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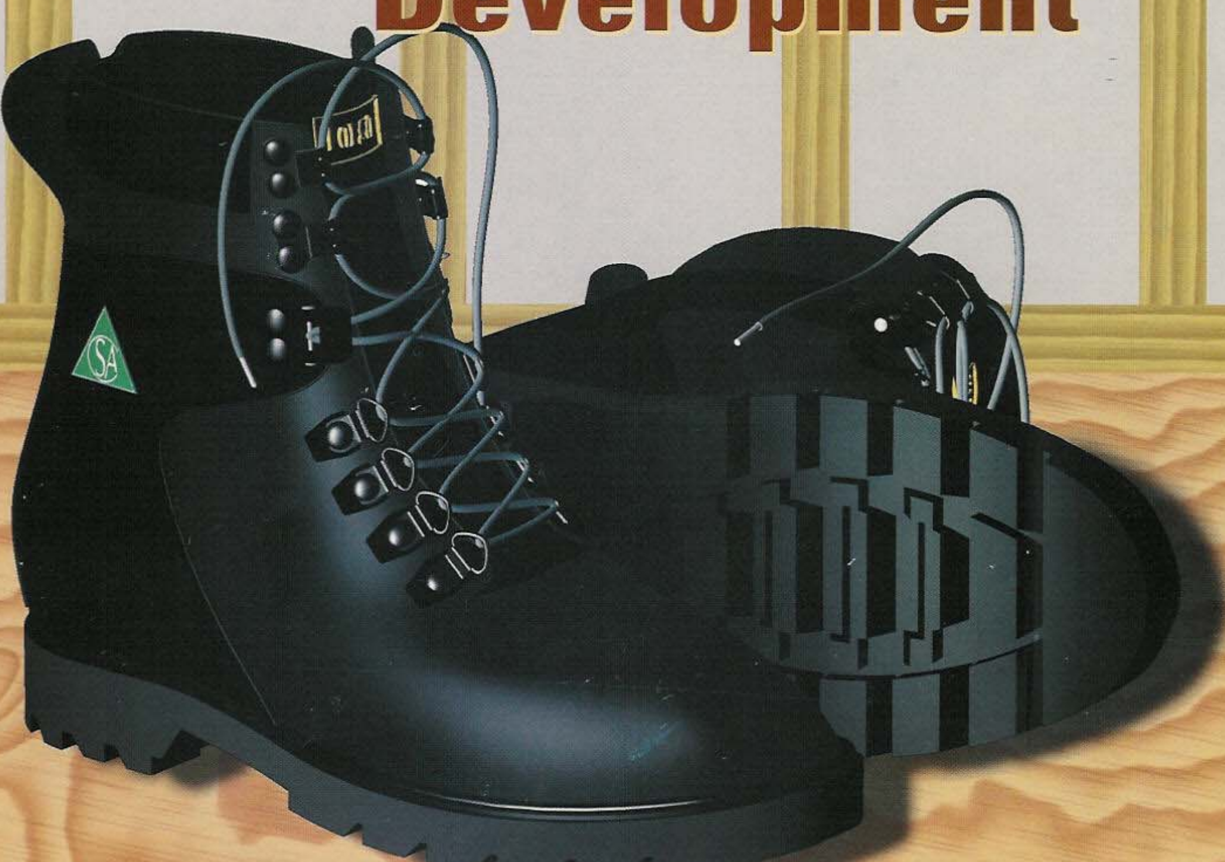
True Product Development



- Center of Gravity Coordinate Systems
- Extending the Ends of a Spring

True Product Development

Practice what we preach

by Jay Sussman

When companies embark on any project—either an upgrade to an existing design or a new invention—they are concerned with three major metrics: time to market, cost and quality. These concerns are paramount in product development as they ultimately affect the bottom line. When Torgon Industries took on an assignment to exclusively use Pro/ENGINEER to develop plastic toe caps for traditional steel-toe boots, it was a breakthrough success. How did this happen? It was a simple focus on reducing cost and time to market, while improving product quality. (See *Figure 1.*) Torgon Industries found the perfect solutions that required advanced engineering skills—and Pro/E's ISDX was a perfect design module.

