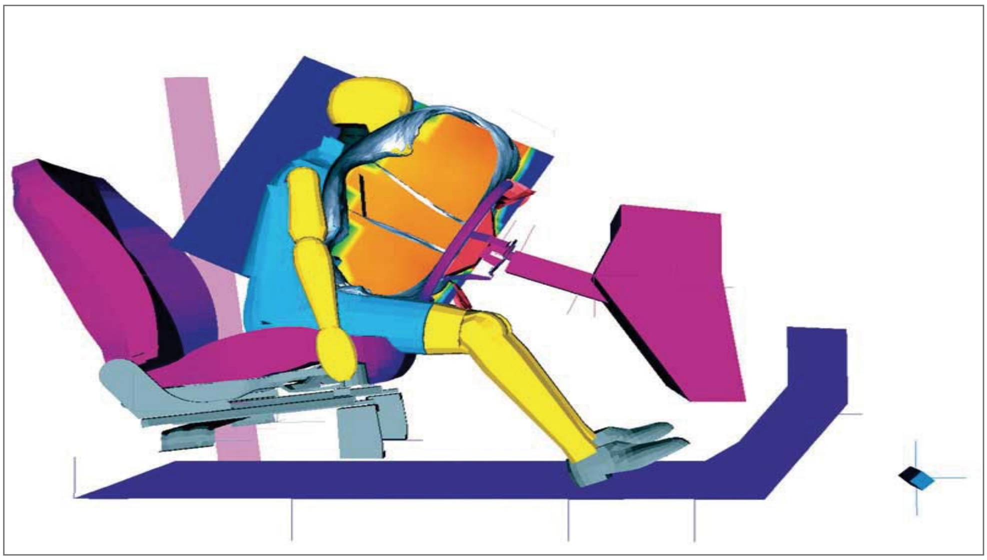
Tougher Airbag System Testing Requires Simulation for Success



> *"VPD can be used to assure the restraint system will function as desired, for all those test conditions, ahead of time.."*

Customer:
Automotive Systems Laboratory, Inc. (ASL), Michigan, USA

Software:
MSC.Dytran®, MSC.Dytran OOP

Summary:
In order to reduce the cost of testing their airbag restraint systems, ASL is using Virtual Product Development tools such as MSC.Dytran. MSC. Dytran offers the advantage of coupled Euler-Lagrange analysis, allowing combined structural and gaseous fluid simulation. Contact analysis is very important in simulating an airbag deployment, and MSC.Dytran provides a number of options for defining contacts. For ASL, MSC.Dytran has proven to be a robust tool that can be applied to the design optimization of vehicle occupant restraint systems for both crash and out-of-position scenarios, which are relevant to the restraint system designs of the future.

The cost of testing airbag restraint systems is growing, because government and industry regulatory groups are phasing in testing requirements for a wide group of drivers and occupants including large males, small females, and children. Some of these tests involve out-of-position (OOP) testing without safety belts. While tests are required for product certification, simulation analysis is the preferred tool during product development, because it is more cost-effective and repeatable than physical tests. More configurations can be analyzed on the computer, without the need for costly prototypes, which results in a better product. By establishing a robust Virtual Product Development (VPD) environment with MSC.Dytran, Automotive Systems Laboratory (ASL) intends to bring solutions to market more quickly.

MSC.Dytran provides coupled Euler-Lagrange analysis, allowing combined structural and gaseous fluid simulation. The Lagrangian method is used for structural components that may undergo large deformations and for which the dimensions, deformed geometry, and residual stress state are of major importance. The benefit of the Lagrangian solver is that the displacements, deformations, and stresses in structures can be monitored with a high degree of precision. However, extreme deformations may lead to drastically reduced time steps and extended run times. The benefit of the Eulerian method is that complex material flow can be modeled with no limit to the amount of deformation. With increasing deformation, however, the boundaries between the materials may become less precise. The Eulerian method is used for bodies of fluids and gas, which may experience extremely large deformations. With Lagrangian simulation, the mesh deforms and the material follows the mesh, while the Eulerian gas/fluid analysis keeps the mesh stationary while the material flows through the mesh. MSC.Dytran has the capability of performing both types of analysis simultaneously by combining both domains. This allows the flow of gas inside a deploying airbag to be modeled.

Over the years, airbags have progressed from using gas generators with a single stage to two stages to better deal with the variance in the size/weight of the driver/passengers. In the mid 1990´s, there was only one stage to the inflator, and the stage was designed to restrain a 50th percentile male Hybrid III dummy model (an average size and weight male) in a 30 MPH rigid barrier crash in an unbelted situation. The inflators had to be quite powerful to pass the test.

> *"MSC.Dytran has proven to be a robust tool that can be applied to the design optimization of vehicle occupant restraint systems for all configurations."*

About 1996, it became evident that the force of the deployment could cause injuries to children who came in close contact with the deploying passenger airbag, and to short-stature females sitting very close to the steering wheel. In reaction, the U.S. government changed the regulatory certification requirements, allowing the industry to reduce the power of the inflators. The so-called depowering rule was a temporary measure to allow the industry to develop restraint systems that could be tailored to a wider variety of crash conditions. To modify the airbag energy for different occupants and restraint conditions, most airbags now have a dual stage inflator with a sensor determining whether zero, one, or two stages are ignited.

