C4 Comparison of Vehicle and Occupant Kinematics in Bumper to Barrier vs. Hitch to Barrier Collisions

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After attending this presentation, attendees will have a greater understanding of the effect a towing hitch has on the vehicle and occupant accelerations as demonstrated in full scale barrier impacts.

Commonly it is believed that the additional structure of a trailer hitch will stiffen a vehicle's structure, thereby reducing the amount of vehicle property damage, while increasing the acceleration, Delta V and occupant loading within the vehicle. However, this is not generally the case. This presentation will show, through a specific physical example, a demonstration on how the presence of a hitch has the potential to increase the damage susceptibility of the struck vehicle's frame, to lengthen the collision dura- tion, and effectively cushion the impact for the vehicle occupants.

There has long been discussion regarding the effect on the struck vehicle and occupant accelerations in motor vehicle accidents that involve the struck vehicles' trailer hitch versus the bumper system. It has been theorized that the additional structure associated with the hitch strengthens and stiffens the vehicle structure, thereby shortening the collision duration, and increas- ing the accelerations experienced by the vehicle and occupant for a given amount of vehicle damage.

In a recent study researchers reported the results of two car-to-car rear- end impacts. While both struck vehicle acceleration durations were on the order of 140 msec and both average accelerations were 3 g's, the hitch equipped vehicle experienced a higher peak acceleration, 9.6 g's vs. 8.0 g's, a higher Delta V, 15.1 kph vs. 14.1 kph, and its driver dummy experienced higher peak lower neck acceleration, 8.9 g's vs. 6.7 g's, as compared to the control car without a hitch. In part, based upon these crash demonstrations, it was concluded that the addition of a tow bar *may* significantly increase the acceleration experienced by the struck vehicle and occupant.[1]

Conversely, it can be argued that the addition of a hitch increases the struck vehicle's frame damage susceptibility by structurally bypassing the bumper and by introducing an additional downward moment on the frame due to the eccentric loading that is not present without the trailer hitch. While the hitch may add structure to the vehicle, the increased damage susceptibility of the hitch-frame combination can actually be more compliant and provide a more effective cushion than the rear bumper.

It stands to reason that penetration of the hitch into the striking vehicle's front structures would effectively increase the cushion in a car-to-car impact by rendering the striking vehicle more compliant. In this demonstration, the effect of the increased compliance of a striking vehicle was eliminated by conducting barrier impacts. The effect of loading through the hitch was isolated by conducting 5 mph rear bumper to barrier and rear hitch to barrier impacts with a 1993 Dodge Grand Caravan equipped with a frame attached hitch receiver assembly.

Following the bumper to barrier impact, there was not any frame damage, but the Dodge sustained rear bumper reinforcement bar, bumper brackets and rear body panel damage, which is consistent with previous test results.[2] In the rear hitch to barrier impact, the Dodge sustained primarily frame damage at the forward portion of the hitch receiver assembly attachment to the frame.

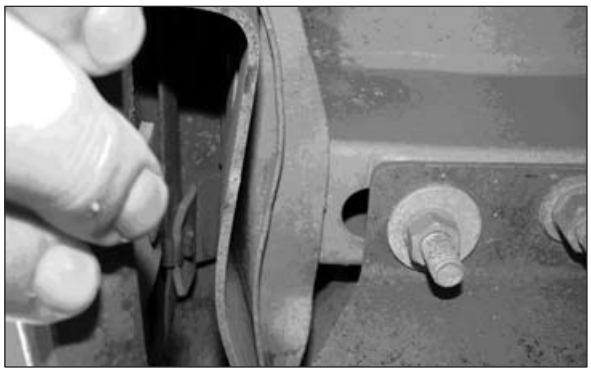

Figure 1: bracket damage in 5 mph rear bumper to barrier

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Figure 2: frame damage in 4.7 mph rear hitch to barrier

In addition to the barrier impact speeds and resultant damage patterns, vehicle and live human occupant accelerations, seat belt forces and seat back displacement data were recorded.

As seen in figures 2 and 4, as compared to the bumper impact, the hitch strike produced a significantly longer pulse, 225 msec vs. 90 msec. The resti- tution dropped from 0.3 in the bumper impact to 0.2 in the hitch strike, thereby producing a reduction in Delta V from 6.5 to 6 mph, respectively.

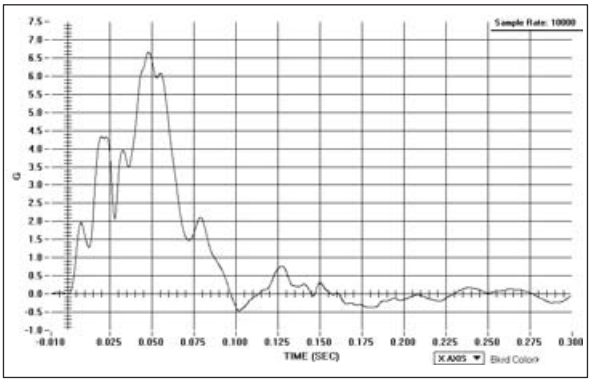

Figure 3: Dodge 5 mph rear bumper to barrier

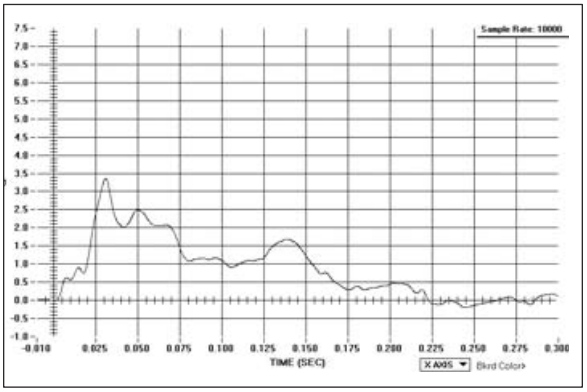

Figure 4: Dodge 5 mph rear hitch to barrier

The hitch strike produced occupant head, lower cervical, and lower lumbar accelerations that were approximately two-thirds that produced in the bumper impact. The dynamic seat back deflection was reduced from 5 to 4 inches, and the seat belt loading during rebound dropped from about 5 pounds to about 3 pounds.

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Commensurate with the above, the occupant described feeling the lower seat bar and being aware of a head to seat strike in the bumper impact, but described the hitch strike as much more “benign” without any awareness of any head to seat contact or any detection of the internal seat structure.

The performance of the vehicle in a hitch strike versus a bumper impact is dependent on the offset or eccentricity of the hitch relative to the frame, the amount of cushion provided by the bumper, the structural nature of the frames themselves etc. Certainly, there are circumstances where the addition of a hitch would decrease vehicle damage while increasing the vehicle acceleration, Delta V and occupant loading. However as demonstrated, the addition of a hitch can also significantly increase the vehicle damage susceptibility while decreasing the vehicle acceleration, Delta V and occu- pant loading. As such, this demonstration emphasizes the danger in over generalization and the importance of the application of sound engineering and mechanical principles in analyzing the role the hitch plays in a particu- lar motor vehicle accident.

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References:

[1] Krafft M, Kullgren A, Tingvall C, Boström O & Fredriksson R, “How Crash Severity in Rear Impacts Influences Short- and Long-Term Consequences to the Neck,” Accident Analysis and Prevention, 32 (2000) pp 187-195.

[2] “Low Speed Crash Tests: 1994 Passenger Vans,” Insurance Institute for Highway Safety, Arlington, VA, January 1994.

Hitch, Barrier, Testing

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