AIR BAGS - ONE

The very mention of air bags evokes strong reactions. What was once heralded as the ultimate device for automotive crash safety is now viewed by some as a hazard. This article will attempt to look at air bags and assess their strengths and weaknesses as they are used in conjunction with other safety measures in automobiles.

Early occupant safety features were fixed seat belts, stronger passenger compartments, crush zones, primarily in front of the passengers, and an improved passenger compartment (removing protrusions and adding padding). In answer to complaints of the seat belts being confining, active seat belt restraint systems were installed.

An active lap belt for example is one where one end of the belt is on a roller, and the roller is free to rollup (spring loaded) or unwind when the belt is stretched. The active part of the device is a mechanical mechanism to stop the roller when there is a crash. Determining when there is a crash is the job of a sensor placed in the vehicle. The simplest sensor is a mechanical one built right into the roller mechanism. Explanations of how these mechanical crash sensors work are in many elementary physics books.

There are many automotive engineers and safety people who are opposed to these active devices on the principle that the safety device attempts to protect the automobile passenger after the accident has happened. The proponents of active safety devices argue that because the belts are not fixed they are more likely to be worn and that the active devices do work. More on this point later.

Air bags are also active devices. How could they be otherwise? The only practical way for the air bag to work is for it to deploy after the accident occurs. With development, the sensors that set off the air bag are becoming more sophisticated. The latest sensors are called integrating sensors in that they look at not just the magnitude of the force but the shape of the force over time in order to make the decision to deploy the air bag. No matter how sophisticated, the air bag cannot be deployed until the accident has occurred. Because the air bag does not deploy until the crash occurs, it suffers the same criticism as the active seat belts; it is attempting to protect automobile passengers after a crash has occurred.

Now let's take a look at the body dynamics, biomechanics if you will, of a driver involved in a reasonably severe frontal collision. A good model to keep in mind is a vehicle going 30 plus miles per hour (MPH) straight into a solid barrier or T-boning another vehicle.

The first scenario to consider is no seat belts. In the crash the driver will move forward and rotate. In the language of physics the center of mass of the driver moves forward and the upper body rotates, naturally about the hips. The head rotates forward also. Using the language of physics to describe the crash, the body keeps moving but the heavier parts move less than the lighter parts so the upper body and the head both rotate forward more than the center of mass. This body moving forward, upper body rotating and head rotating has been seen by most people in the videos of crash dummies. These motions continue until the driver meets the inside of the vehicle.

The next scenario to consider is with the passive lap belt. Here there is less forward motion (those belts do stretch you know), but still the rotation of the upper body and head.

The next scenario is with the passive lap belt and shoulder belt. Here there is less forward motion and less upper body rotation than for the no belt situation. Unfortunately, the head rotation is greater. Here is a greater risk of neck injury.

The next scenario is with the active lap belt and shoulder belt. With the active belts there is more forward motion and rotation than with the fixed belts. Important point: It takes a finite amount of time for the active belt to stop moving and in that time you are moving forward and rotating. The rotation is the most pronounced effect of the active belt scenario, first because the larger center of mass (concentrated near the lap portion of the belt) moves less, and second because the belt is usually anchored to the floor of the vehicle, passes through a latch opposite the driver's door and then to the active roller.

Belts are different, sensors are different, and crashes are different, but a number to keep in mind is that it takes approximately one-one hundredth of a second for a roller to activate in a 50-MPH frontal crash. How do I know this? I took a popular sensor apart and measured it. The Insurance Institute for Highway safety is in general agreement with this number. They even have a video demonstrating the effect.

The next scenario is with the active belts and an air bag. Now you're wondering how long does it take for the air bag to deploy? Again, air bags are different and sensors are different but the air bag does not get deployed much quicker than the belt stops unwinding. It does deploy before the belt stops unwinding. Otherwise, air bags would only help unbelted drivers.

With this short background on seat belts and air bags, we can get to the current controversy concerning air bags. A sensor in the vehicle activates the air bag. The mechanism for inflating the bags is the release of gas into the folded up bag stored in front of the driver. The complaint concerning air bags is that small people, especially children, are being injured and in some cases killed (National Highway Traffic Safety Administration statistics say 50+ per year are killed by air bags).

