Software tool helps develop intelligent seat-belt system

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Next-generation automotive restraints
Over the past 40 years, technology to reduce occupant injury in automotive collisions has advanced remarkably. Pre-crash shoulder belt tensioning is one promising new technology designed to reduce automotive crash injuries.

Current technology enables a seat belt to be tightened by about 10 cm (4 in) and air bags to be deployed simultaneously, milliseconds after a collision. However, pre-crash tensioning technology increases the opportunity to secure a passenger safely before a crash. Sensors and logic, designed to anticipate a crash, activate a motorized seat belt retractor that secures a shoulder belt around an occupant before a crash actually occurs.

The figure above shows the lumped mass model of an occupant subject to shoulder belt tensioning. There is an optimal position for occupants to minimize the effects of an automotive crash. Observational studies report that 10% of drivers and 22% of passengers in crashes were poorly positioned on impact.

The motorized shoulder belt tensioner is powerful enough to pull a forward-leaning occupant back to position prior to impact, provided the possibility of impact is determined sufficiently early. Such a
system can reduce injury by repositioning the occupant and controlling occupant movement in pre-crash maneuvers. A motorized tensioning system also reduces injury for occupants who are seated correctly.

**Study objectives**
Craig Good, a partner at Collision Analysis conducted a research program to develop further understanding of the biomechanics of shoulder belt tensioning. The objective of this study was to experimentally measure the response of a diverse group of forward-leaning occupants to shoulder belt tensioning during straight-line, pre-crash braking (below), and then model the results. The study intended to develop and validate a mechanical model to characterize the biomechanical response of forward leaning volunteers during the motorized shoulder belt tensioning.

This seat-belted volunteer is subjected to motorized shoulder-belt tensioning while leaning forward.

The biomechanics of human exposure to shoulder belt tensioning in a vehicle environment must be understood to enhance protection of a diverse population. A previous study measured the upper torso biomechanics of three populations of forward leaning adult volunteers during motorized shoulder belt tensioning. The current study used a small representative group of volunteers of different sizes. This analysis was helpful in determining the requirements to enhance the protection of a varied group of occupants. The ultimate goal is to provide the best level of crash protection for all occupants using motorized shoulder belt tensioning.

The three dimensional model incorporated the biomechanical properties of the occupant populations, a motorized shoulder belt tensioner (DC motor and controller), and shoulder-belt webbing models. Model validation was achieved against the volunteer experiments for angular torso position, torso velocity, and shoulder belt moment applied to the torso.

**Creating the model**
Good used DynaFlexPro™ (DFP) from Maplesoft™ to create a 2D occupant model, using the experimentally measured data for validation. DFP is a software package for modeling and simulating the dynamics of mechanical multibody systems. The computation capabilities of Maple™ are used to create concise and efficient sets of system equations in symbolic form, which facilitate visualization,
physical insight, and information sharing. These tools simplify the process of design, optimization, simulation, and control of complex engineering system models. **Problems**

Given the experimentally observed range of occupant movement in three dimensions, Good's original idea for a simple 2D model proved to be insufficient. Using integrated DFP and Maple technologies, he extended the model to three dimensions in a way that encompassed these complexities, and yet, was simple and accessible enough to be used by a wide group of engineers. The model was verified against data from the study to ensure accuracy.

Once the model was created, it gave Good the flexibility to evaluate different scenarios to optimize the system. For example, a larger sample size varying in occupant size could be incorporated, enabling the study to encompass a wide range of occupants.

"DynaFlexPro proved to be the fastest way to describe the system," said Good. "I was able to quickly generate equations of motion and verify the data. I could have done it by hand or by using a numeric-only package, but that would have been rather cumbersome. With DFP, in a couple of days, I was able to do something that would have typically taken a few weeks."

Since the completion of this project, Maplesoft has introduced **MapleSim**[^1], a high performance, multi-domain modeling and simulation tool. In MapleSim, users can take advantage of DynaFlexPro technology to develop multibody mechanical system models, and then easily connect them to other components such as motors, gearboxes, and electrical and hydraulic systems.

With MapleSim, systems are described in a compact and intuitive component diagram using next-generation physical modeling techniques, making them easier to build and understand. Model equations are automatically generated and simplified, yielding efficient models and high-speed simulations of sophisticated systems. With MapleSim, users can optimize products and shorten the product development cycle.

**Conclusions**

The data collected in this study will facilitate future work aimed at modeling the responses of subjects to pre-crash or pre-impact shoulder belt tensioning. The DFP-based model made it easier and quicker to arrive at results involving complex situations.

The study further predicted that the motor used in the volunteer experiments was not sufficiently powerful to retract bigger male groups in moderately-hard, pre-impact braking. A more powerful motor and better speed control on the motorized tensioner was needed for others such as smaller female groups to achieve best retraction responses. The model has wide application in the further development of restraint systems with shoulder belt tensioning.

With help from tools such as Maple, safety engineers can now optimize hardware and initiate the design process for pre-crash shoulder belt tensioning to provide the best level of protection for occupants of all types.

**Setting new trends**

Automotive manufacturers are beginning to evaluate the benefits of incorporating advanced motorized shoulder belt tensioning into their vehicles. Mercedes has introduced the technology in its S-class and E-class models, based on brake pedal activation sensors. With tools such as Maple, engineers can bring about complex technology more easily. In the future, such tools will certainly influence the development of occupant protection for more automobiles.