A Simulation Study of Neck Injury for Dummy Position Change in Low Speed Rear Impact

Jonghyun Yim, Mansu Lee, Namkyoung Lim, Sangwoo Shim

I. INTRODUCTION

Whiplash injury is the most commonly occurring injury in road traffic accidents, although it is classed as a minor injury in low speed rear impact. It is not easy to define the relationship between medical diagnostic and dummy injury values of physical test, but it frequently results in a high social cost, such as body injury insurance claims. According to traffic statistics data in TASS (Traffic Accident Analysis System) and KIDI (Korea Insurance Development Institute), about 52% (708,000) of insurance claims stemmed from rear impact accidents, despite the fact that rear impact accounted for only 27.8% of total car-to-car accidents in 2013 and neck 'cervical spinal' injury accounted for 37.8% of total rear impact claims [1-2]. New Car Assessment Program (NCAP) and insurance companies published whiplash performance assessment results using a BioRID II 50th percentile dummy, which was developed specifically for use in low-severity rear impact. In this paper, simulation of injury values based on dummy position changes that can occur in real-life driving situations was estimated in low speed (10 km/h, 16 km/h) rear impact scenarios using multibody dynamics simulation software MADYMO.

II. METHODS

Mid-size passenger vehicle's rear impact test was conducted using 10 km/h RCAR moving barrier as striking vehicle. Sled test base model with BioRID II dummy on front driver seat according to IIWPG (International Insurance Whiplash Prevention Group) protocol was built by using vehicle acceleration pulse. MADYMO simulation model was also generated using Madymo dummy and FE seat, which was pre-crushed considering dummy weight, and Madymo simulation model was correlated with sled test in terms of head/thorax acceleration and neck force by less 10% of internal energy, as shown in Fig. 1 and Fig. 2.

Fig. 1. Sled model and MADYMO dummy & seat model.

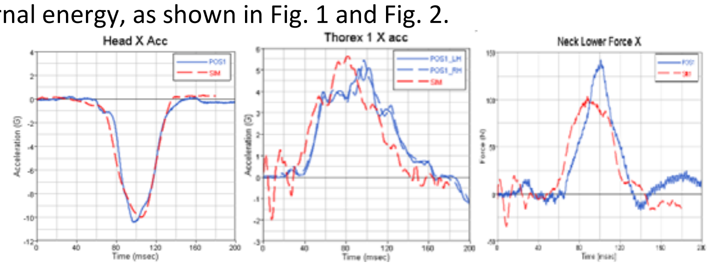

Fig. 2. Correlation between sled and simulation.

Table I shows MADYMO simulation case matrix and results of 10 km/h and 16 km/h impact velocity.

TABLE I

SIMULATION CASE STUDY MATRIX AND RESULTS SUMMARY

	Case study model condition					Simulation results					
	Head angle (degree)		Pelvic (degree)	Seat back angle (degree)	Headrest height	10 kph MDB			16 kph IIWPG		
	Vert.	Hori.				Head x(g)	T1 x(g)	NIC	Head x(g)	T1 x(g)	NIC
Base	0	0	26.5°	25°	Mid	10.0	5.6	7.7	29.3	15.1	17.1
Case 1	0	0	20°	25°	Mid	10.6	5.3	9.1	34.0	18.2	23.6
Case 2	0	0	11°	25°	Mid	9.3	5.4	9.8	35.5	22.8	36.9
Case 3	0	0	As base	Base+10°	Mid	11.2	6.2	10.9	30.0	18.0	24.0
Case 4	0	0	As base	Base-10°	Mid	9.1	6.6	6.2	29.1	15.2	15.8
Case 5	0	0	As base	25°	Upper	9.6	5.7	8.1	28.1	15.2	17.8
Case 6	0	0	As base	25°	Lower	11.7	6.3	10.0	33.1	15.8	20.7

JH Yim is a senior manager in GM Korea (tel: 82-32-520-4245, e-mail: jonghyun.yim@gm.com). MS Lee is a director of vehicle safety division in GM Korea. NK Lim is a senior research engineer and SW Shim is a crash team manager in Korea Automobile Insurance Repair Research & Training Center/Korea Insurance Development Institute.

III. INITIAL FINDINGS

The NIC considers the relative acceleration between head and thorax spine, as shown in equation (1):

$$NIC(t) = 0.2m * a_{rel}(t) + (v_{rel}(t))^2 \text{ with } a_{rel} = a_x^{T1} - a_x^{head} \text{ and } v_{rel} = \int a_{rel}\,dt \qquad (1)$$

where v_{rel} and a_{rel} are the relative horizontal velocity and acceleration of the head and the T1.

