Implementation and Calibration of Active Reflexive Cervical Muscles on Female Head-Neck Model

I Putu Alit Putra, Johan Iraeus, Robert Thomson, Mats Svensson
Division of Vehicle Safety, Department of Mechanics and Maritime Sciences,
Chalmers University of Technology

Problem outline

ViVA OpenHBM is an open source human body model that represents the 50th percentile female population for assessing whiplash protection systems in car. ViVA OpenHBM was developed with intention to fill the gap of current available HBMs which excluded the average female size although injury statistics since 1960s have shown that females have three times higher risk to sustain whiplash injury compared to males. In this study, the current model is being enhanced by implementing active muscles as previous studies have shown that cervical muscles could alter the head and neck kinematics of the occupant during low-speed rear- crashes.

Study objectives

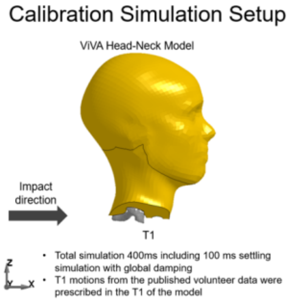
The first goal of this study was to implement a Proportional Integral Derivative (PID) feedback control mechanism adding to the Finite Element models of cervical muscles. The second goal was to calibrate the PID control gains by conducting an optimization-based parameter identification with published-volunteer data and to analyze the effects of three calibration objectives to the head and cervical kinematics of the model.

Methodology

The VIVA OpenHBM head-neck model, previously validated to PMHS data, was used. To represent the 34 cervical muscles, 129 beam elements with Hill-type material models were implemented. A closed-loop control strategy was applied to activate these muscles mimicking the human body's vestibular system. Calibration studies of head and cervical spine kinematics were conducted by comparing the model against published-volunteer responses to identify reasonable gain values for the controller. Three different calibrations were conducted with three different objectives: head kinematics in linear and angular direction, head and cervical spine kinematics in angular direction, and head and cervical spine kinematics in linear and angular direction.

Results and Conclusion

The simulation results show that the reflexive feedback control was numerically stable and able to control model muscle's activation. Gain values of the implemented muscle control strategies were able to be identified from calibration simulations. Muscle activation changed the head kinematics by reducing peak linear and angular displacements, as compared to the model without muscle activation. The agreement of specific kinematic variables such as head kinematic and cervical spine angular displacement was dependent on the controller calibration objectives. Best agreement of head kinematics was observed in the model that calibrated against only volunteer head kinematics. However, in the vertical and angular direction there was a discrepancy of head response caused by anterior-posterior buckling of the cervical spine. In the model that was calibrated against head and cervical spine in angular direction, less contraction of cervical muscles was observed. As the result, good agreement was obtained in the cervical spine angular kinematics but not in the head kinematics. The best agreement was obtained by the model that calibrated against both linear and angular displacement of volunteer head and cervical spine kinematics although reduced the agreement of head kinematics compared to the model that was calibrated against only volunteer head kinematics. This was because of different calibration objectives that opposing each other.



No	Simulation Name	Calibration Objectives
1	APF 1	• Head Linear Displacement (X and Z direction) • Head Angular Displacement (Y direction)
2	APF 2	• Head Angular Displacement (Y direction) • C1-C7 Angular Displacement (Y direction)
3	APF 3	• Head Linear Displacement (X and Z direction) • Head Angular Displacement (Y direction) • C1-C7 Angular Displacement (Y direction)