Impact and Damage Analyses of Motor Vehicle Accidents – Commonly Asked Questions

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General Overview

- Basic Terms in accident reconstruction and injury analysis – delta-V and acceleration.
- Methods of speed determination in accident reconstruction- tire marks, momentum.
- Event Data Recorders – Air Bag Control Modules.
- Crush Analysis.
- Seat belt Evidence
- Lamp Evidence

Delta-V (ΔV)

- A primary description of crash severity and injury potential is “Delta-V.”
- Delta-V is the change in velocity of a vehicle due to a collision. The difference between a vehicle’s speed at impact and immediately after velocity.
- \( \Delta v = v_{final} - v_{initial} \)
**Delta-V (ΔV)**

Red vehicle is initially traveling at 10 mph. After impact it is slowed to 3.2 mph. Delta-V is the difference between both speeds: 3.2 - 10 = -6.8 mph.

Blue is initially stopped or 0 mph. After impact it moving at 7.7 mph. Delta-V is the difference between both speeds, 7.7 - 0 = +7.7 mph.

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**Definition of Acceleration**

- While delta-V is often used, the forces that an occupant experiences is actually related to the acceleration.
- Acceleration is the change in speed over the time of the collision.
- Acceleration, \( a = \frac{\Delta v}{\Delta t} \). The numerator is the delta-V and the denominator is the "delta-t."
- Delta-t is the period from the time when a vehicle starts contacting the obstacle to the time when the acceleration caused by the crash diminishes to a negligible level.
- Estimates of delta-t are usually based on rigid barrier tests which overestimate the severity of the crash.
- Acceleration is generally expressed in terms of "Gs".
- \( G_s = \frac{\text{Acceleration}}{\text{gravity}} \)
Common Methods of Speed Determination:

- Energy Lost to Road Surface
- Linear Momentum Analysis
- Speed from Event Data Recorder
- Energy Resulting in Vehicle Damage - Crush Analyses

Speed from Skid Marks & Different Tire Markings

\[ v = \sqrt{60 \times f \times d} \]

Typical values of friction - \( f \):
- Dry asphalt or cement: 0.7 - 0.8
- Wet asphalt or cement: 0.6 - 0.7
- Ice, loose snow: 0.3 - 0.5

Example, if the length of a skid mark is 150 ft on dry asphalt, then \( d \) is 150 and \( f \) is 0.75.

\[ v = \sqrt{60 \times 0.75 \times 150} \]

\[ v = 50 \text{ mph} \]

Motorcycle Skid Marks

Typical single axle skid from motorbike; basic equation does not in this example.
Yaw Marks

Yaw marks are created when a vehicle starts to slip sideways and the tires are rotating. The forces created by the turning motion are greater than the available roadway friction. Therefore, the vehicle slides or yaws.

Distinct diagonal marking are characteristic of yaw marks.

Speed from Yaw Marks

Speed determination requires the radius of path to be known.

Skid Marks and Yaw Marks

Direction of travel

Direction of travel

Right Rear Yaw Mark

Left Rear Yaw Mark

AOI
Skid marks for right rear axles only; dual tires on rear create 2 parallel markings.

Post impact inspection of tractor showed that none of the left side brakes were functional.

Collision Speed Analysis – Speed Determination of both vehicles.

\[ m_1 V_1 \cos(\theta_1) + m_2 V_2 \cos(\theta_2) = m_1 V_1' \cos(\theta_1') + m_2 V_2' \cos(\theta_2') \]

\[ m_1 V_1 \sin(\theta_1) + m_2 V_2 \sin(\theta_2) = m_1 V_1' \sin(\theta_1') + m_2 V_2' \sin(\theta_2') \]

\[ \varepsilon (V_1 - V_2) = (V_2' - V_1') \]

\[ m_1 V_1^2 + m_2 V_2^2 = m_1 V_1'^2 + m_2 V_2'^2 + I_1 \zeta_1'^2 + I_2 \zeta_2'^2 \]

\[ m_1 (V_1' - V_1)^2 + m_2 (V_2' - V_2)^2 \]

Linear Momentum Analyses – Speed Determination of both vehicles.
Speed from Event Data Recorders (EDR)

EDR Functions within the Air Bag Control Module:

Primary Roles:
- To detect the occurrence of a crash, predict the severity of the impact, evaluate the appropriateness of air bag deployment, and, if needed, send a command to deploy the air bag.
- Perform continuous system monitoring and failure detection.
- Receive inputs regarding occupants and produce output for restraint deployment.

