Out of harm's way

A company is working on a load cell to make the air bag safer for the passenger at risk. By John DeGaspari, Associate Editor

Although air bags have saved thousands of lives, they also have been responsible for more than 160 deaths in low-severity crashes, in which serious injuries would otherwise have been unlikely. Children, small adults, and out-of-position passengers in the front seats of cars risk serious injury when air bags are deployed at full force during automobile accidents.

According to the U.S. Department of Transportation's National Highway Traffic Safety Administration in Washington, 100 children and at least 26 women were among those killed out of a total of 169 confirmed air bag deaths in low-severity crashes. By contrast, NHTSA estimates that 6,138 lives (5,185 drivers and 953 front-right passengers) have been saved by air bags.

To address the issue of deaths from air bags, NHTSA recently stepped in with a new standard to make air bags themselves safer. On May 12, the agency published an interim final rule regarding air bag deployment, which is designed to protect children and short-stature adults who are the most vulnerable to injury. Essentially, the rulemaking encourages new safety system designs by implementing new tests that take into account children in the front seat and small adults, as drivers and front-seat passengers. The tests will be phased in over the next several years.

A final version of the test standards is still three to seven years off, according to Tom Hollowell, chief of NHTSA's Crashworthiness Research Division. Issues that still must be ironed out include maximum test speed and the development of a dynamic out-of-position test.

Still, the interim standard is now in place to encourage automakers to make use of more sophisticated safety systems, such as smart air bags, which take into account the size and position of the occupant during deployment. These kinds of air bags require the use of sophisticated sensors to determine the weight and position of occupants.

Surviving Crashes

One approach to occupant sensing is being developed by GageTek LLC in Rancho Cordova, Calif. The company, which designs and manufactures digital pressure gauges, load cells, and weight scales, has designed a system consisting of torsion-sensing load cells that calculate the weight as well as the position of the passenger. Output from the sensors can be used to calculate...
reduce air bag force to protect children, small-stature adults, and out-of-position occupants, according to Bob Bruns, an engineer with GageTek. The system is intended for front seats, primarily on the passenger side, where most air bag fatalities have occurred, he said.

“Weight-based systems are a very good measure of the size of the individual in the seat,” explained Bruns. “The fact that we can tailor our load cells for pretty high loads in the single direction and have high sensitivity in the orthogonal direction is what makes our system work very well.”

One of the challenges in designing a system is that the load cells must have the capability to survive a 35-mile-per-hour collision, which is an NHTSA requirement. Bruns said that the load cell provides full output at 500 pounds of force per load cell, and is able to meet a crash requirement of 35 mph, or 8,000 pounds of force in the crash direction.

**SPRING-LIKE ACTION**

GageTek’s load cell, which it calls a torsional sensing load cell, or TSLC, is a U-shaped piece of metal that acts like a spring. Basically a rectangular block of steel in which a slot has been cut, the TSLC is a simple shape that can be produced at low cost, said Bruns. The load cell works the way a spring does, by converting linear force to a torsional force, or twisting, at the other end. The torsion results in a strain that is present on the surface of the load cell that can be measured. In the TSLC, the strain is measured by a pair of strain gauges diametrically opposed to each other across the slot of the load cell.

One advantage of the TSLC is that it is insensitive to errors that may be introduced by off-axis loads, said Bruns. This is desirable for a car seat, in which off-axis loads may be introduced by the occupant or even during seat assembly, he said. With many load cells, a platform that is loaded off center will result in twisting that will introduce an error in the signal.

The TSLC is insensitive to off-axis loads because of the way the torsion propagates around the sensing element. The TSLC converts the torsion and the distance between the two strain gauges across the slot, essentially fixing the relationship between the two, he explained.

“Even though the torsion changes, the relationship of the torsion on both sides stays exactly the same,” Bruns said. “That’s the mathematical relationship that makes the load cell work very well.”

The TSLC is essentially an I-beam construction, but without the web in the center, said Bruns. The I-beam is constructed by drilling a hole through the steel block where the strain gauges are placed. Like an I-beam, the TSLC can be twisted easily, giving the load cell high output when the occupant is seated. The back, or solid end, of the load cell, is very strong in the direction of the crash.

The TSLC uses LN-100 silicon strain gauges, which were recently developed by BFGoodrich Advanced Micro Machines of Cleveland.

The devices exhibit high gauge factor, which is the measure of the ratio of the mechanical strength to the electrical output. The higher the gauge factor, the higher the output for a given amount of strain.

Advanced Micro Machines claims that the LN-100 strain gauges have an output approximately 50 times that of conventional foil gauges. The high output can be an advantage because it reduces cabling and amplification requirements to get the signal into the car’s computer, said Bruns. He estimated that cost savings could be on the order of a dollar or two per seat—significant savings by automotive standards.

The LN-100 was designed as a highly sensitive drop-in replacement for metal foil strain gauges. It can be assembled on load cells using the same adhesives and cure times as with metal foil gauges, according to the company.

**LOAD CELLS UNDER THE SEAT**

The TSLCs are placed at each corner of the seat. Calculation of the center of gravity, or position of the occupant, is done by determining the seat occupant’s center of mass.

In general, car seats sit on rails that are configured either vertically or horizontally. GageTek has successfully mounted load cells for both types of seats. The structure of the load cell is the same in both cases, differing only in the mounting holes.

