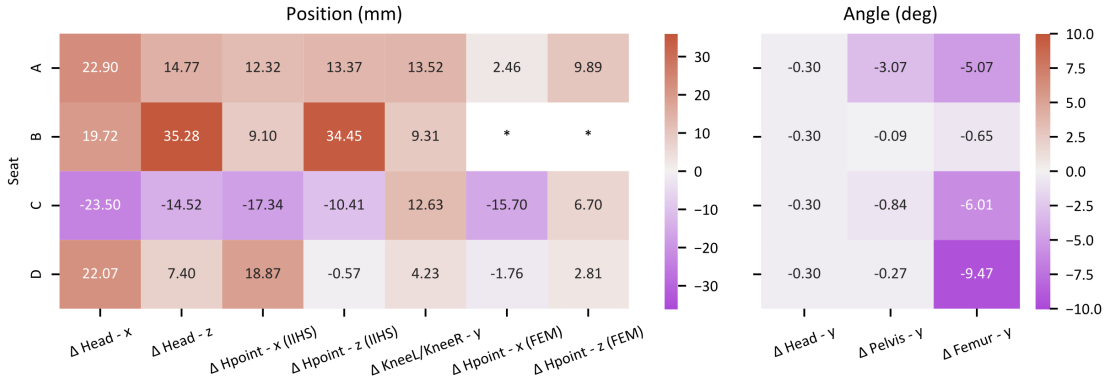

Fig. 1. BioRID positioning simulation results compared to IIHS tests. (*Data were not available.)

IV. DISCUSSION

This procedure allows modelers to perform occupant model positioning in the absence of a physical dummy, H-point machine, or HRMD to use as a reference. It is applicable with a certain level of autonomy since the user does not need to re-adapt their simulation conditions to match the physical results. This method relies solely on the characteristics of the FE seat and the occupant model, facilitating use with occupant models that do not have physical analogs with physical reference measurements (e.g. occupant models of different anthropometries).

This method comes with some known limitations, such as having differences in the location of reference points with respect to the physical matched seat results, and in certain cases these are larger than typical protocol limits (±10 mm for displacement and ±1° in rotation in the IIHS protocol) [1]. It must also be considered that all the seats were positioned to match reference measurements from IIHS's rear impact tests. A potential next step could be to check this method with different dummies and seats to evaluate the robustness of the procedure, and refine it accordingly.

V. REFERENCES

[1] IIHS, Vehicle Seat/Head Restraint Evaluation Protocol, Dynamic Criteria (Version VI), 2020.
[2] Oasys Ltd, PRIMER Manual, Version 20.1, 2023.
[3] Oasys Ltd, Oasys PRIMER, Training Course, 2012.