By **Lynn Manning**, Parker Group

Build a Better Running Shoe from the Inside

adidas achieved significant design cycle reduction for their ForMotion™ line of running shoes by coupling surface-based computer aided design (CAD) with SIMULIA's finite element analysis software, Abaqus. A unique sliding plate technology in the heel of the shoe absorbs shock in three dimensions. Wear testing of the heel unit, using a bespoke test device, reproduces the motion and impact of an actual runner using the shoes.

The designers and engineers at adidas know that shin splints, a twisted knee, or one bad turn of the ankle can ruin any runner's day. Using materials science, biomechanics, and finite element analysis (FEA) software, they are building motion-responsive, stress-reducing technologies-similar to ones found in earthquake-resistant buildings and car stability systems-right into the heels of their running shoes. The shoes look good, of course. But the best parts of the sneaker are now definitely those you can't see.

SIMULATION SOFTWARE IS KEY

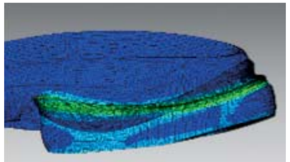
In creating their new ForMotion™ line of running shoes, adidas has achieved significant design cycle reduction by coupling their surface-based computer aided design (CAD) tool with FEA software (Abaqus/Explicit and Abaqus/CAE) from SIMULIA. "If you were going to retool and test a whole new shoe it could take six to eight weeks," says adidas Mechanical Engineer Tim Robinson. "But when you run simulations it only takes a few days. In terms of speeding up the entire development process, Abaqus from SIMULIA has proved invaluable." Robinson is part of the adidas innovation team made up of designers, engineers, and biomechanists working together from two locations: adidas' birthplace outside Nuremberg, Germany, and Portland, Oregon, U.S.A.

UNIQUE SLIDING PLATE TECHNOLOGY

A key element in the creation of the ForMotion™ line of running shoes is a unit comprised of a pair of sliding polyamide plates with a spherical bearing located in the heel of the shoe. Stiffness is provided to the system by way of a thin polymer seal, and sometimes also polymer springs and washers, depending on the model. "Instead of just absorbing the shock in a vertical axis, the sliding plates adjust to shock in three dimensions," Robinson says. "Decoupling the heel with sliding plates slows down 'sole angle velocity,' the speed at which your toes slap the ground after your heel makes contact - when it happens too fast you can end up with the common runner's complaint called shin splints. The plates can also rotate to counteract pronation, the amount your foot rolls inwards with each step. The spherical plates automatically correct for this, with the rotational motion 'give' protecting the knee. Overstraining in the opposite direction is prevented by displacement limiters. And finally, the unit automatically adjusts to each individual foot strike (how turned out your feet are when you run)."

TURNING THE CONCEPT INTO REALITY

With the concept in hand, the next step for the innovation team is ensuring that the heel unit works as intended in an actual running shoe and can also be functionally graded to



different shoe sizes. From the CAD models, 3D meshes are created and imported into Abaqus/CAE. "We create the modeling interface and then use it to apply boundary conditions and material properties to the mesh, and tie everything together defining contact, friction, connectors, and other factors," says Robinson. "Then we solve it using Abaqus/-Explicit." Material characteristics come from custom libraries adidas creates based on their highly proprietary materials. Biomechanics data, the basis of the boundary conditions, are equally confidential; they are generated in-house using a Vicon motion-capture system of tiny markers placed at strategic points on a human runner, which are then tracked with infrared cameras as the person moves.

SEEING INSIDE THE VIRTUAL SHOE

For postprocessing, Abaqus/CAE is used again. The engineers look for areas of strain and/or friction by applying simulated horizontal and vertical displacement forces. "It's definitely very useful to be able to 'see' inside the actual shoe, and even cut through the modeling for a closer look," Robinson notes. "It greatly helps communication with our designers about any changes we recommend." Since human feet—and bodies—come in many different sizes, an important part of FEA modeling at this stage is the functional grading of the shoes. "From our biomechanics

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results we have data about the correlation between shoe size and average weight," Robinson points out. "The radius above the ankle joint will change with a larger size. We use this relationship to functionally grade the shape of the plates, employing FEA to predict the optimum stiffness of the heel unit required for each shoe size." The shoes also come in four variations for control, cushion, trail, and competition.

TESTING, TESTING

When prototypes are ready for testing in the real world, a bespoke adidas test device is used to measure the "horizontal stiffness" of the ForMotion™ shoes. The shoe is held at an angle of 30° - the "male" foot strike angle - and a quasistatic displacement is applied to the heel. At this point there are rarely any surprises, Robinson notes. "Since we've already used FEA to run simulations that are comparable to movements of our test devices, we are very confident that when we get the first sample shoes back they will be very close to what we predicted them to be." Wear testing is done using another bespoke device, Performance Evaluation Test Equipment (PETE). This uses the previously obtained Vicon biometric input to reproduce the motion and impact of an actual runner wearing the shoes. Testing runs up to 100,000 cycles, comparable to 1000 km of running. All that running will now take less of a toll on legs, thanks to adidas' ForMotion line of shoes. "Engineering shoes to work with hips might be next. We are continually making improvements using Abaqus software to advance the science of shoe design," concludes Robinson •

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