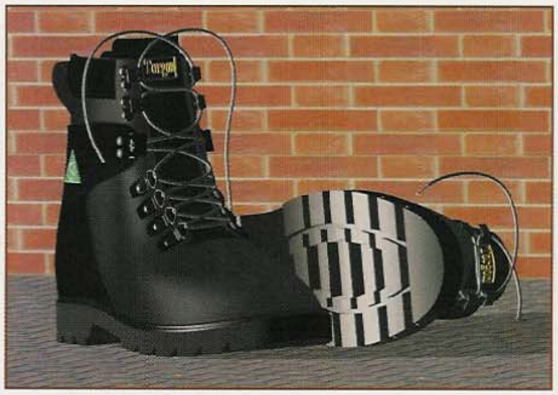


Figure 1. Torgon Industries exclusively used PTC products to design plastic toe caps for workboots.

Our work began last summer when a friend approached Torgon offices carrying a steel toe work boot in one hand and a bunch of plastic toe caps in the other. He had a distinct smirk on his face. When he said "no one has ever been able to make this work," I knew we were about to undertake an interesting endeavor. I smirked back, knowing we had PTC's suite of products in our toolbox.

Figure 2. The plastic insert had to look good and be comfortable.

The idea to create plastic toe caps surfaced because of problems with steel in boots. Steel is heavy, magnetic, extremely uncomfortable in cold weather and permanently deformable when impacted. And while a steel toe shields the tip of a foot, steel rarely is used to protect the instep or the metatarsal bones. Plastic is a perfect material for boots because it is not only lightweight and non-magnetic, but also can be molded to a much better fit than steel.

At the time, all safety work boots approved by the Canadian Standards Association (CSA) had steel-toe inserts. Some also had metatarsal protection. But no one had been able to design an integrated plastic toe insert with metatarsal protection that could withstand the CSA's vigorous impact test. While we formulated a plan to address this challenge, we kept the standards of the impact test in mind. We also considered the overall look and comfort of the insert. (See *Figure 2.*)

In the CSA test, a one-inch diameter steel rod welded to a balanced weight is dropped from a series of heights onto the toe of the boot. The mockup is similar to *Figure 3.* The clearance is measured on the inside of the boot, and the test simulates how the toes would be affected if something heavy were dropped on them. Numerous acceptable clearances, which vary based on boot size tested, were only part of the challenge. Obviously, the toe caps cannot fracture, crack or shatter during the test. Another factor was that the test is performed at two temperatures—room temperature and -18 degrees Celsius.

Testing at room temperature poses some difficulty due the immense impact strength the resin must have. But we knew the cold test would prove to be a bigger challenge due to plastic resin's inherent ability to lose impact strength exponentially as temperature decreases. Other companies that attempted the test with similar prototype toe caps had failed repeatedly because the cold caused the plastic to crack or shatter on impact. Knowing this, we sought to not only optimize the toe cap design, but also to use a plastic that could withstand the cold test.

Pro/E's ISDX allows the engineer to create free-form datum curves and surfaces interfacing the fit and form to the contour of the desired shape—a human foot in this case. In

Figure 3. Impact testing.

the analysis and manufacturing of complex and contoured plastics, Pro/MECHANICA and the Pro/MANUFACTURING modules of Pro/MOLDESIGN and Pro/Plastics Advisor were essential. We focused on designing a newly shaped part from an unknown polymer-based material that could withstand impact in a range of temperatures. The material had to be non-magnetic and non-reactive to chemical compounds, fit within the confines of the existing boot design and look and feel great. (See *Figure 4*.)

Figure 4.

The entire process, completed within Pro/E and Pro/E modules, resulted in three patents. Our clients, who had been struggling to develop the toe caps for years, said the project is four years ahead of their predicted schedule.

Our work started like many tasks in Pro/E—we planned and established design intent, which was form, fit and function. For the form aspect, we considered what we wanted the design to look like and how might it change in the future. Fit was simply how the product would fit within the boot. For function, we considered how we planned to use the Pro/E model.

