C11 Observed Damage Patterns of Narrow Object Impacts

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Introduction: Frontal traffic collisions produce unique vehicle deformation patterns that depend on the object that is struck. Oftentimes the investigating engineer can quickly determine what category of object was impacted based on the observed residual collision damage, because collisions with other vehicles, concrete walls, or trees will produce unique crush patterns. Impacts with narrow objects such as trees or utility poles create knife-like deformation patterns. Narrow object impacts often create deformation that penetrates deeper into the vehicle's structure when compared to an impact with an object that distributes collision forces over a greater width of the vehicle at the same speed. Induced damage is created when the vehicle wraps around the narrow object, and pulls the lateral components at the left and right inward.

The deformation pattern of two vehicles impacting trees will be presented. A damage energy analysis was used to determine the impact speed from the measured longitudinal collision damage and other scene information. The extent of vehicle damage and the subsequent structural compromises will be explored. The vehicle models in these two cases are the same and the vehicle weights are similar, but what is different is the location of the tree impact relative to the vehicle centerline. In the first case, the tree impact location is inches to the left of the vehicle centerline, whereas in the second case, the tree impact location is at the extreme left end of the bumper.

Collision Overview: The first case concerns a 1988 Nissan Maxima 4-door sedan (Nissan #1), containing two male occupants, a driver and right front passenger, traveling at approximately 55 to 65 mph. After crossing a broken double-yellow centerline while attempting to pass slower traffic ahead, the Maxima was struck on the right by another vehicle also attempting to pass slower traffic. The Maxima's heading was forcefully redirected to the left, and it subsequently entered the left-hand shoulder. Differential friction between the inadequately packed, loose shoulder material and the asphalt covered road created an unfortunate situation for which the driver could not recover. The vehicle entered the shoulder and then re-entered the roadway several times until it ultimately struck a 12- inch diameter tree head-on located approximately 17 feet measured perpendicular from the road.

The second case concerns a 1987 Nissan Maxima 4-door sedan (Nissan #2), containing only a female driver, traveling in the #1 lane at approximately 45 mph. A vehicle in lane #2 suddenly veered left into lane #1, sideswiping the right side of the Nissan. The impact caused the Nissan driver to lose control, suddenly steer to the left and rise over the 5½ inch curb of the center median, and then strike a 14-inch diameter tree head-on. Due to the offset nature of the frontal impact with the tree, the Nissan subsequently yawed counter-clockwise, and then rolled over passenger side leading, coming to rest on its wheels approximately 48 feet beyond the tree.

Energy Analysis: Both collision vehicles were inspected and the residual collision damage was measured across the front bumper using a suitable reference coordinate system. An exemplar vehicle was inspected and its front bumper was similarly profiled. Scale drawings were used to quantify the residual collision damage. Vehicle crush stiffness characteristics (A and B values) were calculated from available government-sponsored barrier crash tests. The Campbell model, assuming a linear relationship between energy and crush, was used to calculate the vehicle's pre-impact speed.

Nissan #1, including the two occupants, weighed approximately 3570 lb. It sustained 20 inches of average residual crush. The corresponding crush energy was approximately 1.941x10^6 in-lb. After impact, Nissan #1 came to rest very close to the tree. That is, Nissan #1 had very little post- impact energy. Its pre-impact speed was determined to be approximately 37 mph.

By comparison, Nissan #2, including the driver, weighed approximately 3330 lb. It sustained 20.7 inches of average residual crush. The corresponding crush energy was approximately 1.804x10^6 in-lb. After impact, Nissan #2 rotated away from the tree, and the vehicle subsequently rolled over. After calculating the post-impact energy, the pre- impact speed was determined to be approximately 44 mph.

Restraint System Performance/Driver's Injuries: The vehicles involved are equipped with outboard

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front seat passive motorized shoulder belts and manual lap belts. Studies have shown that only approximately one-third of the driving population wear the available manual lap belt. The remainder of the drivers forget to buckle it, or are completely unaware that a manual lap belt exists, and more importantly, is vital to the enhancement of their occupant protection system.

The driver of Nissan #1 suffered closed head injuries and facial fractures. He suffers from extreme mental deficit. The driver of Nissan #2 suffered closed head injuries and significant facial fractures. She continues to suffer from facial disfigurement.

Structural Response to Tree Impact: The collision energy of Nissan #1 and #2 are within 7 percent, but the structural responses of these vehicles are quite different. The response of Nissan #1 to the tree impact is unremarkable, and exhibits many of the characteristics often observed in narrow object impacts, including knife-like penetration from the tree trunk, a semi-circular damage profile, and the wrapping of the left and right fenders around the intruding tree. However, the damage observed in Nissan #2 that resulted from the offset nature of the impact is exaggerated, such that there is considerably more induced damage, i.e. the pulling toward the tree of the structures far from the area of contact damage. More importantly is the vehicle's response to the tree penetration and the vehicle deformation that is outside the left frame rail.

In response to the tree impacting outside the left frame rail, the vehicle side structures becomes vital to the structural integrity of the vehicle. In Nissan #2, the left front door beam separated from the vehicle, because the welds at the front and rear of the beam failed. The left front door hinge post and cowl moved approximately 10 inches rearward. Without the stiffness afforded to the vehicle by the door beam, the occupant compartment was compromised. Intrusion rearward into the occupant compartment was considerable as the instrument panel and steering system were thrust toward the driver.

Conclusion: The structural response of a vehicle in a narrow object impact is dependent on the location of the point of contact. Near centerline impacts result in frequently observed deformation and wrap around. However, if the point of contact is eccentric to the vehicle centerline and misses stiff frontal structures, then the lateral vehicle structures become more important in sustaining the integrity of the occupant compartment.

In the case of Nissan #1, the vehicle deformation and restraint system performance were sidelined in the suit against the State for improper maintenance and compaction of the shoulder material which was at the heart of the differential friction phenomena and subsequent loss of control. In the case of Nissan #2, the structural response of the vehicle and inadequate occupant protection resulting from significant vehicle intrusion was the foremost theory of the analysis.

Narrow Object Impact, Structural Integrity, Tree Impact