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VEHICLE ACCIDENT RECONSTRUCTION TECHNIQUES

Presented to

Investigative Engineers Association

November 13, 2009

Las Vegas, Nevada

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Abstract: *The purpose of this paper is to present both a review of vehicle accident reconstruction techniques for various accident conditions and also to introduce the reader to problem concepts for unique conditions.*

Prior to 1925 vehicle accident investigation and reconstruction was unheard of (and rarely needed). In 1929, the Evanston, Illinois Police Deapartment created an Accident Prevention Bureau which expanded to several cities and states. Essentially these programs were established by police officers for police officers to (1) gather information in a logical and procedural manner and (2) to get convictions. The Northwestern University Traffic Institute was established in 1936 and four years later the first edition of the *Accident Investigation Manual* was published.

TERMS AND RELEVANCY

Seemingly obvious should be the difference between the terms, vehicle accident investigation and vehicle accident reconstruction; however, many experts stress their experience in investigation while testifying to reconstruction techniques. Typical of this class of experts are active and retired police. That may be a reasonable phenomenon since police personnel are typically first trained in investigative techniques while some seek additional training in analytical principles.

It is not uncommon for the police-trained experts to emphasize his or her advanced training at prestigious schools of higher learning such as Northwestern University, University of Florida, or Texas A & M. While it is admirable these individuals seek advanced educational opportunities, weeks of training is unlikely to prepare anyone to compete against the expert with years of formal college training in principles of engineering and physics. Simply put, attendance at a traffic seminar held on university property does not equate to attendance at a university for credit.

Several years ago at least two organizations were created to advance the field of vehicle accident reconstruction and to promote their practitioners. Magazines specializing in accident reconstruction were published, various computer programs were offered, a “seal” was even offered with the with the claim the seal would provide the user a seal “just like those used by engineers.”

Sadly, a polarization between engineers and police-trained analysts currently exists. More disturbing is confusion or potential biases experienced by judges and juries regarding the qualification of the opposing experts. While I do not see this trend changing in the near future, the expert, police-trained expert or engineer, must advise the attorney of his/her strengths and the opposing expert’s weaknesses.

Vehicle accident investigation collects and disseminates information hopefully in a complete and thorough manner. The **Investigative Engineers Association** provides an extensive outline and checklist for vehicular accident reconstruction investigation. Ideal and thorough as it may be, by the time a professional expert is retained, the scene investigation is typically long past. The engineer/reconstructionist is generally left with a police report, possible witness statements and, dependant on the severity of the incident, a diagram and police photos. Fortunately, many scene diagrams are now created as a result of electronic distance measuring devices.

At the other end of the spectrum, vehicle accident reconstruction may include investigation techniques but extends to higher analytical principles, essentially those of Newtonian physics. Therefore, the collection of data including measurements, photographs, road and traffic observations, etc., are critical elements of investigation. The ultimate goal is often reconstruction.

Reconstruction techniques may include evaluation of crush damage, analysis of pre and post-impact positions, conservation of linear momentum principles, and other techniques, all of which are based on application of engineering and physics principles.

VEHICLE ACCIDENTS

For purposes of this presentation, the following discussions relate to three of the most common types of vehicle accidents based on my professional experience. The first to be discussed is the condition wherein one or more vehicles either leaves a roadway and strikes an object or when two or more vehicle collide. A second category is what is typically categorized as a “low-speed” impact, which generally leaves little visible damage to either vehicle. Finally, motorcycle impacts will be presented. Strictly for the sake of brevity, roadway design and conditions, traffic control, and pedestrian accidents will not be presented herein, although that may be a considerable portion of the expert’s experience.

One or More Vehicles (Autos/Trucks)

When a vehicle leaves a roadway, assuming an obstacle is in the path, there is measurable damage as a result of the impact. Numerous sources are now available for estimation of coefficients of restitution, the aspect of material deformation, which will attempt to retain its original shape. The damaged vehicle will typically remain in a measurable crushed configuation. Permanent damage (plastic deformation) remains following the removal of force. Residual crush can be measured and compared against tested deformation vs. Impact speed into a stationary object.