A typical analysis performed at ASL might include a vehicle driver-side geometry with a 5th percentile female Hybrid III dummy under various loading conditions, including OOP1, OOP2, 25 mph unbelted rigid barrier impact and 35 mph belted rigid barrier impact. A 5th percentile female is smaller than 95% of the adult female population at approximately 4'9" (1.45 m) and 110 lbs (50 kg). OOP1 and OOP2 are specified in U.S. Federal Vehicle Motor Safety Standard 208 which is applicable to frontal impact restraint systems. OOP1 puts the 5th percentile female in close proximity to the steering wheel with her chin resting on the airbag module before the airbag is set off. The airbag is deployed against the head and neck of the dummy, which tests the loads in the neck to make sure they are not so high as to cause serious injury. OOP2 is similar, but the chin rests on the rim of the steering wheel. The airbag deploys against the chest to make sure the rib cage is not traumatized to the extent it would be life-threatening. The analysis may set guidelines for the product design, to help it go from the concept stage to a working prototype or from a general design to an optimized design.

Material properties used in the simulation analysis include an airbag fabric modeled with an orthotropic material model and airbag module cover modeled with an elastic-plasticfailure material model. The airbag material has a coating on the inside to make the fabric more airtight. Typically shell elements are used for the module and membrane elements for an airbag. The airbag cushion is packaged inside the module, which is only visible as the plastic enclosure seen in the center of the steering wheel. The cushion can be folded in many different ways to fit inside this enclosure. For the modeler, this means folding the airbag mesh. In this process some of the elements invariably get distorted. MSC.Dytran features an initial metric method that can be used to specify the undistorted geometry of membrane elements, as well as the distorted geometry. During the analysis, stresses will be slowly introduced into those elements, so the initial distortions of the elements will not adversely affect the simulation results.

There are different methods for inflating the airbag. Typically, a component called an inflator generates gas very quickly, by burning a material not unlike that of the solid propellant rocket boosters of the space shuttle. The gas is pushed through tiny holes in the metal inflator and blows into the bag, which pressurizes and punches through the module cover to deploy the airbag. Gas is released out of the bag, in a controlled manner, through discrete holes in the cushion. The high speed of deployment and impact make the gas behave like a viscous fluid, in turn making the cushion act like a nonlinear damper when it catches the occupant and lets him ride down the crash. A typical frontal crash has a duration of less than a quarter of a second, which is about the time it takes to blink.

The mesh for the airbag model is made of approximately 16,000 Lagrangian elements with a nominal size of 10 mm, and some 16,000 variable-size Euler elements. Additional elements are used for the airbag module, dummy, and vehicle environment. Total number of degrees of freedom is approximately 250,000. Typically, the loads include Crash Pulse loading on the dummy (when applicable) through body force definitions, and interaction of the dummy with the airbag, belt system, and vehicle environment through contact definitions. Contact analysis is very important in simulating an airbag deployment, and MSC.Dytran provides a number of options for defining contacts. One of the most difficult contacts for any software is the airbag self contact. Upon initiation, the airbag is typically folded into multiple layers and as pressure is applied to the inner layer of elements and nodes, they want to fly off in all directions. MSC.Dytran has a good contact algorithm for keeping everything in check when all the layers start contacting each other, transferring the load from the innermost layer of fabric all the way to the module cover. Contact described between the airbag and the occupant is straightforward in MSC. Dytran, using surface-to-surface contacts. For other contact areas, such as feet against the toeboard or buttocks against the seat, simple force-penetration contact models are often used.

Since putting a moratorium on the depowering rule in effect, the regulatory agencies have again changed the vehicle certification testing program. In the early 1990´s, there were only four certification tests with just the 50th percentile (average-size) male crash dummy, including a 30 mph unbelted and belted crash into a rigid barrier. The same tests were repeated only to hit the rigid barrier at an angle.

Beginning with a phased introduction for model year 2004, a total of 14 tests, with four different-size test dummies, will be required for certification. These include driver-side tests with the average-size male dummy and 5th percentile female dummy and passenger-side tests with three- and six-year-old child dummies.

In addition, other organizations, such as the Insurance Institute for Highway Safety, have designed crash tests. Because these test results are published, every automaker wants to participate and show good performance. In Europe, there are additional tests required. With a growing number of expensive physical tests required, VPD can be used to assure the restraint system will function as desired, for all those test conditions, ahead of time. MSC.Dytran has proven to be a robust tool that can be applied to the design optimization of vehicle occupant restraint systems for all configurations, including both crash and out-of-position scenarios, which are relevant to the restraint system designs of the future.

Corporate
MSC.Software Corporation
2 MacArthur Place
Santa Ana, California 92707
Telephone 714 540 8900

www.mscsoftware.com

Europe, Middle East, Africa
MSC.Software GmbH
Am Moosfeld 13
81829 Munich, Germany
Telephone 49 89 431 98 70

Asia-Pacific
MSC.Software Japan LTD.
Shinjuku First West 8F
23-7 Nishi Shinjuku
1-Chome, Shinjuku-Ku
Tokyo, Japan 160-0023
Telephone 81 3 6911 1200