Modelling of Whiplash Trauma: A study of vehicle and crash parameters on local tissue loading using FEM and CFD

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Background

Whiplash neck extension trauma in rear impacts at low impact velocities (<20 km/h) often causes pain in the neck region as well as a number of other neurological symptoms. The same symptoms are found also after frontal and lateral car collisions. More than 1 million European citizens suffer neck injuries implying tremendous societal cost roughly at least 10 billion Euro annually.

Several hypotheses regarding the injury site in the neck and the injury mechanism have been presented. Two of the most widely recognized injury sites are the cervical facet joints and the cervical spinal ganglia (Siegmund et al., 2009). Two recent projects at Chalmers (Liu and Yang, 2008; and Goeury, 2008), Fig. 2, have created and refined a CFD model of the spinal canal that replicates pressure transients in the Central Nervous System (CNS) using neck vertebral motion data as input.

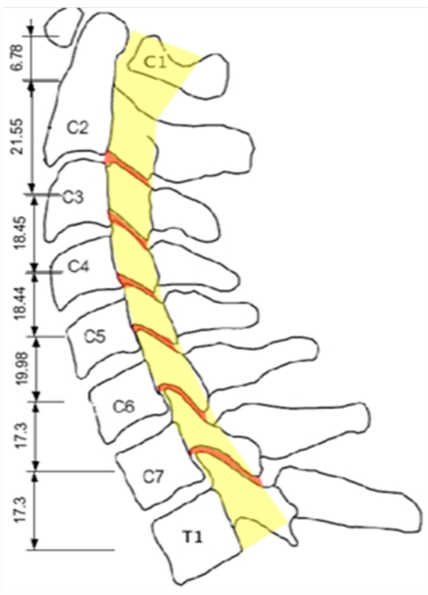
The Vehicle Safety Division has very recently obtained an upgraded version of the Human Body Model "THUMS" in the FEM code LS-DYNA via an agreement with Toyota Motor Co. The THUMS model has a high degree of bio-fidelity with a detailed representation of the neck vertebrae, ligaments and other important structures.

Project Proposal

The proposed project will use the **THUMS model** to generate new motion data that will be used as new input to **CFD** simulations using **OpenFOAM** (www.openfoam.org) of the spinal canal. The CFD simulations will be carried out using a moving mesh technique where the movement of the boundaries of the **CFD simulations** will ge given by the **FEM simulations.**

Figure 1: The THUMS human body model. Hole model (left) and spine (right)

A parameter study will be carried out with the THUMS using input in the form of a variety of crash pulses and crash conditions that have a known relative risk of long term neck injuries. The THUMS model (Fig. 1) has a high degree of bio-fidelity with a detailed representation of the neck vertebrae, ligaments and other important structures. The correlation between facet joint loads as well as pressure transient magnitudes and the neck injury outcome will be investigated.



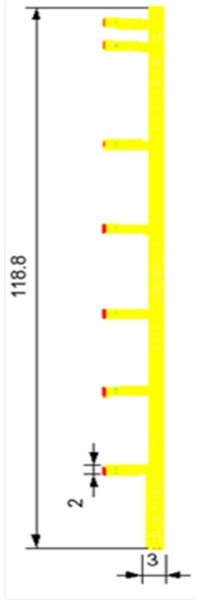


Figure 2 Geometry of the Human Cervical Spine Spinal Canal (yellow) Facet Joint (red)

Geometry of the spinal canal CFD-model

The results are expected to give new input to the scientific debate about the true injury site. If one of the two hypotheses show a higher degree of correlation with the field accident findings this will new strong support. The results are also expected to give new important input for the development of further refined protective systems such as head restraints.

The proposed project is an interesting example of how to combine **solid mechanics** (finite element method) with **fluid mechanics** (CFD with OpenFOAM).

Project Plan

1. Literature study and modeling startup.
2. A set of THUMS simulations will be carried out in order to study the influence of various crash related parameters. These could for instance be crash acceleration pulse or crash type (rear, frontal etc.).
3. The results from the THUMS model will be used as input for the OpenFoam simulations.
4. Comparisons between field accident injury outcome and calculated facet joint loads as well as the modeled CNS pressure transients will be done in order to identify the most promising hypothesis.

References

1. Liu, F. and Yang J. (2008): Modeling of Whiplash Injuries using CFD, Department of Applied Mechanics, Division of Fluid Dynamics / Division of Vehicle Safety, Chalmers University of Technology, Master's Thesis 2008:38[1]
2. Goeury, C. (2008): Modelling Whiplash Injuries using compressible CFD, Department of Applied Mechanics, Division of Fluid Dynamics / Division of Vehicle Safety, Chalmers University of Technology. Master's Thesis 2008:38[1]
3. Siegmund, Gunter P.; Winkelstein, Beth A.; Ivancic, Paul C.; Svensson, Mats Y.; Vasavada, Anita (2009): The Anatomy and Biomechanics of Acute and Chronic Whiplash Injury. *Traffic Injury Prevention*, 10 (2) pp. 101-112.

1 can be downloaded from www.tfd.chalmers.se/~lada