

## System Level Evaluation of THOR Response in Front Oblique Condition

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### I. INTRODUCTION

National Highway Traffic Safety Administration (NHTSA) is working to develop a test mode in which an oblique moving deformable barrier (OMDB) impacts a stationary vehicle at 90.1 kph, with a 15 degree angle and with 35% vehicle overlap. This test mode uses the 50<sup>th</sup> %ile male THOR in both the occupant positions i.e. near-side (driver) and far-side (passenger) [1][4]. In an effort to study this mode of crash, Hyundai conducted a series of four OMDB tests on sedan research vehicles. During these tests, it was observed that the driver Anthropomorphic Test Device (ATD) exceeded head (mainly Brain Rotational Injury Criteria BrIC [2]) and chest injury assessment reference values primarily due to insufficient driver and curtain airbag coverage. The passenger ATD also sustained higher head injury assessment reference value due to excessive dummy lateral movement and insufficient passenger airbag coverage.

The purpose of this study was to develop a methodology to closely represent NHTSA OMDB test ATD kinematics and injury assessment parameters BrIC, HIC15 and chest deflection for driver and passenger using sled tests.

### II. METHODS

A systematic approach of Computer Aided Engineering (CAE) modeling, design of experiments (DOE) study and sled testing was adopted to derive this methodology.

#### CAE Modelling

The vehicle components influencing dummy kinematics and head and chest injury assessment parameters were identified and studied in a MADYMO model of vehicle subjected to an oblique impact. The MADYMO model included the same vehicle interior geometry, baseline restraint system and oblique crash acceleration versus time history data as the sedan research vehicle. Dynamic vehicle pitching and dynamic intrusions of vehicle components such as A-pillar, steering column, knee bolster and floor were omitted from the model to represent the sled environment. The MADYMO THOR dummy with shoulder modification kit was used for driver and passenger model validation. Free body head motion was traced from the vehicle test and the sled model was rotated by head trajectory angle as a starting point as shown in Fig. 1. Emphasis was placed on obtaining similar dummy kinematics in the model to the vehicle baseline test.

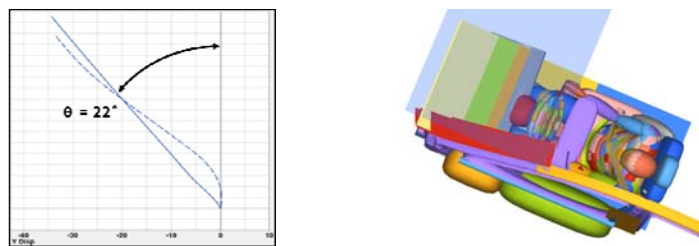


Fig. 1. Sled model rotation based on head trajectory

Multiple DOE simulations were conducted using a validated model to study the influence of various parameters on dummy kinematics and head and chest injury assessment parameters. The goal of this DOE study was to match dummy kinematics and head and chest injury assessment parameters closely to the test. The DOE

parameters included sled rotation angle (to simulate direction of free flying mass -head), ATD seated height (to simulate vehicle pitching and head contact point on airbags), and steering column static intrusion (to simulate instrument panel intrusions).

**Sled Testing**

Based on DOE results, parametric variation was studied on sled tests. The structure of the small sedan was converted into a sled buck and relevant driver and passenger side trim components were installed. A baseline restraint system including driver airbag, driver curtain airbag, passenger airbag and driver and passenger seat belt system were installed. The sled buck was mounted on ‘adapter plates’ that were in turn mounted to the sled carriage. The ‘adapter plates’ were designed to allow the sled buck to be rotated from 16 to 28 degrees from nominal to simulate different head trajectory angles. The steering column was statically intruded by extending steering wheel mounting. The resultant X and Y acceleration versus time history data was used as a ‘sled pulse’.

Fig. 2 shows a sled set-up. Latest version of THOR NT dummies with most recent modification kit were used on driver and passenger side [3]. A set of 12 tests was run on driver and passenger by varying above parameters to dummy kinematics and head and chest injury assessment parameters closely to the test.

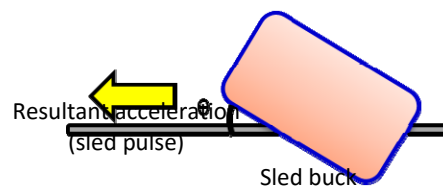


Fig. 2. Sled set-up

**III. RESULTS**

Sled test observations show that driver and passenger ATD kinematic response is similar to the full vehicle crash test. Head and chest injury assessment parameters represent similar trends and peak values as observed in full vehicle test. Fig. 3 compares driver ATD kinematics and Fig. 4 compares the driver head injury assessment parameter comparison between the sled test and the vehicle test.