Secondary Role:
- To retain portions of the input data in electronic memory.

Not an intended Role:
- “Black Box.”

Certain Make and Model Vehicles with Accessible EDR Data

- Acura 2012 to 2014
- BMW 2013 to 2014
- Chrysler 2006 to 2014
- Dodge 2006 to 2014
- Fiat 2012 to 2014
- Ford 2001 to 2014
- GM 1994 to 2014
- Honda 2012 to 2014
- Infiniti 2012 to 2014
- Isuzu 1998 to 2009
- Jeep 2006 to 2014
- Lancia 2012 to 2014
- Lexus 2001 to 2014
- Lincoln 2006 to 2014
- Mazda 2011 to 2014
- Mercedes Benz 2014
- Mercury 2001 to 2011
- Mitsubishi Limited Vehicles 2007 to 2010
- Nissan 2012 to 2014
- Ram 2010 to 2014 (also Dodge predecessor)
- Opel 2013
- Rolls Royce 2013-2014
- SAAB 2005-2009
- Saturn 1995 to 2010
- Scion 2004 to 2014
- Sterling Bullet series 2008 & 2009
- Suzuki 1995 to 2014
- Toyota 2002 to 2014
- Volkswagen 2000 to 2014
- Volvo 2011 to 2014

Some of possible data, which is typically recorded in 1 second intervals for 5 seconds or more in some vehicles, includes:

- Speed
- Braking
- Steering Angle
- Order of Impact (Toyota)
- Seat belt Buckled
- Accident Severity – Delta-V and acceleration
Impact speed from Crush Only? No!

- Crush analyses predicts the delta-Vs of each vehicle and the closing speed – not the impact speeds.
- Closing speed provides the relative speed of each vehicle, not the traveling speed.

What is the impact speed of this car?

Recorded Delta-V from Vehicle's EDR

SDM Recorded Velocity Change 5.77 mph
Delta-V is related to the energy dissipated in the deformation process and the closing speed, but not necessarily the speed of a vehicle. As there really isn't a great deal of damage, a near 6 mph barrier speed seems reasonable.

Vehicle Speed 88 mph. Pre-Crash EDR downloaded from vehicle

Impact speed from Crush Only? NO!

- In a two car crash the damage profile can be used to approximate the delta-Vs and the closure speed between the two vehicles.

- In this case the bullet vehicle was traveling at 88 mph and struck the rear of vehicle that was traveling at approximately 75 mph. Closing speed = 88-75=11 mph. The sum of the delta-V's sustained by each vehicle is the closing speed.
Crush Analysis

Crush analysis provides an analytical way of determining how much energy and Delta-V was expended during the crushing process.

Crush Analyses requires a comparison between the deformed and un-deformed configurations. Comparisons can be performed by:
- Measurements
- Laser mapping
- Photogrammetry

Crush Analysis
Crush Analysis

Photogrammetry allows photographs to be converted to distinct mathematical points in a three-dimensional space. Can use own camera or photographs taken by an unknown camera. However, photographs must have sufficient angles to define each target point and must be sufficient in numbers.

Outline of exemplar vehicle superimposed on accident vehicle.

Digitized model.
Crush Analysis

Crush analysis provides an analytical way of determining how much energy and Delta-V was expended during the crash. Useful for injury expectation.

Can relate frontal and rear crash test results to specific accident vehicles. Therefore, if the stiffer vehicles shows more crush then the weaker vehicle, then report event is not possible.

Can determine how much force is required to generate the demonstrated damage. Newton’s 3rd Law of Motion, required opposite and equal reactions. Therefore, if force required to generate the damage demonstrated on one vehicle is much greater than the force required to generate the damage demonstrated on the vehicle, then the reported event is not possible.

Evidence of Seatbelt Usage

Dyeing abrasions on load bearing surfaces.