Analysis of Side Underride Crashes
Part 1 – Misconceptions and The Problems

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Introduction

A number of years ago the author visited an accident reconstruction expert's office. The expert had a small shop and was measuring the force it took to bend down an upper A pillar from a passenger vehicle front clip. This was being done so that the force could be used in a speed calculation for a car that had traveled under a trailer, of a tractor-trailer unit. The expert explained that there was little or no information on side underrides. The conventional computer programs that were used did not include side underride and override speed calculations as part of their protocol. Research showed that there was no established method to document and reconstruct the speed of a vehicle that underrode a trailer or any object where there was only damage to the roof and roof support structure. The reconstruction applications varied and yielded a wide range of answers for the same underride crash. Detailed below are several misconceptions in the analysis of underride crashes.

A. Improper and Under Reporting

Accident analysis studies have shown that the number of fatalities that occur in side underride cases are about 70% to 80% of those that occur due to rear underride. But the underride fatalities, in general, have been shown in a study by Braver, et al, to be significantly under reported in the Fatal Accident Reporting System (FARS). The apparent reason for the under reporting is the lack of adequate identification and coding of the accident as an underride incidence in the data collection system. Braver reports that some improvements have been made in recent years, but the system still needs improvement in the quality of police reporting.

The police report, even when an underride is recognized, seldom includes measurements of the trailer, identification and/or location along the rear or side of the trailer of marks produced by the underriding vehicles upper A pillars. There are rarely good supporting photographs of trailer damage especially to the undercarriage and trailer components. The police do not record the angle of the trailer at impact; therefore, if the angle is necessary, then it must be established from the photographs, if available. Usually the underriding vehicle is traveling straight in its lane on the approach to the truck, however if there is evasive steering and the underriding vehicle is at an angle to the trailer, that angle is rarely documented and reported. The angle of impact does effect the impact velocity calculations.

Sometimes the underriding vehicle will slide along the trailer frame and rotate as it is traveling under the trailer. This slide and rotational distance measurements are usually not noted.

At other times when a vehicle leaves the travel way, the vehicle will underride other objects such as a low hanging tree branch or travel under construction equipment. When it only involves the roof and roof support structure of a vehicle, it is still considered an underride collision.

B. Incorrect Investigation and Reconstruction - Misconceptions

The most common speed calculation error in an underride collision is the application of the conservation of linear momentum and energy calculations where it has been assumed that the trailer was pushed laterally during the impact. The physical evidence utilized in support of the lateral distance is a gouge mark on the roadway where it is assumed that the undercarriage of the engine or front suspension of the underriding vehicle was forced down to the road surface.

The distance from the gouges to the edge of the trailer is approximately 8 to 12 feet. This is generally carried over from the investigator's experience with typical crashes, where the vehicle front undercarriage may be forced downward, which often results in gouges in the road surface. Contrarily in an underride collision, the front of the car is typically lifted up during the initial stage of the underride, as the roof panel begins to offer resistance during the early deformation period of the crash. This causes the rear of the vehicle to angle downward. Depending upon the rear overhang of the vehicle and ground clearance to the bottom of the bumper and other undercarriage components (tie down hooks, mufflers, tailpipes etc.), these components or the rear bumper can also contact the road surface leaving scrapes and gouges. It is these gouges that are commonly misinterpreted as frontal component gouges from downward compression of the vehicle undercarriage during the crash. There have even been instances where the investigating officer or accident reconstructionist misconstrues the gouges as originating from the trailer as it is supposedly sliding sideways.

When the investigator then measures from the gouges to the trailer after the accident, he has established the plane that the contact edge of the trailer occupied as it supposedly forced the car downward. This then becomes the distance that the trailer 'moved laterally' and is inserted as a distance variable for post crash speed calculation, which is used in the momentum formula. This improper initial speed reconstruction approach typically over estimates the speed of the vehicle as it collided with the trailer. Depending upon the weights and the calculated post impact speed, the over estimation can be a large magnitude. From time to time the reconstructionist will consider rotation points for the trailer and then calculate the impact speed. This can result in errors that are either greatly overestimated or underestimated.

In actuality, when a car impacts the side of a trailer (and the trailer is not sliding sideways at the time), unless there is interaction between the underriding vehicle body below the belt line with some substantial underbelly structure on the trailer, there is very little movement of the trailer. In most of the side underride crashes that the authors have conducted using empty trailers attached to trucks, if the trailer slid laterally at all, it was only for a distance of approximately two or three inches. On some occasions the trailer only rocked back and forth, with very little noticeable lateral movement at all. Even when the vehicle stuck the dollies, the slider frame and the duals, there was little lateral trailer movement. There is also an upward vector of the trailer in the Z-axis, however this has not as yet been quantified. The upward trailer movement is in part determined by the crush profile of the underriding vehicle roof and roof support structure. In some of the underrides, the roof structure folds over and forms a ramp or wedge that raises the trailer and allows more compression of the vehicle.

Because of the lack of underride data, many investigators tend to overestimate the speed of a vehicle. This overestimation is greater if the vehicle goes completely under the trailer and out the other side with some amount of residual speed. Professionals attending the ICA underride crash tests were amazed at the low speeds causing the large amount of deformation to the vehicle roof structures. Some vehicles completely pass under the trailers at speeds in the upper twenties. Very few passenger vehicles will survive a crash speed above 35 mph and not pass completely under the trailer. The exceptions to this are vans and full size station wagons.

