C8 Momentum and Elastic-Plastic Vehicle Collisions: A *Daubert* Accuracy Analysis

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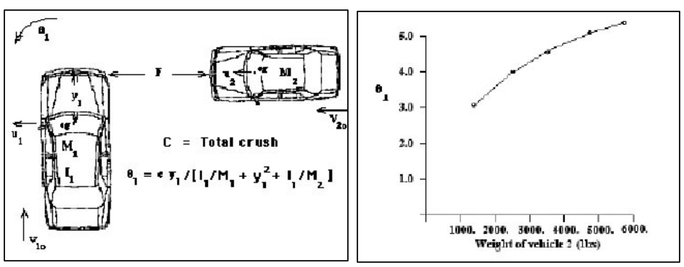
The goal of this presentation is to present to the forensic engineering community an analysis of the validity of a momentum and elastic-plastic model for vehicle collisions to examine the *Daubert* error requirement.

This presentation will impact the forensic community and/or humanity by examining the theory of three methods for predicting velocity in accident reconstruction. It makes clear that the method using preand post-impact motion in comparison with the highway witness marks is the most accurate. As such, it provides a means for guaranteeing the civil rights of defendants in criminal actions.

This paper will present an analysis of the right-angle impact between two 4-wheeled passenger vehicles that are defined by their dimensions, masses, moments of inertia, and vehicle crush. The equations of mechanics in impact are integrated using a Taylor's expansion of the impact force, proving that the error in the mean force is proportional to the time of impact if the first term in the series is defined by the impulse between the vehicles. The equations are also shown to be invariant with respect to the impulse on first integration.

The second integration to yield the displacements at impact is shown to have meaning only if measurable crush is found on the vehicles. By using an elastic-plastic model for crush and demonstrating that the elastic motion is dominated by the plastic crush, closed-form expressions are derived for both the *time-of-impact* and the *mean force of impact*.

The error analysis for the *Daubert* requirement on accuracy continues with the developments from the equations of mechanics. By using the *time-of-impact* derived from the crush, the angular changes of a target vehicle of 4105 lbs (1866 kg), moment of inertia of 2285 lb sec ft^2, and bullet vehicles between 1500 lbs (682 kg) and 6000 lbs (2727 kg), shown in the figure below, were found.



The results for angle changes are shown to yield an error in angle less than 5^o that produces a cosine of 0.996 and a sin of 0.087. This proof demonstrates that impulsive motion theory can be used to study preand post-impact motion, validating the requirement of *Daubert* on knowledge of error.

By using a standard ASTM tensile test for a body part of an American car, the theory of plasticity is shown to closely approximate a perfectly plastic steel model, at least for moderate strains near the yield point. The error induced by ignoring *strain hardening* is estimated and the resulting errors in approach and departure velocities are determined for the common pair of vehicles in the example.

Finally, the *chaos* in crash testing of vehicles to determine the coefficients of crush is examined relative to the requirements of *Daubert*. In this study, the literature has been searched to examine multiple crash tests of identical vehicles in identical crashes. The *theory of chaos* is shown to apply to these crash tests because the deformation of the vehicle in crush is dependent on small changes in the initial conditions of the crash in both the structural geometry and in the angles of approach. *Chaos* appears in the results because these small changes in initial conditions cause disproportionately large changes in the folding patterns of the vehicle panels and beam supports. As is predicted by the *theory of chaos*, derived crush coefficients have considerable variation. Even with a large sample size, there can be no guarantee that a given crash will follow one family of crush parameters over another. It would seem that the *finite element method* would yield the best results, assuming that the vehicle is available so that the crush sequence can be defined and measured. This makes the analysis a deterministic model.

The closure of the paper describes the validation of the theory of the basic equations of mechanics

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through the study of impulse-momentum. It cautions the accident reconstructionist to make sure that predictions for the motions of the vehicle come from both the *witness marks* on the highway (using photogrammetry) as well as any crush and momentum simulation attempted. Of particular concern is the use of such impact models to determine speed when it is known that *chaos* is present in the crash tests from which crush data are determined. The authors' conclusion is that it is better to use the equations of dynamics to study the highway *witness marks* than to depend on v calculations of a chaotic system.

Impact, Momentum, Chaos

