FINE-TUNING THE ANATOMY OF CAR-SEAT COMFORT

New muscle detail in Wölfel's 3D human-body model gives realistic simulations more accurate predictive power as the field evolves

Although driving a car is done sitting down, feeling physically tired after a long car ride is no accident: While navigating busy city streets, curvy country roads, or even slow-moving commuter traffic, drivers are in an almost constant state of motion, pushing and releasing the vehicle's pedals to accelerate, brake or clutch.

Legs and feet change position: as the ankle flexes, the lower leg extends and retracts, and the muscles in the thigh and buttocks contract and relax. Since the thigh muscles are in constant use, it follows that the seat design—especially the front of the pad that supports the thigh—will be important when determining driver comfort.

"Even holding the accelerator pedal at a desired position requires constant muscle activation," says Alexander Siefert, manager of Seating Comfort and Biomechanics at Wölfel Group—a German-based company specializing in engineering services and related testing systems for the design and development of car seats. "This alters the stiffness of the muscles involved. It also has a significant effect on seat-pressure distribution and stress/strain values within the tissue, which are important measures of seat comfort."

Engineers on Wölfel's Seating Comfort and Biomechanics team know what they're talking about. Their finite-element model CASIMIR helped set current German occupational and health standards (vibration and shock) for working drivers of vehicles such as trucks, taxis, buses, and construction equipment. As human-body modeling rapidly evolves, Wölfel has turned to the issue of comfort with both commercial and passenger vehicles in mind.

SIMULIA SOLUTIONS FINE-TUNE COMFORT

Longtime users of SIMULIA Abaqus finite element analysis (FEA) software from Dassault Systèmes, The **3D**EXPERIENCE Company, Wölfel has enhanced CASIMIR to include models that make their digital-driving simulations even closer approximations of real-world conditions.

"We have high confidence in our Abaqus analyses because of the software's advanced non-linear and contact capabilities," says Siefert. "Its material models for seat foam and human tissue are extremely useful when conducting human-body simulations for car seats."

Wölfel has drawn on extensive medical imaging data (CT scans, MRI cross-sections, and dissection photographs) from the U.S. National Library of Medicine's (NLM) Visible Human project to more accurately model the soft tissues, and especially the muscles, of the body parts that either contact the seat or are important in sitting. [see SIMULIA Insights Sept./Oct. 2010 pp. 20-22: http://www.3ds.com/fileadmin/PRODUCTS/SIMULIA/PDF/case-study/SIMULIA-Wolfel.pdf].

Recently, they refined their simulations to represent the intricacies of muscles in motion, developing a method that couples two models: a volumetric model representing passive nonlinear muscle behavior; and a filamentary model representing the active muscle force required to either maintain posture or make the movements, such as pedal operation, that are necessary for driving. By coupling the two models it can be demonstrated that the passive volume stiffens when the filamentary model is activated.

Pursuing this strategy, the team performed simulations for driving studies in which muscle activation was accounted for. In one study, they validated muscle activity in the abdomen and back for use in upright-seating-posture studies. In another, they analyzed the thigh and buttocks and began to understand the importance of pedal operation on seat comfort.

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>
> —Alexander Siefert, Wölfel Group

Looking to increase the robustness of these types of active-muscle simulations, the team decided that additional enhancements and studies were required.

VALIDATING THE COUPLED-MODEL APPROACH IN A SINGLE ISOLATED MUSCLE

To further prove out the concept and benefits of coupling the volumetric and filamentary muscle models, the team decided first to simulate an imaginary muscle outside of their CASIMIR software. After setting up simulations of different loads on the volumetric model and different states of muscle contraction on the filamentary model, the engineers used the embedded element option in Abaqus to generate a kinematic relationship between the two. In an experimental set-up designed to demonstrate the real-world veracity of this coupled scenario, measurements were made after an indenter mass of five different weights was lowered onto a sample calf muscle (from a rat) to mimic muscle contraction. The team observed that the upper muscle volume in the calf lifted up in both the coupled simulation and the real-muscle experiment.