To understand the underride crash, the investigator should look at several factors such as:

a) angle of the impact
b) angle of the crush to the roof
c) crush area of the roof
d) crush pattern of the roof
e) deformation to the vehicle pillars and frame
f) lateral tire marks from either the trailer or the underriding vehicle

g) interaction between the vehicle with any trailer components (i.e. dollies, rear dual slider frames, rear dual wheels, cages for spare tires and/or cargo)
h) post crash movement caused by the tractor trailer if it was not stopped at impact
i) exit speeds
j) stopping distance from the off side of the trailer in the event of a complete underride
k) document the impact location on the trailer

In one crash test a vehicle traveled completely under the trailer and the right C pillar was not completely crushed. The car compressed downward and lifted the trailer during the crash. In other crash tests the roof collapsed to the B pillar and then buckled the car at the rocker panel where the lower B pillar attached.

One factor that stands out from testing is when a typical passenger vehicle underrides a trailer and the speed is above 15 mph, there is a great potential to have serious head injury or death for front seat occupants. This injury potential is more likely for the occupant(s) in the seat(s) on the side that the leading A pillar makes contact to the trailer in an angled impact.

C. Component Damage

A trailer or straight truck typically has components that hang down from the trailer floor sub frame. These components include:

1. Spare tire hangers
2. Dollies
3. Underride bars
4. Tires and suspension components
5. Rear axle slider frames
6. Trailer undercarriage frames
7. Special trailer components

Each of these components is different in nature. They are designed for totally different uses, which means that they deform in different ways when involved in a crash. When doing speed analysis of an underriding vehicle that has been damaged by and caused damage to these types of components, the damage to the underriding vehicle and to the component(s) must be assessed. For example, a simple underride bar or tire hanger cage offers very little resistance to a vehicle that strikes them from the side because they were not designed for lateral loads. The damage may vary from the components connections to the trailer simply separating to twisting and bending.

The damage caused to a vehicle contacting these components varies in location and pattern. The impact damage is narrow when striking the trailer dollies and it is wide when striking the dual tires and wheels. It may be limited to the side panels of the vehicle or the outer metal panels of the hood or trunk. The peeling of outer sheet metal and contact to ‘hollow’ points on the vehicle do not slow the underriding vehicle down to any great extent. After all the damage is evaluated the information can be incorporated into calculating the initial speed range.

Vehicles with strong vertical members at the B, C or D pillars can cause the vehicle to bend at the rocker panel attachment point at the base of the respective pillar. This has been termed ‘bend down’. The “bend-down” condition was noted on several of the crashes and occurred as the forces were transmitted down the vertical member of the central and rear pillars to the rocker panel. The large moment arm of the central and rear pillar caused the rocker panel to deform at the base of the lower B pillar. The upper part

of the B pillar shifted rearward causing the entire rear of the car, rearward of the pillar, to bend downward.

D. Vehicle Roof Types

Stiffness is not constant along the longitudinal roof structure as the roof is crushing in an underride crash. The stiffness will vary to some extent from one roof style of vehicle to another. Consider the roof structures for the following list of vehicle types:

1. Sedans (with large and small B pillars)
2. Hardtops
3. Convertibles
4. Station Wagons
5. Vans
6. Pickups
7. Motor Cycles

The sedans typically have an upper A, B and C pillar. The A and B pillars are sometimes continuous from the roof side rail to the rocker panel. But in some sedans the B pillar changes in size at the beltline and the upper B pillar is not a substantial structural member, that will resist a force that is acting from the front to the rear. The C pillars vary in fore-aft length. Many upper C pillars are not actual pillars but are only sheet metal that tears during the underride.

E. Type of damage to the roof and roof support structures in the underride

When the roof crushes it typically deforms in one of four patterns:

1. Roof Crush
2. Roof Fold
3. Roof Wedge
4. Combination Roof and Below the Beltline Body Damage

The contact point on the upper A pillar, which is related to the relative height of the underriding vehicle to the lower edge of the trailer, are some factors that determine the damage type. Each pattern will cause slightly different deformation to the roof support structures. The type of damage should be noted and photographed.

F. Type of damage to the vehicle below the beltline in the underride

Vans, pickups and other vehicles where the top of the hood is as high as the bottom of the overriding vehicle may display additional damage to the vehicle that extends below the beltline. The damage can range from compressed sheet metal to the displacement of structural components. As testing continues information is being developed that will allow a more refined speed analysis for these types of vehicles and damage patterns.

Summary

The problems as noted above exist because there is a general lack of information on the side underride crash. Rear underride crashes were studied and yielded some helpful information. This led to a series of trailer side underride crash tests that were performed to determine if there were sufficient relationships between different body and roof styles to allow the formation of a general formula for underride analysis of a vehicle where only the roof and roof support structure of the vehicle was damaged. It was found that existing analyses did not account for the above-mentioned factors. Part II, appearing in the next issue, will contain the general formulation for underride crash analysis, which accounts for many of the differences between 'classic' crashes and underride crashes.