Newton on Motorcycle Collisions

A frequent question at the EDC customer technical support desk is “Can I use HVE to study motorcycle collisions?” During the pre-impact phase, HVE is perfect for producing a time-distance study to determine avoidability. You get a *free* visibility study to boot! But, what about the collision? To get the best possible answer, we decided to ask the man himself, Sir Isaac Newton.

EDC: Thank you for coming back for this interview. So tell us, can we study the dynamics of a vehicle vs. motorcycle collision?

SIN: In a word, *NO*. I mean, you can do the calculations, but the result is worthless!

EDC: Why is that?

SIN: If you believe in my laws of motion, the answer lies in my second and third laws.

EDC: Please explain.

SIN: OK, according to my third law, the collision force on the vehicle is the same as the force on the motorcycle, but in opposite directions. Now, according to my second law, the force on each object is equal to the product of mass times acceleration. In equation form,

$$F_1 = -F_2 \quad \text{(3}^{\text{rd}}\text{ law)}$$

and

$$F_1 = m_1 a_1 \quad and \quad F_2 = m_2 a_2 \quad \text{(2}^{\text{nd}}\text{ law)}$$

Substituting for F_1 and F_2,

$$m_1 a_1 = -m_2 a_2$$

Now, since $a = dV/dt$ (thank goodness I also invented the calculus!), or $a = \Delta V/\Delta t$ for the entire collision interval, we can again substitute

$$m_1 \frac{\Delta V_1}{\Delta t_1} = -m_2 \frac{\Delta V_2}{\Delta t_2}$$

Since Δt is the same for both the motorcycle and the vehicle,

$$m_1 \Delta V_1 = -m_2 \Delta V_2$$

In the above equation lies the reason that the calculation of speed change for a motorcycle collision is worthless. A simple rearrangement results in

$$\frac{m_1}{m_2} = -\frac{\Delta V_2}{\Delta V_1}$$

Or, stated in words, the ratio of the speed changes during the collision is inversely proportional to the ratio of the masses. Note that I didn’t make any assumptions here, other than assuming my laws are valid (you can ignore Dr. Einstein, unless your vehicles are traveling at the speed of light). So the above result is true for every collision throughout the universe – whether you’re talking about a car hitting a pickup or a motorcycle hitting a car. And it doesn’t matter if you’re using a hand-held calculator, a fancy computer program or the back of an envelope.

EDC: Sounds good. So, what’s the problem?

SIN: It’s the *mass ratio*! When analyzing anything, one should always study the sensitivity of the results to the inputs. If you perform such a study by varying the ranges of the estimated input parameters (such as stiffness, crush, approach and departure directions – not to mention the fact that the motorcycle’s mass changes during the collision when its rider flies off) you’ll find that the range of possible speed change for the car (heavier object) is quite reasonable (say 2 to 5 mph), but the range for the motorcycle (lighter object) is huge! Say, 20 to 50 mph. So, if you use such an approach, the findings in your report would be something like, “The speed of the Cadillac at impact was 35 to 40 mph and the speed of the motorcycle at impact was 25 to 75 mph.” Now, if that’s helpful…

EDC: Now I get it. The calculation is valid, but it’s too sensitive to be useful. But what about studying a collision between a car and a fully loaded semi-truck? Don’t you have the same problem?

SIN: You sure do! Now, I have a question for you.

EDC: Fire away.

SIN: What’s a motorcycle?