"We're still fine-tuning our simulations so that they'll even more closely correspond to measurements," notes Siefert. "But after our study validated the coupled-model method in the isolated muscle, we wanted to show it would work in the full body-model."

VALIDATING THE COUPLED APPROACH IN CASIMIR

To prepare the full-body model for a similar coupled analysis, the separate thigh and buttocks models needed to be further enhanced. High-contrast photos from NLM were especially useful in achieving more accurate muscle volumes; whole-body MRI scans in the prone and supine positions (from another source) provided additional detail as well. In the volumetric thigh model, smaller muscles were assembled into one volume to simplify the calculation. For the filamentary model, the team first focused on the hamstrings (flexor), since that is the muscle group that contacts the seat and is activated during driving.

CASIMIR's thigh and buttocks were then placed on a cuboidal piece of foam representative of a car seat. The model was loaded for its own weight, as well as with the hamstrings activated. When the team compared calculations from this set-up with actual measurements from test subjects, the gravity-loaded scenario results were in close agreement (there was lateral expansion of the full thigh and movement between the muscle volumes). For the muscle contraction case, the vertical displacement (lifting up) of the leg also matched expectations (see Figure 1).

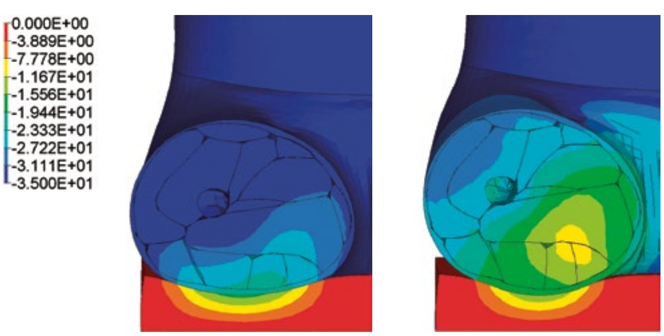

Figure 1. Abaqus FEA graphics of the thigh muscles (shown in cross-section) illustrate vertical displacement for gravity loading only (left) and with the hamstrings activated (right).

Finally, it was time to try out CASIMIR's full-body model on a seat-pressure distribution scenario with muscle activation. The team explored a number of different loads including gravity and then knee flexion with resulting heel forces. Simulation and test results were in close enough agreement to validate coupling of the muscle models in future full-body-model simulations.

WHAT'S NEXT FOR CASIMIR

Now that CASIMIR is capable of simulating not only passive reactions of tissue to external forces but also active muscle contractions, Wölfel can offer its customers the most sophisticated seat-design and driving-comfort guidelines to date. According to Andreas Nuber, assistant manager for research and development, the Wölfel team envisions a number of next steps to further increase the model's capabilities.

For one, they would like to more fully validate other muscle groups, besides the thigh/buttocks, with measurements on test subjects. They are also busy improving muscle-tissue modeling to more realistically represent contraction dynamics, as well as vertebral-disc characterization to accurately predict loading on the lumbar spine.

Other high-level seating-comfort initiatives are under way as well: The team has conducted first tests using Isight (Dassault Systèmes SIMULIA's time-saving process automation and optimization software) for the identification of seat-cushion viscoelastic-foam properties; they are also working with the developers of other body models, such as RAMSIS and AnyBody, (under the UDASim project funded by the German government) on data exchange formats to make a global seating-comfort analysis a possibility.

Wölfel's research clearly benefits not only drivers, but the bottom line of car-seat suppliers and manufacturers everywhere. "Experimental seat-comfort studies have traditionally required many subjects and the testing of several hardware prototypes, all of which can be time consuming and expensive," says Nuber. "Simulating comfort using FEA greatly simplifies the process. It's objective, reproducible, and cost-effective. If we eliminate just a single hardware prototype during the design process, the savings can be as large as 50,000 €."

For More Information

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