Study of model validation method for Rear-impact Virtual Testing

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I. INTRODUCTION

A study [1] revealed that many recent vehicles receive a good score in rear-impact neck injury assessments, yet there are still claims in insurance data. To gain more injury mitigation in the field it is necessary to consider a wide range of occupant size, gender, postures and seat positions, but currently only one size occupant is used in assessments: the anthropometric test device (ATD) “BioRID-II”. Therefore, a recent trend in assessments has been to introduce virtual testing (VT) to better account for the variations seen in real-world scenarios.

The Insurance Institute for Highway Safety (IIHS) has announced the introduction of VT in rear-impact whiplash injury assessment as a first pilot case. In VT, it is important that the model used is reliable. In this study, the model validation requirements for rear-impact were studied by considering test variations between in-house test data and outside laboratory test data.

II. METHODS

The rear-impact sled experiments were simulated using the BioRID-II FE model (DYNAmore version 4.0.1) in 16 km/h and 24 km/h sled pulses. Two models were prepared. One was an initial model created without any test data for its validation. The other was an improved model validated to the seat kinematics during the sled tests. To capture sliding movement observed at the bolted joints between the upper and lower seat frames, the bolt modelling was changed by defining a tightening force and sliding contact friction. The seat back pad material compression characteristics were defined by force-displacement testing on the seat back pad component. Additionally, modifications were made to the BioRID-II FE Model to improve correlation to physical test. The accelerometer of neck C4 was removed to match the test conditions. The model of the top of the upper neck load cell was modified to be stiffer, to reduce unrealistic deformation inducing contact between the load cell and occipital interface plate. A total of eight simulations were conducted, as shown in Table I. In-house rear-impact sled tests were performed with a SUV seat to validate the model. Sled tests were also conducted at IIHS considering the model validation requirement check for future virtual testing. The seat position and the BioRID-II were set following IIHS rear-impact protocol [2]. The torso angle was 25 degrees, and the backset between the head and head restraint was 38 mm in all cases.

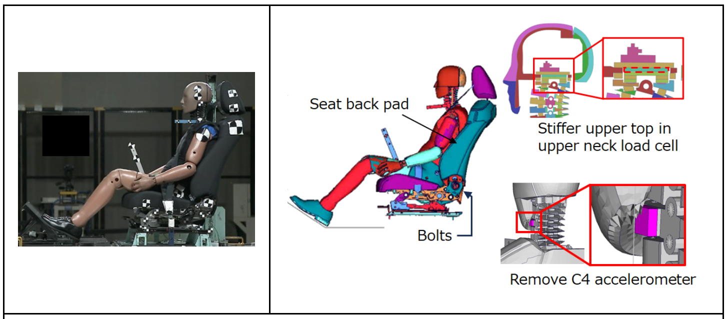

Fig. 1. Rear impact setup (test and CAE)

TABLE I
TEST AND SIMULATION MATRIX

Case	Pulse	Test location	CAE
1	16 km/h IIHS and Euro NCAP medium	In-house	Initial Model
2			Improved Model
3		IIHS	-
4			-
5	24 km/h Euro NCAP high	In-house	Initial Model
6			Improved Model
7		IIHS	-
8			-

To study the model validation requirement, requirements for dummy response were created to distinguish the original model and the improved model. For the waveform comparison between test and CAE of dummy sensor output, ISO18571 (ISO) was used [3]. ISO threshold of “0.7” for kinematics output of head, T1 and pelvis Gx was set. ISO value of “0.5” for upper neck output of Fx, Fz, My (+-) and Nkm was set. Those outputs will possibly be used for injury value assessment in the forthcoming IIHS VT protocol. It is known that waveforms with low outputs are likely to have lower ISO values and could possibly receive unacceptable validation results.

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On the other hand, low sensor output of neck means generally good restraint performance. To avoid this conflict, temporary injury limit values were referred from IIHS [2] and the European New Car Assessment Programme (Euro NCAP) rating protocol [4], as described in Table II. If the neck signal outputs are less than 40% of the injury limit in test, the CAE model validation of neck in ISO is not required to check validation. Injury peak value estimation in CAE is also important for model validation. However, as described with regard to the waveform check in ISO, low injury values that are less than 30% of the injury limit based on IIHS and Euro NCAP protocols [2][4] are not considered for validation (Table III). And in the case of injury value output higher than 30% of the injury limit in test, the deviation between test and CAE-estimated injury values against the injury limit were set to be less than 20% for the model validation.