	80 ms	100 ms	120 ms
<b>Sled</b>			
<b>Vehicle</b>			

Fig. 3. Driver ATD kinematic comparison: Sled versus test

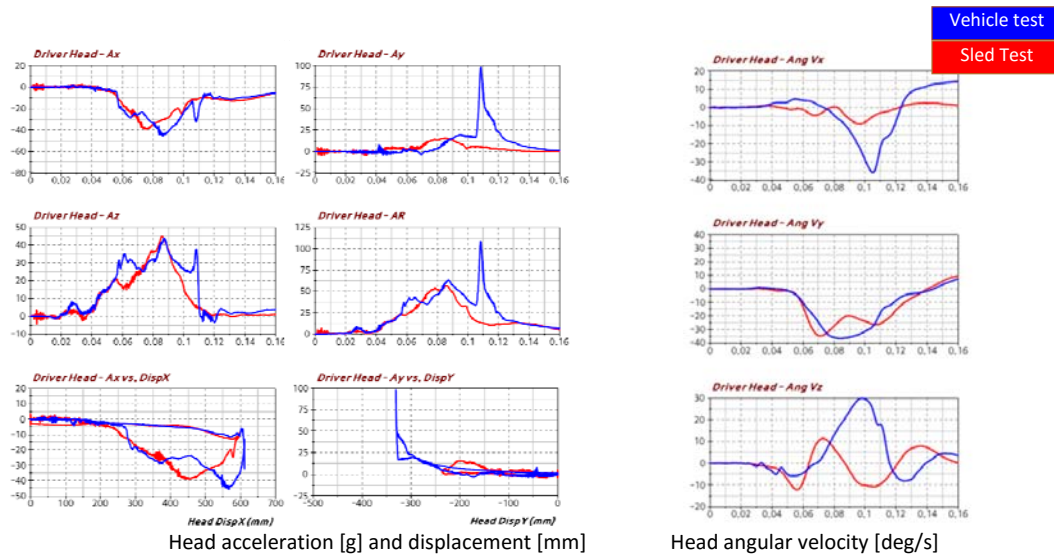


Fig. 4. Driver ATD head injury assessment parameters comparison: Sled versus test

The DOE parameters showed significant influence on the driver dummy kinematics. ATD head rotation showed high dependency on dynamic vehicle pitching. Due to lack of dynamic pitching ability of the sled, seated height was raised to achieve similar driver ATD head contact point on driver airbag to that of on the vehicle test. The driver dummy head and chest excursion were achieved by intruding the steering column statically. The direction of head travel (free flying mass) was attained similar to the vehicle test by varying sled angle.

This sled set-up was then used to test restraint system countermeasures for driver and passenger. Curtain airbag countermeasures (extended geometry and improved stiffness) minimised head excursion, but did not show significant improvement in the head injury assessment parameter BrIC. Passenger airbag countermeasures (added support chamber and improved stiffness) demonstrated better support to the head and minimised head rotations with improved passenger head injury assessment parameter BrIC.

#### IV. DISCUSSION

The actual vehicle response to an oblique impact by OMDB includes dynamic vehicle rotations around 3 axes and also dynamic interior intrusion. The ability to simulate the occupant injury mechanisms is limited by representing the complex vehicle response with static prepositioning of the vehicle orientation, steering column intrusion and seated height.

While the driver dummy in the sled test did move forward into the driver airbag and then slid between driver airbag and curtain airbag, it did not have the magnitude of excursion as observed in the full vehicle test. The sled test had longer coupling of driver shoulder to seat belt. The driver injury assessment parameters head acceleration, chest acceleration and chest deflection matched well with the test. However, matching X and Z head rotation velocities were challenging.

For the passenger ATD, similar to the driver, it had longer coupling of shoulder and seat belt. It resulted in avoiding head strike on the instrument panel which was observed in the vehicle test. The dummy head contact point on the passenger airbag was lower. The passenger injury assessment parameters head acceleration, head rotation, chest acceleration and chest deflection matched well with the test.

#### V. REFERENCES

- [1] Saunders, J. SAE Int. 2012.
- [2] Takhounts, E.G. Stapp 2013.
- [3] Ridella, S. ESV 2009.
- [4] Saunders, J. ESV 2011.