Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7001 *(Invited Keynote Paper)*

STRATEGIES FOR IMPROVED VEHICLE SAFETY: SURVIVABILITY OF OCCUPANTS

Shaker A. Meguid(*), Mohamed T.Z. Hassan

Mechanics and Aerospace Design Laboratory, University of Toronto, Canada
(*)*Email:* meguid@mie.utoronto.ca

ABSTRACT

The Mechanics and Aerospace Design Laboratory at the University of Toronto has been engaged in research concerned with crashworthiness and automotive safety for two decades. In this presentation, we shall summarize our efforts and address occupants' response to varied collision scenarios analytically, numerically and experimentally. The analytical is based on multibody dynamics, the numerical on nonlinear dynamic elasto-plastic finite element and the experimental on crush and crash-worthiness tests of shock absorbers. Detailed Finite element model of a human body is used to study occupant's response during frontal, rear, frontal-to-rear and side collisions in car accidents. The research intends to show the effect of the different parameters on altering the dynamic response of the occupants with emphasis on their survivability using injury criteria. Specifically, the effect of deploying (or lack of) airbags, seat belt, head rest, occupant's awareness and posture will be examined and their influence on occupants' safety assessed. Additionally, the effect of the introduction of ultralight cylindrical and conical shock absorbers, filled with metallic foam or unfilled, in vehicles upon the reduction of the impact energy collisions is examined. We shall also examine future trends in automotive safety and occupants' survivability.

Keywords: whiplash, strategies, car safety, multibody dynamics, FEM, crashworthiness.

INTRODUCTION

Despite the significant enhancement in safety of motor vehicles in the last few decades, whiplash, resulting from rear collisions, remains a serious injury and a source of trauma. It is estimated that more than 800,000 whiplash injuries occur annually in the United States alone, resulting in neck pain, limited neck movement, visual disturbance and dizziness. According to the National Highway Traffic Safety Administration (NHTSA) the number of injuries resulting from rear-ends collisions increased during 2007-2015 from 485,000 incidents to 556,000 incidents becoming the most common reason for injuries during motor vehicle collisions. In order to provide better protection for occupants, it is important to identify and compute the occupant's response during collisions. Many techniques have been devised to study occupants' response during rear-end collisions. A number of experimental studies were also conducted on volunteers. However, to limit injury to those volunteers, the level of impact severity is reduced to an acceptable level. As a result, such studies are very limited. To overcome this limitation, cadavers have been used in other experimental studies. Although the use of cadavers allows testing at higher impact forces, the cadavers lack responsiveness due to the absence of muscle activation. Anthropomorphic test dummies (ATDs) such as HybridIII-have been widely used in crash tests and they too have many limitations. This does not in any way reduce the great results and advance made as a result of these efforts in developing car safety strategies for the passenger car. Advance in computer modeling and simulation has added significantly to these strategies.

SAMPLE RESULTS AND CONCLUSIONS

A dynamics model of the head and neck to simulate occupant's response in rear impact was analyzed using Lagrange's principle as given by:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_k}\right) - \frac{\partial L}{\partial q_k} + \frac{\partial f}{\partial \dot{q}_k} = Q_k \quad (1)$$

where L is the Lagrangian given by $L = T - V$, $\dot{q}_k$ is the generalized velocities, q_k is the generalized coordinates, f is the dissipation function given by Eq. (2), Q_k is the generalized forces, T is the kinetic energy of the system given by Eq. (3) and V is the potential energy of the system given by Eq. (4)

$$f = \frac{1}{2}\sum_{i=1}^{8} c_i \dot{\theta}_{i,r}^2 \quad (2)$$

$$T = \frac{1}{2}\sum_{i=1}^{8} I_i \dot{\theta}_i^2 + \frac{1}{2}\sum_{i=1}^{8} m_i v_i^2 \quad (3)$$

$$V = \frac{1}{2}\sum_{i=1}^{8} k_i \theta_{i,r}^2 \quad (4)$$

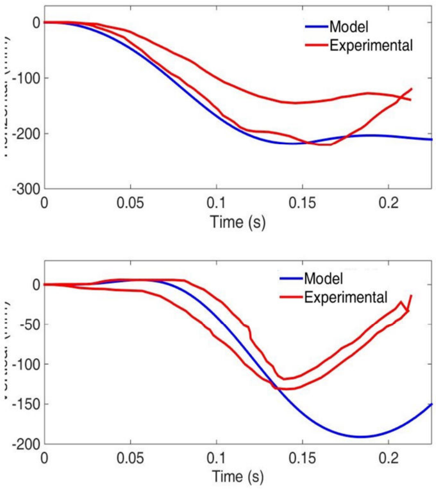

Fig. 1 - Head displacement with respect to T1 vertebra

where I_i is the mass moment of inertia of the body, m_i is the mass of the body, k_i is the joint stiffness, c_i is the joint damping coefficient, $\dot{\theta}_i$ is the absolute angular velocity, v_i is the absolute linear velocity, $\theta_{i,r}$ and $\dot{\theta}_{i,r}$ are the angle and angular velocity relative to the torso, respectively. Figure 1 shows the resulting head displacement. The seated FE model response is shown in Figure 2. Our results show clearly that impact accelerations not only affect the resulting head displacements, rotations and forces to which the neck is subjected during collision, but also the time at which peak displacements and forces occur. Peak normal force and peak moment at the occipital condyle occur during the extension phase of the neck (Fice *et al.*).

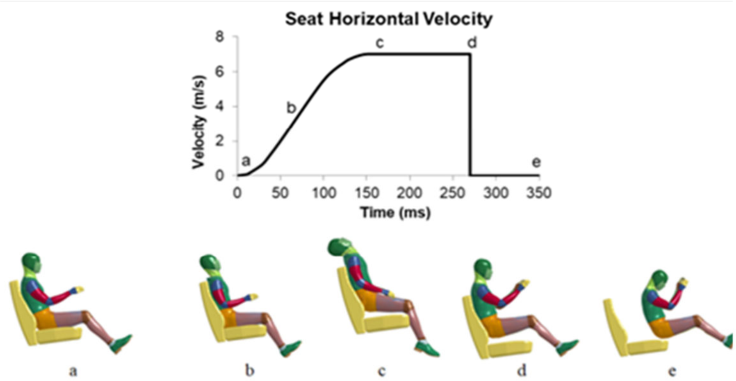

Fig. 2 - Occupant's response during the entire simulation for seat arrangement with no seat belt: Figures (a-e) show the occupant's position with respect to the car sear at 0 ms, 75 ms, 150 ms, 270 ms and 350 ms.

ACKNOWLEDGMENTS

NPRP grant #6 - 292 - 2 - 127 from Qatar National Research Fund. The authors also wish to acknowledge the Global Human Body Model Consortium.

REFERENCES

[1] Fice J.B., Cronin SD.S., Panzer M. B. "Cervical Spine Model to Predict Capsular Ligament Response in Rear Impact". 2011, Vol. 39, 8, pp. 2152-2162.