Our plan included Pro/MECHANICA analysis, rapid prototypes and math data via Pro/MOLDESIGN and Pro/Plastics Advisor for the tooling and mold makers. Once we conceptionally agreed on this plan, we created a Pro/E model of the boot last, as shown in *Figure 5*. The boot manufacturer provided the last. Using ISDX, Torgon team member Steve Burke designed a conceptual toe cap based on the boot last that not only matched the geometry of the last, but also contained datum curves that could

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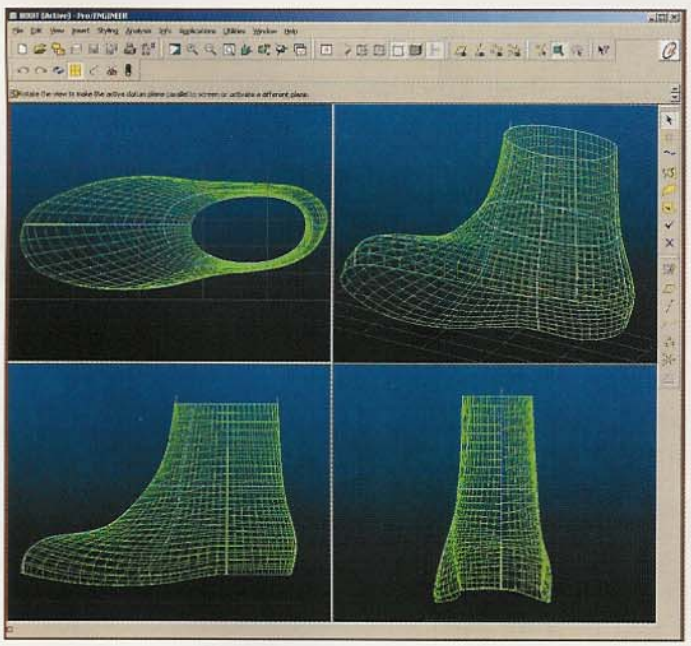

Figure 5. Pro/E model of boot last.

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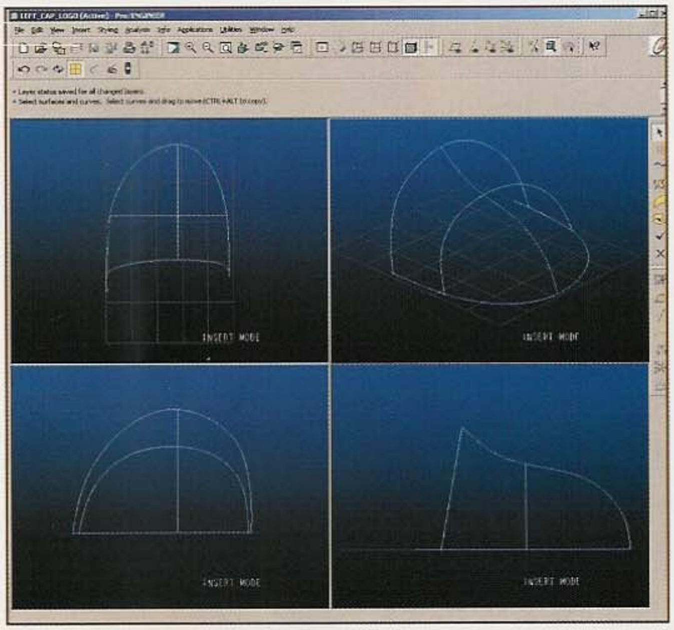

Figure 6.

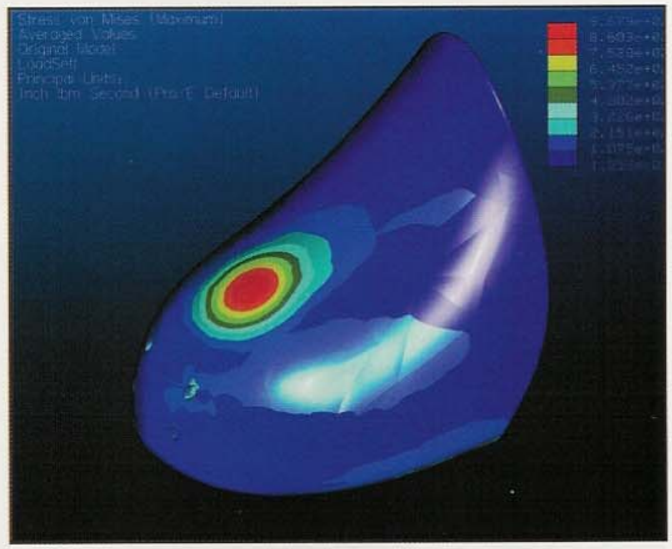

Figure 7.

be easily modified to account for larger or smaller sizes. (See *Figure 6.*) Pro/E family tables were selected because we knew that the design would have toe caps built for various boot sizes. By choosing certain dimensions and parameters in our Pro/E model to vary by size, instances could be made using the Patternize option in the Family Table menus. This can produce an endless number of sizes of a design based on varying specific dimensions or parameters on a part. The advantage of using Family Tables is that the different instances (or sizes of parts) are stored in a single Pro/E part file, which saves hard drive space and makes it easy to make changes to the entire family of toe caps.