TABLE II
SENSOR OUTPUT LIMIT FOR ISO CHECK

	Upper Neck			
	Fx (N)	Fz (N)	My+-(Nm)	Nkm
16 km/h	260	1167	30	0.69
24 km/h	260	1167	30	0.78

TABLE III
INJURY LIMIT FOR PEAK VALUE CHECK

	HCT (ms)	T1G (g)	Upper Neck		
			Fx (N)	Fz (N)	Nkm
16 km/h	70	9.5	260	1167	0.69
24 km/h	70	9.5	260	1167	0.78

III. INITIAL FINDINGS

Figure 2 and Fig. 3 show the result of comparison between initial model and improved model in (a) waveform ISO check and (b) injury value estimation check for model validation. Overall, the improved model showed better ISO scores. The initial model failed in pelvis G at 16 km/h to the threshold “ISO 0.7”. T1 G, pelvis G and upper neck My at 24 km/h were failed. Upper neck sensor outputs were not required in 16 km/h for ISO check due to an output lower than 40% of the sensor limit listed in Table II. Sensor output of upper neck Fx and Fz were less than 40% of the limit in 24 km/h. All estimated injury values were less than 20% deviation threshold. However, some sensor outputs were close to threshold in original model for Nkm at 16 km/h.

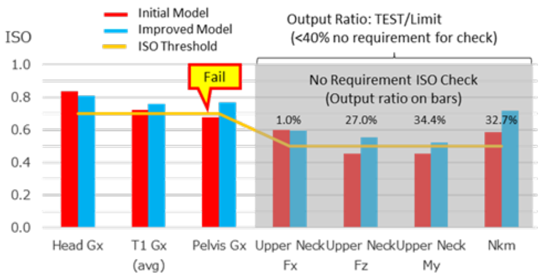

Fig. 2 (a) Waveform ISO check in 16 km/h.

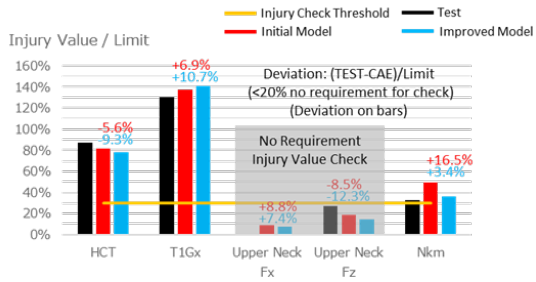

Fig. 2 (b) Injury value estimation check in 16 km/h.

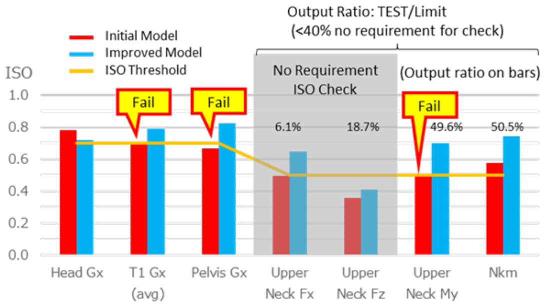

Fig. 3 (a) Waveform ISO check in 24 km/h.

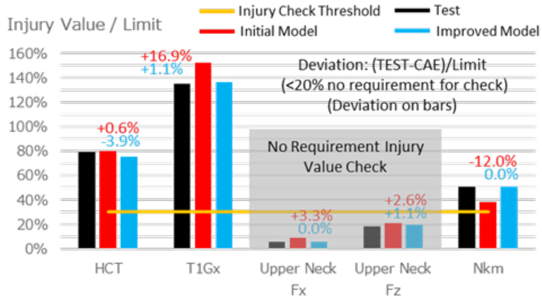

Fig. 3 (a) Injury value estimation check in 24 km/h.

IV. DISCUSSION

This study aimed to provide a simulation model validation method for rear-impact future VT. To this end, it was considered that low sensor output, meaning good restraint, should not be applied for model validation in ISO check and injury value estimation check for model validation to avoid misreading the safety assessment.

V. REFERENCES

[1] Edward M. et al., IRCOBI 2023
[2] IIHS, Protocol, Test protocols and technical information
[3] ISO/DTS18571, 2022
[4] Euro NCAP, PROTOCOL, https://www.euroncap.com