Work and energy equations are then used to determine the ultimate striking speed of a vehicle. Work is simply energy performed. **Conservation of Energy** is an often misunderstood principle and is freely utilized by many experts without a true understanding. Essentially this principle establishes that energy is neither created nor destroyed and as such is conserved. Accordingly, if one combines all the relevant energy (sans thermal and noise), one can equate all energy related elements such as speed.

For example, we can determine the initial speed of a vehicle of a vehicle while sliding by the formula:

$$E_s = wfd$$

where *w* = weight of vehicle, *f* = sliding friction, and *d* = distance traveled. This value gives us the minimum energy value without damage or other energy dissipation.

Assuming damage to other vehicles, the energy resultant from damage is calculated

$$E_1 = w_1 v_1^2 / 2g$$

where *w* = *weight of vehicle, v* = *velocity* in feet per second, and *g* = *gravity* at 32.2 ft/sec^2. (V_1 is equivalent speed into an unmovable object obtained from crush data charts or tables for a specific make of vehicle or a similar model.)

Likewise, the damage to additional vehicles is calculated as needed. In a two vehicle accident, damage is attributed to the striking vehicle by calculating E_2 and E_3.

Conservation of Energy (for the example above) is therefore:

$$E_T = \sum E \text{ or } E_s + E_1 + E_2 + E_3 + \ldots$$

To calculate (the speed aspect of) velocity for the striking vehicle at the inception of skid, we then use the formula:

$$v = [2gEt/w_1]^{1/2}$$ (where w_1 is the weight of the striking vehicle)

Another widely accepted method is **Conservation of Linear Momentum**. This principle requires some combination of pre and post-impact speed and direction. The simplest example of this principle (as I use to explain to a jury) is a game of pool. Everyone has experienced a game of billiards or pool or at least warned their children of its potential detriments later in life (as in “an ill-spent youth”)!

If one can visualize a cue ball striking an “8 ball” at an angle with reasonable striking force, one can predict the resultant movement of both balls following impact. The same principle applies to striking vehicles.

In a two or more vehicle impact, the post-impact directions are often not well established. In some impacts, the difference between the masses (weights) of the two vehicles is occasionally too great to assume a non-plastic impact such as exists with two pool balls. If the vehicles are similar in construction and the missing criteria is abundant, then the principle of conservation of momentum is a valid process. I suggest, however, to be on the conservative side, one may establish a range of values in utilizing this principle.

Low Speed Impacts

It is my firm belief that, of all the elements of vehicle accident reconstruction, low-speed impacts is the most mis-understood and misapplied. Analysis of these events by experts often verge on “junk science!”

The following statements are occasionally heard in testimony.

> *Since the impact speed of the striking vehicle was found to be extremely low, virtually no energy was transferred to the occupants of the struck vehicle.*

Energy is always, without question, transferred to a struck vehicle and to its occupants in an impact. The only question is the degree of impact. Isaac Newton’s *1687 Philosophiae naturalis pincipia mathematica* established principles of motion used to this day. Newton’s second principle essentially states that an object will move in the direction of a striking force, relative to the weight of the object being move and the force generated. Nowhere does this principle state an object will not move if struck. Impact energy causes motion.

> *Based on a calculated speed of less than 3 MPH, no injury could have occurred.*

Be aware, this comment should only be offered by medical practitioners. In any event, this statement is statistically false. Statements such as this are generally offered by a defense expert offing a published document (often by the Society of Automotive Engineers, SAE or similar entity), for the purpose of offering the result of tests performed and funded by said agencies in order to determine the likelihood of injury. Before proceeding, a legal affidavit, authored by Stephen Daum, legal administrator for SAE, concluded that, the opinions offered via SAE articles are not necessarily those of SAE. This document also establishes that the articles are not necessarily peer-reviewed.

While it may be impressive to hoist a prestigious looking document as a credible source, the impact/injury studies are often laden with biases and not based on scientific credibility.

For example, a study may be offered where 5 employees of XYZ firm were subjected to 5 tests each where a Tucker automobile (God forbid) with its doors removed for ease of video, was struck from behind by a Ford Pinto. I suggest a consideration of the following:

- 5 employees do not constitute a statistical sample.
- 5 employees reeks of bias.
- 5 employees are aware of the potential impact, therefore no surprise factor.
- 5 tests do not constitute a statistical sample.
- Doors removed on any vehicle alters the structure of the vehicle.