Next, Torgon's Radu Papara ran a Pro/MECHANICA analysis to check for the required impact strength attributes and deflection. (See *Figure 7.*) Not only did this give us a better idea of the stress concentrations produced when the part is tested, but it also gave us a chance to experiment with different material properties, eliminating the weaker ones. To narrow our choices, we used our existing knowledge about plastics and referred to the "Machinery's Handbook." Later, we discovered another option.

This new option, an inexpensive software called RMA by Resinate Corp., helps select plastic materials. It runs in Pro/E and includes material comparison and pricing information updated daily. The application was unavailable last fall when we created the design. Just for kicks, we later tested our part through this application. The software recommended the exact material we chose and suggested a few others of which we were not aware.

To check the fit once the model was complete, we ran a rapid prototype by exporting a STL file. We could have used a 3D scanner and one of PTC's 3D software scan tools to scan in the boot last for a virtual fit, but we did not have that hardware at the time. Additionally, we needed a hard copy of the part for patent discussions and sales and marketing meetings. This rapid prototype was completed in one day and the fit was nearly perfect. Using Pro/E's parametric and associative capabilities, we made minor changes to refine the part.

With a snug fit on the inside of the part, we needed to check our design for strength. Because the part was designed to fit the last inside the boot, the part could only be changed on the outside wall. Changes on

Figure 8.

the inside would affect the boot last mold and would require the boot maker to incur expensive changes to the final manufacturing process. Based on preliminary calculations, we had an idea about how thick to make the part. We refined the thickness of the part by creating a loading analysis within Pro/MECHANICA. The results from Pro/MECHANICA gave us only estimates with which to work because this was an impact load, not a static load. In the end, we maximized the design for a static load to help achieve impact load conditions. With those results, a second prototype was made and manufactured into the final boot for impact testing, visual and marketing efforts. When preliminary impact tests performed on the prototypes showed the same stress distributions as did the Pro/MECHANICA analysis results, we decided our next step was the production mold.

We were ready to start the production mold because we were confident that we had optimized the strength of the design. The only other variables would be mold flow and material selection. Our focus turned to material selection and molding parameters. Pro/E Plastic Advisor was a terrific tool for getting preliminary data on the actual flow of the material, fill time and injection ports and pressures for our production plastic injection mold tool. This helped us select major molding parameters to optimize our tool design. Pro/MOLDESIGN was used to apply shrinkage and other molding parameters to create the mold inserts that were machined within a few weeks (See *Figure 8*) and the mold base was selected from a simple list of industry standard components.

Last-minute changes to the part would have been easy, since a change made anywhere in Pro/E updates everywhere in Pro/E including all the Pro/MANUFACTURING modules, such as Pro/MOLDESIGN and Pro/E Plastics Advisor. Once the tool was complete, we ran samples with a preferred material and performed preliminary impact tests to check the numbers. Those samples were built into the design of the final boots created for testing at the CSA.

Figure 9.

The final test was a success—a safer, warmer and more durable safety boot that will not set off metal detectors and will bounce back into shape if it is ever impacted. (See *Figure 9*.) It is actually stronger in the cold than it is at room temperature.

We met our goals with a streamlined product development process. Not only did we reduce time to market, we lowered costs by avoiding costly prototypes and errors. Managers at the boot company told us they worked on this application for four years and failed to achieve a deliverable product. We turned a competitor into a customer with terrific engineering tools, applied properly from conceptual design to production.

Engineer Jay Sussman is the president and chief executive officer of Torgon Industries Inc., an engineering design firm and PTC reseller specializing in Pro/E and Pro/INTRALINK services. Torgon has offices in Oakville, Ontario, Canada; Woodbridge, New Jersey; and San Diego and Mountain View, Calif. Sussman is a Level 1 and Level 2 CEP, as well as a PTC-certified instruction provider and has taught PTC classes for five years. Design team members Steve Burke and Radu Papara, both Pro/E specialists, contributed extensively to the toe cap design. Sussman can be reached at jay@torgon.com. *For information about Torgon, visit* www.torgon.com.

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