Many researchers tried to validate the NIC against the actual occurrence of injuries on humans. *Per* these research results, the NIC value of 15 m^2/s^2 appears to be a safe threshold for long-term injuries [3]. In the simulation case studies, NIC values as neck injury criteria were estimated and compared with Base model results [Fig. 3–Fig. 5]. In Base result, NIC value (17.1 m^2/s^2) of 16 km/h impact speed was 225% higher than 10 km/h impact speed result (7.7 m^2/s^2). In Case 2, for smaller pelvic angle (11°), NIC was increased 27% (10 km/h) and 116% (16 km/h). In Case 4 and with a reduced seat back angle (15°), it made slightly decreased NIC value 19% (10 km/h) and 8% (16 km/h). In Case 6, with lower headrest position, NIC was increased 30% (10 km/h) and 21% (16 km/h).

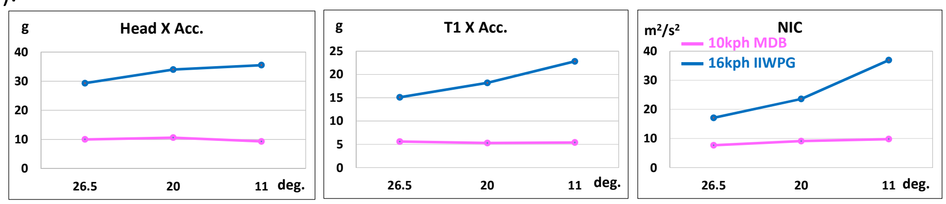

Fig. 3. Pelvic angle change: Head X & T1 acceleration, NIC of BioRID II dummy.

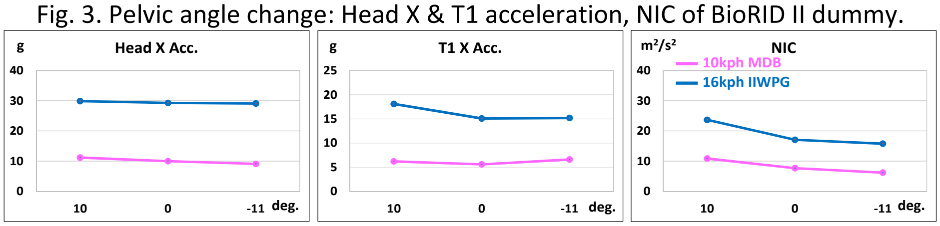

Fig. 4. Seat back angle change: Head X & T1 acceleration, NIC of BioRID II dummy.

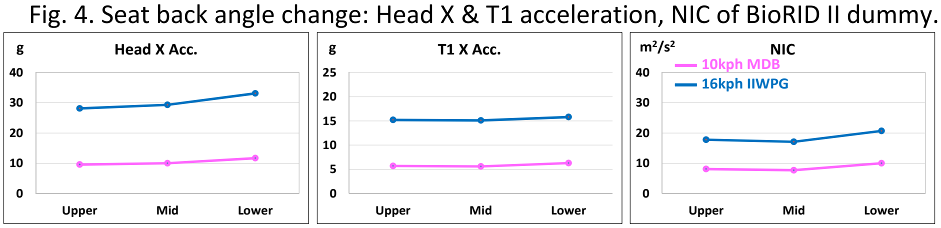

Fig. 5. Seat headrest height change: Head X & T1 acceleration, NIC of BioRID II dummy.

IV. DISCUSSION

In this paper, the MADYMO simulation model was correlated with sled test in terms of head acceleration, thorax and neck force within 10% of internal energy. Through simulation case studies, the NIC-neck injury criteria were evaluated to know the effect of pelvic angle change, seat back angle change and headrest height change in lower speed rear impact condition (10 km/h, 16 km/h) as follows:

- smaller pelvic angle (26.5°/20°/11°) shows rapidly increased NIC values due to enlarged space between dummy and seatback/headrest during rear impact (Base, Case 1 and Case 2);
- smaller seat back angle (35°/25°/15°) shows gradually decreased NIC values due to reduced space between dummy and seatback/headrest (Base, Case 3 and Case 4);
- 15° seat back angle shows the best NIC value among all cases (Case 4);
- NIC value variation in 16 km/h (15.8–36.9 m^2/s^2) was larger than 10 km/h result (6.2–10.9 m^2/s^2).

Finally, the analysis indicates that seat headrest design should focus on having a smaller gap between head and headrest, while seat back design should consist of an energy-absorbing cushion and structure for increased protection during rear impact collision.

V. REFERENCES

[1] TASS (Traffic Accident Analysis System) data base, 2013.

[2] Namkyoung Lim, Whiplash Injury Studies through Low speed Rear-end Crash Test, KSAE, 2015.

[3] Wheeler, J. Validation of the Neck Injury Criterion(NIC) Using Kinematic and Clinical Results from Human Subjects in Rear-end Collisions, IRCOBI Conference, Goteborg, 1999.