Statistical sampling is a complex subject; however, the general principle is that the sample

population should be representative of the overall group. A proper sampling of 300 million people potentially subjected to a rear-end impact at some time may consider the following elements. Assume the proper sampling population considers the following categories:

Population Classification	**Minimum Number**
Male/female	2
Age (consider 0 - 80 years old in groups of 10 years)	8
Restrained/non-restrained	2
Alertness (pre occupied, aware, absolute)	3
Physical Stature (below avg., avg., above avg.)	3
Interpretive Value (min., avg., max.)	3
Population Size per Group (assume 10)	10
Cumulative Number	**8640**

A minimum of 8640 individuals should be tested assuming the above minimum criteria. Five persons in one or two automobiles subjected to 5 or so tests is simply not statistically relevant.

> *Lacking physical evidence of any damage, the striking speed could not have exceeded 5 MPH, which equates to no potential for physical injuries to the vehicle's occupants.*

Disregarding the afore-referenced statistical scenario, consider that the Federal Vehicle Information and Cost Savings Act of 1972 mandated a 5 MPH barrier standard. This standard essentially required that a vehicle should be able to sustain an impact into an immovable barrier at 5 MPH without significant damage to the doors, truck, gas tank, etc. This standard was reduced to 2.5 MPH as a result of an effective manufacturer's lobby; however, by the time the reduction occurred, 5 MPH bumpers were common. Logic dictates that if a bumper must perform to a 5 MPH standard, a factor of safety may suggest a 6, 7, or 8 MPH design. For this reason, bumper performance often exceeds the manufacturer's published standards.

Often, a removal of the flexible bumper cover will reveal distortion or compression of bumper isolators or damage to the molded structure hidden by the bumper cover. Suggested sources of additional information regarding this issue are: King, David J., Siegmund, Gunter P., MacKinnis Eningeering Assoc, Ltd, SAE Technical Paper No. 930211, SAE International, Warrendale, PA, 1993, and Presswood, Gary A. ScD, PE, *Myths of Low-Speed , Rear-End Impacts Revealed*, www.accidentexpert.com.)

Motorcycle Accidents

Principles of motorcycle accident reconstruction often do not follow those of vehicle accidents. Perhaps the most obvious issue is the disparity between a motorcycle and a larger vehicle or immovable object. The expert is most often incorrect in utilizing Conservation of Momentum Principles to establish elements of motorcycle impacts. The primary issue is one of weight and structure differences. A motorcycle, upon impact, will collapse upon impact much different than that of a larger automobile or truck. Also, drag factors are considerably different for motorcycle tires and the all too common motorcycle sliding on its side. Finally, motorcycles rarely move any significant distance following a broad-side impact. Note the following excerpt:

> *In many cases the vehicles and motorcycle operator (and motorcycle passenger, if present) travel very little after the collision. Occasionally a momentum analysis is attempted. Rarely does this work well. The momentum analysis is quite sensitive to heading and departure angles when the angles of approach are nearly collinear and the weight difference between the colliding vehicles is fairly large[1].*

In the event of a motorcycle's frontal impact, the distortion to the forks is often the best indicator of striking speed. A problem exists, however, in that there are a great number of motorcycles of differing designs. To add to that issue, there have been few studies regarding the speed results of distorted front forks. It should be obvious the structural differences between the extremes of a motocross motorcycle and a Harley Davidson Softail. The same differences apply to all motorcycles unless one can locate a credible study and apply it to a similar vehicle.

CONCLUSION

It has been my intent to clarify some misconceptions among reconstruction experts and to prepare the expert for adverse opinions and issues of credibility. Furthermore, the expert is cautioned that the trier of fact (i.e, jury) possesses little technical knowledge. As an expert, you must present your analysis in an authoritative manner hopefully superior to that of the opposing expert.

The application of proper techniques critical to successful reconstruction for the event at hand. While computer programs can be extremely valuable to an expert, the same principles may not apply to every event. Therefore, your best advantage is your professional standing, experience, and knowledge .

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[1] Fricke, Lynn B. Editor, *Traffic Accident Reconstruction*, Vol. 2 of The Traffic Accident Investigation Manual, Northwestern University Traffic Institute, 1Art. 7, pg. 74-16, 1990.