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EFFECT OF IMPACT SEVERITY ON OCCUPANT'S RESPONSE DURING REAR-END COLLISIONS

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ABSTRACT

The most common injury suffered by the occupant in rear-end collision is whiplash which may result in acute and/or chronic injuries. Injury severity is affected by factors such as impact severity and occupant related factors such as gender. In this work, the effect of impact severity of an accelerating vehicle on occupant's response for both male and female during rear-end collisions. Nonlinear dynamic finite element simulations were conducted of seated 50th percentile male and female occupants subject to four different accelerations: 1.5 g, 2.4 g, 3.6 g and 4.8 g resulting from rear end collisions. Our results reveal that head displacement and rotation as well as the time of occurrence are greatly influenced by the impact acceleration. The work also shows that the simulated female experiences greater levels of linear and angular displacements when compared with the male counterpart leading to greater strains in the female intervertebral discs. The outcomes of this study can be used to better understand and identify injury mechanism during rear impacts in male and female occupants.

Keywords: whiplash, rear impact, nonlinear, finite element, occupant kinematics.

INTRODUCTION

Rear-end impacts represent approximately 24% of all multiple vehicles crashes in the United States [1] with a significant number of these crashes resulting in whiplash injury. More than 800,000 whiplash injuries occur annually in the US costing over $9 billion [2] and this number is increasing. Injury severity and duration depends on many factors like occupant's gender, posture, seat geometry, and collision severity. Studying occupant's response is during impact is essential for enhancing occupant protection. A number of studies have been conducted to evaluate the human response during rear impacts. Experimental studies considered volunteers, cadavers and anthropomorphic test dummies (ATDs). Multibody dynamics is one of the numerical techniques used to simulate whiplash in which the body is modelled using a number of rigid elements connected using revolute joints, elastic springs, dampers, and/or viscoelastic elements. The stresses and strains in soft tissues are a key factor in understanding whiplash injury, which multibody dynamics does not address. Therefore, finite element method (FEM) has been considered to construct more detailed models of the human body. Several FE models were developed to study the cervical spine under different types of loading. In further efforts to develop full human body FE models, the Global Human Body Model Consortium (GHBMC) developed a number of detailed FE models of the human body for both male and female occupants and pedestrians, the Virtual Vehicle-safety Assessment (ViVA) developed a FE model of the 50th percentile female occupant and the PIPER project which developed a scalable FE model of a child occupant. In this study, two full human body finite element models of male and female occupants are used to compute the effect of the impact severity on the occupant's response and the loads to which the neck is subjected during rear-end collisions.

SAMPLE RESULTS AND CONCLUSIONS

The GHBMC 50th percentile male and the ViVA 50th percentile male FE models were seated on a car seat, as shown in Figure 1. The GHBMC model consists of 988 parts discretized using 2.18 million elements while the female model consists of 620 parts discretized using ~318,000 elements including solid, shell, beam and discrete elements. Since the FE models have different masses, the seat frame was assumed to be rigid to prevent the effect of seat deformation on occupant response. The seat cushion material was assumed to be made of polyurethane foam which was modelled using low density foam material model. To simulate a rear-impact, a velocity profile was applied horizontally (+X direction) to the lower part of the seat frame denoted by line A in Figure 1, while constraining its motion in the vertical (Z axis) and lateral (Y axis) directions. The nonlinear dynamic analysis was conducted using the explicit solver of LS-DYNA.
For the same collision acceleration, the female occupant shows a more severe response resulting in larger head displacement and rotation, especially for lower accelerations (1.5 g and 2.4 g). Our results indicate 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. The work further reveals that the female response is more sensitive to the change in seat acceleration. Furthermore, the strain in the IVDs is higher in females compared to males for the same seat acceleration as shown in Figure 2.

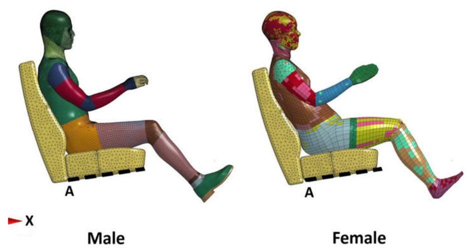

Fig. 1 - The male and female finite element models seated.

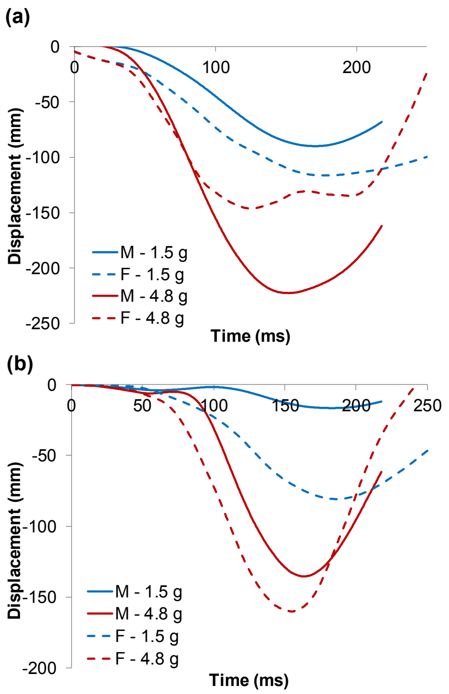

Fig. 2 - The head displacement relative to T1 vertebra of the male and the female FE models: (a) horizontal and (b) vertical.

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