In either case, the base of the seat structure must be
New Test Requirements Aim to Improve Occupant Protection

ON MAY 12, THE U.S. Department of Transportation's National Highway Traffic Safety Administration published an interim final rule designed to make air bag deployment safer for small adults and children. The new standards present air bag tests intended to encourage automakers to modify air bag deployment power. Without specifying how automakers will do it, the rules are intended to minimize the risk of injury and death from air bag deployment in low-speed crashes that present little hazard by themselves, while providing occupant protection in severe crashes.

One temporary change, intended to get automakers to decrease the amount of deployment power in an air bag, was to replace unbelted crash tests with a sled test. A crash test runs a vehicle into a rigid wall; in a sled test, the vehicle is mounted on a device that gives it a predetermined acceleration profile. The sled test, which is less severe, is aimed at prompting the industry to implement less severe deployment of air bags, and still have air bags serve under severe crash conditions.

“We knew that there were technologies available that could be used to provide a less aggressive deployment as well as meet severe crash conditions,” said Tom Hollowell, chief of the agency's Crashworthiness Research Division.

NHTSA is now phasing the crash test back in, because it is more representative of crashes under real-world conditions. However, the agency has incorporated a number of other changes in test requirements that are designed to encourage automakers to use advanced air bag technologies. NHTSA calls its latest standards an "interim" final rule, with some exact test conditions still to be ironed out. However, the basic test requirements are in place.

To represent small-stature passengers, a fifth percentile dummy is specified for head-on and plus or minus 30-degree rigid barrier crash tests for both belted and unbelted passengers. Originally, only 50th-percentile, 164-pound dummies were used, representing an average male.

The new rules incorporate a 40 percent offset frontal test into a barrier with a relatively soft honeycomb block. The test represents low-severity crashes in which the air bag may or may not be needed. If the air bag deploys, it protects the passenger, and if it does not deploy, the vehicle is designed so that the person is not injured. The offset test is between 0 and 25 mph for belted passengers. The rules specify a static deployment test to represent what happens when the driver is against the steering wheel. The test uses a fifth-percentile dummy to replicate what happens when a steering wheel air bag deploys against the chest and between the head and chest—two scenarios that may result in death. The test places a fifth-percentile dummy against the steering wheel and deploys the air bag. In the case of multistage air bags, which use more than one inflator, a 16-mph crash test is run prior to the static test. That information is used to determine if one or both gas generators should be set off in the static test.

On the passenger side, where most of the fatalities have been children, NHTSA specifies three-year-old and six-year-old dummies for out-of-position tests, simulating a passenger not sitting firmly in the seat. The tests specify two conditions: chest, and head and neck. For children (three- and six-year-olds and infants) on the front passen-

New air bag test rules are intended to minimize the risk of injury to small adults and children.
isolated from the sliding rails by a 1-mm gap separating the two parts of the seat structure. The gap is important so that all of the weight is transferred through the load cell, explained Bruns. Otherwise, part of the seat could shift to contact the rail, causing part of the load not to be transferred through the load cells. The load cells do not interfere with the seat's operation, according to Bruns.

Each load cell is mounted so that the slot runs from front to back, strengthening the beam sections for front and rear collisions. “That’s the way we do it to optimize the load for the sled 35-mph crash test,” explained Bruns. Also, front-to-back mounting aligns with the movement of the seat along the rails.

In the event of a side crash, the gap on one side of the seat collapses, making the load cell effectively a solid under compressive load, protecting the structural integrity of the seat. This enables it to resist very high loads from the side, he said. “By closing the gap and making it solid, you are gaining all the strength of the seat’s structure. The seat can’t come off its mounts.”

**Accurate Positioning**

GageTek is currently using live test subjects to determine the accuracy of the sensor, as well as looking at how the load relates to the position of the head and torso, which are the heaviest parts of a person.

Bruns said that the centroid, or center of mass, “has excellent resolution as to the position of the torso. It’s very accurate, to several centimeters.” If the head moves forward, the torso will also tend to move forward. “That’s going to cause the center of gravity to go forward. You want to detect that and change the force of the air bag.”

During the coming year, GageTek will test for potential errors in air bag deployment. One example may be the head fully forward while the torso is positioned back, or if the head is leaning to the side, perhaps against the passenger side window. As Bruns put it: “How much of an error would there be and can you spot that? Will there be enough of a shift to indicate that perhaps you shouldn’t deploy the side air bag?”

**Margin for Error**

Two additional forces may introduce errors into the weight measurement. One source is the occupant’s foot on the firewall of the vehicle. The other is pressure on the seat’s back, which can be caused by a rear-seat passenger who puts his hands on the back of the front seat. In the company’s tests so far, Bruns said, neither would introduce errors significant enough to affect the safety of passengers. In the case of a back-seat passenger pushing the seat forward, this would shift the center of gravity toward the air bag, in effect reducing the amount of deployment force, he said.

The load cell sensor is currently being evaluated by a number of automotive manufacturers, Bruns said. One issue in commercialization is cost, because silicon gauges are comparatively expensive.

GageTek estimates that it will cost from $12 to $20 to implement this for each seat. About 60 percent of the cost is for load cell elements and 40 percent for encapsulation, packaging, and connectors. The cost is likely to be offset by the higher output and reduced requirement for low-noise instrumentation electronics that are possible with these load cells, he said.