Assessing the Accuracy of Surrogate Child Restraint Seat Models in Frontal Impact Simulations

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Introduction

Creating a finite element (FE) model of a child restraint seat (CRS) that replicates the real-life counterpart requires numerous separate parts, materials, and hundreds of components, all of which must be considered. The process of building a detailed CRS model is time-consuming and complex. Therefore, using a simpler surrogate model that mimics the shape and weight of the real CRS could streamline the process of setting up simulations or having to develop detailed CRS designs.

Objective

The goal of this study was to determine whether simpler surrogate models of CRSs can accurately represent actual CRSs in FE simulations.

Methodology:

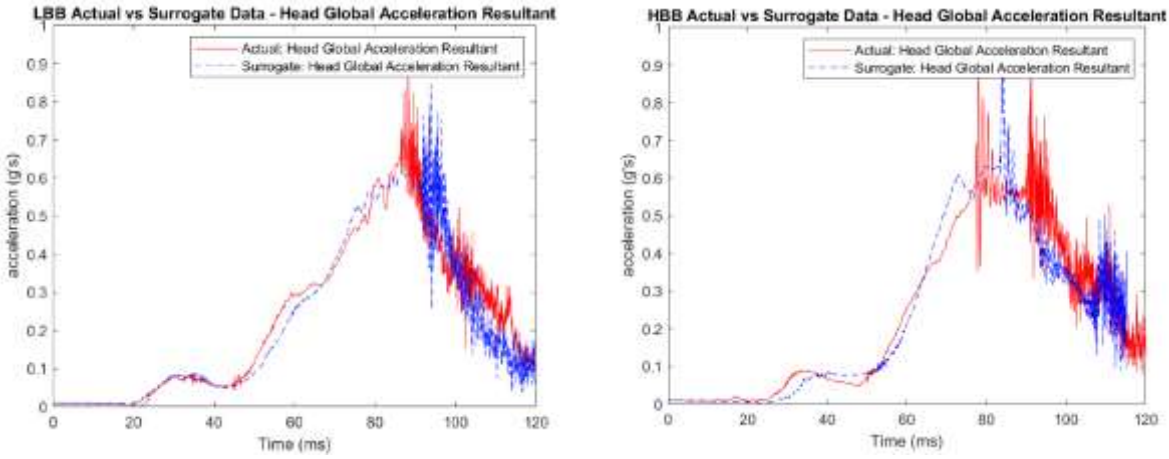
The PIPER 6YO pediatric human body model was restrained in a low-back booster (LBB) and a high-back booster (HBB) CRS on the FMVSS 213 test bench using a 3-point lap-shoulder belt. CRSs were modeled using deformable polypropylene plastic material properties. The environment was subjected to an FMVSS 213 frontal impact. For both CRS types, identical positioning and contact points for the PIPER model, and weights of the CRSs were ensured for the surrogate and actual CRS models. Four simulations (2 LBB + 2 HBB) were run using LS-Dyna R12.0.0. Kinematic and kinetic data including head, chest, and pelvis accelerations, upper neck, lower neck, and lumbar loads and moments, chest deflection, and head excursion were extracted from the PIPER model, filtered as per SAE J-211 conventions, and compared across conditions.

Similarity of the data trends between surrogate and actual CRS models was assessed using the Pearson Correlation Coefficient (PCC). A PCC closer to +1 indicated that the surrogate model closely matched the actual CRS model.

Results:

Comparison of the data for the LBB CRS models (both surrogate and actual) revealed strong correlations, with 9 out of 13 parameters (approximately 70%) showing a PCC of 0.7 or higher. This indicates a strong agreement between the surrogate and actual models.

For the HBB CRS models, the correlation was weaker, with some PCC values approaching zero or negative. However, 5 out of 13 parameters (nearly 40%) had a PCC greater than 0.7, indicating a moderate correlation between the surrogate and actual HBB CRS models.



The comparison of resultant head acceleration graphs for both LBB and HBB CRS configurations displayed highly similar trends, with PCC values of 0.96 for LBB and 0.95 for HBB, further supporting the potential of surrogate models for these CRS types.

Conclusions:

The PIPER model demonstrated similar kinematic and kinetic behavior in both the surrogate and actual LBB CRS configurations, confirming the viability of the surrogate model as a reliable alternative for simulations. Although the HBB models showed moderate correlation, refinements to the surrogate model, such as adding more components or aligning the setup more closely with the actual CRS, could improve the accuracy. The increased complexity of setting up the HBB model was acknowledged, though it still required less time than building a full CRS model. This study supports the use of surrogate models as a practical and time-efficient alternative in CRS simulations.