C11 Crashworthiness Simulations of Glass Mat Thermoplastic (GMT) and High Strength Steel (HSS) Sedan Bumper Beam Designs Using Explicit Finite Element Analysis

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After attending this presentation, attendees will be exposed to how explicit finite element analysis can be used to investigate deficiencies in crashworthiness, as well as how it can be used to suggest superior alternative designs. The state-of-the-art in bumper design will be discussed. The importance of materials testing to failure investigations will be emphasized through examples of specific cases where it proved valuable.

This presentation will impact the forensic science community by showing and recognizing shortcomings of some current bumper designs as well as broadening their exposure to tools that can be used to investigate crashworthiness in general. Identifying these problems and educating others about it will serve to create a driving force toward solving them.

Nearly all front and rear bumpers on modern sedans use either a High-Strength Steel (HSS) bumper beam or a Glass Mat Thermoplastic (GMT) composite bumper beam. GMT bumper beams are better at absorbing energy in low speed crashes than HSS and perform better in pedestrian protection tests; however, at higher speeds they fracture. GMT and HSS designs were investigated for crashworthiness at high and low speeds using explicit finite element analysis.

Three-dimentional models were created of the frame and bumper structural parts located at the front of one sedan and the rear of another. The 3D models were created using a portable Coordinate Measuring Machine (CMM). Using the CMM, data was collected from two production sedans. The data was used to create very accurate 3D models of the frame structures that contributed the most interaction in the collisions studied. The portion of the sedan that was not expected to deform or contribute much interaction other than mass and inertial properties was modeled with a sled based on the Advanced European Movable Deformable Barrier version 3.10 specification. The sleds were given the inertial properties of the modeled sedans.

Samples of bumper materials and frame materials were extracted and tested. Tensile testing was performed on all steel samples. Fourier Transform Infrared Spectroscopy (FTIR), tensile tests, flexural tests, and out-of-plane shear testing was performed on Original Equipment Manufaturer (OEM) and aftermarket GMT bumpers. Mechanical properties obtained from the tests were incorporated into the finite element model. Significant differences were found between the manufacturers' mechanical material property specifications and those obtained from testing the material. The effect of these differences was investigated with the Finite Element Analysis (FEA) model.

The sedan with the modeled front bumper was placed behind the sedan with the modeled rear bumper. The front sedan was at rest, while the rear sedan was given varying initial velocities and allowed to impact the front sedan. Simulations were performed with changes made to the front sedan's rear bumper geometry and material and results were compared. Vehicle velocity versus intrusion was plotted and the energy absorbed by the different bumper designs was compared. Real world crash testing was performed using the two sedans which was used to validate the FEA model. All simulations were performed using the commercial finite element analysis software LS-Dyna.

It was found that actual mechanical properties of tested OEM GMT bumpers were significantly less than specified by the manufacturer and that this significantly reduced the bumpers' real world performance. It was found that at speeds over 5mph the GMT bumper beam fractured and completely separated, while the HSS bumper beam did not. This leads to significant differences in the energy absorbed by the bumper beam designs at speeds higher than 5mph. It was also found that the bumper design can affect whether the bullet vehicle is directed down and into the frame or up and into the trunk where little structure exists to absorb energy and keep intrusion out of the passenger compartment.

Crashworthiness, FEA, Bumper

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