Let's look at what goes on when the air bag is activated. Gas is released at roughly a constant rate into a balloon-like bag inflating it rapidly. The rate at which the radius of the bag is increasing drops dramatically as the bag inflates. If you happen to be right over the bag when it deploys, you get hit with a small portion of the bag moving very rapidly. Further away, you get hit with a larger portion of the bag moving slower.

If air (gas) is forced into a balloon at a fixed rate, the rate at which the radius expands falls off as the square of the radius. In understandable terms if you double the distance from the balloon you one-fourth the speed of the piece that hits you. Doubling the distance from the balloon when it hits you also increases the area. Think about blowing up a balloon. The first lung full of air produces a large change in radius, the next lung full of air a smaller change in radius and so on. Problems similar to this are done in elementary calculus books. See Calculus for the Utterly Confused by Robert M. Oman and Daniel M. Oman available at your favorite bookstore or online through this web site. Return to our home page, go to the publications page and you can link directly to this book on amazon.com. You didn't think I was going to pass up the opportunity to plug the book did you?

The model of an airbag as a balloon inflated by gas entering at a fixed rate is not a perfect model for airbags. Airbags tend to look a little more like mushrooms than balloons, and the gas probably enters the air bag faster at the beginning of the expansion than later. The results are essentially correct. The piece of the air bag that hits you moves faster earlier in the inflation, and the area of the piece of the air bag that hits you increases as the airbag expands. Both effects are important. If you're going to be hit by an airbag, it's better to be hit when it is nearly fully expanded than when it is just starting to expand. The effect is not linear. Doubling your distance from the airbag reduces the speed of the bag by one-fourth!

Now let's look at some real world crash scenarios. Start with a driver wearing active lap and over the shoulder belts in a vehicle with no air bags. In a frontal crash the driver moves forward and rotates until the belts restrain him. A simplistic view is that a belted person is restrained and protected from hitting the insides of the vehicle. Are you sure? Is there a difference between say a 200 pound male and a 120 pound female? Yes, there is. I could go off into the language of the physicist describing motion and talk about masses in accelerating reference systems, but let's keep this in as simple a terms as possible. The car in the frontal crash is accelerating backwards while the unrestrained occupant is continuing to move forward, so the situation is equivalent to the driver being accelerated forward with respect to the vehicle. In simple language when the car stops the driver continues forward, actually accelerating forward with respect to the inside of the vehicle with a smaller mass accelerating more than a larger mass. (Remember F = ma?) For the same force, a smaller mass accelerates more than a larger mass. So the 200 pounder accelerates forward less than the 120 pounder. The 120 pounder also rotates more. Further (and don't blame me, I just report the situation) the female, because she has more mass in her lower body than the (same mass) male, rotates more than the male.

It gets worse. The lighter female most likely has shorter arms and sits closer to the steering wheel than her heavier male counterpart. This means she has less distance to rotate to impact the steering wheel.

I made the calculations for a 150 pound female sitting with her chin 12 inches from the steering wheel in a 50-MPH crash into a solid barrier (part of an actual case) asking if she would rotate into the steering wheel. She hit the steering wheel with her chin at approximately 45-MPH before the shoulder roller stopped. Her injuries confirmed the calculations. This is a severe but not totally unrealistic crash.

What can our 120 pound female do? A passive belt system would help. Even better would be a shoulder belt that had a graduated restraint. A graduate restraint system becomes more rigid as you stretch the belt. The purpose is to bring your rotation to a stop as slowly as possible and before you hit the inside of the vehicle. This is a great idea but impractical. The only realistic defense is to sit as far away from the steering wheel as possible. It may not be comfortable for you, the 120 pound or "short" female, to be at nearly arm's length from the steering wheel, but the further you are away the better your chances in a high end crash.

For this same scenario add an airbag. The 200-pound male who does not rotate as much as the 120-pound female has his restraint cushioned by the airbag when it is well along the way to being fully inflated. The 120 pound female, however, sitting closer to the bag because of shorter arms, moving faster because of her lower weight and rotating faster because of her weight distribution gets hit with the bag moving much faster than when it hits her 200 pound male counterpart.

Airbags work well for larger people but not so well for smaller people. Instead of a 120-pound female, make the person an even smaller passenger and the problem is compounded, greater forward motion, greater rotation and less mass to "absorb" the hit from the expanding air bag.

Airbags do a job. They protect most people in most crashes from hitting the inside of the vehicle. For shorter and lighter weight people the best response to the potential danger of rapidly expanding airbags is to sit as far away from them as possible.