Finite element method

The finite element method is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential.

The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method approximates the unknown function over the domain.

To solve the problem, it subdivides a large system into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Advanced neck finite element modeling and development of neck injury criteria are important for the design of optimal neck protection systems in automotive and other environments. They are also important in virtual tests. The objectives of the present study were to develop a detailed finite element model (FEM) of the human neck and couple it to the existing head model, validate the model with kinematic data from legacy human volunteer and human cadaver impact datasets, and derive lateral impact neck injury risk curves using survival analysis from the upper and lower neck forces and moments. The detailed model represented the anatomy of a young adult mid-size male. It included all the cervical and first thoracic vertebrae, intervening discs, upper and lower spinal ligaments, bilateral facet joints, and passive musculature. Material properties were obtained from literature. Frontal, oblique, and lateral impacts to the distal end of the model was applied based on human volunteer and human cadaver experimental data. Corridor and cross-correlation methods were used for validation. The CORrelation and Analysis (CORA) score was used for objective assessments. Forces and moments were obtained at the occipital condyles (OC) and T1, and parametric survival analysis was used to derive injury risk curves to define human neck injury tolerance to lateral impact. The Brier Score Metric (BSM) was used to determine the hierarchical sequence among the injury metrics. The CORA scores for the lateral, frontal, and oblique impact loading conditions were 0.80, 0.91, and 0.87, respectively, for human volunteer data, and the mean score was 0.7 for human cadaver lateral impacts. Injury risk curves along with ±95% confidence intervals are given for all the four biomechanical metrics. The OC shear force was the optimal metric based on the BSM. A force of 1.5 kN was associated with the 50% probability level of AIS3+ neck injury. As a first step, the presented risk curves serve as human tolerance criteria under lateral impact, hitherto not available in published literatures, and they can be used in virtual testing and advancing restraint systems for improving human safety [1].

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Meyer F, Humm J, Yoganandan N, Leszczynski A, Bourdet N, Deck C, Willinger R. Development of a detailed human neck finite element model and injury risk curves under lateral impact. J Mech Behav Biomed Mater. 2021 Jan 19;116:104318. doi: 10.1016/j.jmbbm.2021.104318. Epub ahead of print. PMID: 33516127.