Engineering a Safer Bounce

Matrix Applied Computing helps Springfree optimize the backyard trampoline

Figure 1. A Springfree trampoline is put to the test by an enthusiastic user.

Ask a kid if they like trampolines and their eyes are sure to light up with joy. But ask some parents and you may get an entirely different response. Despite tightened manufacturing standards, covered springs and frames, and safety net enclosures, some 90,000 children are still injured on traditional trampolines every year in the United States alone. Still, the equipment is becoming increasingly popular worldwide.

Dr. Keith Alexander, an associate professor of engineering at Canterbury University, New Zealand, felt there had to be a safer way to enjoy the trampoline. “I always believed that, as an engineer, I should be doing things that benefit people,” he says. When his wife nixed his plans to buy a conventional trampoline for his daughter Katie out of safety concerns, he decided to build a better one. He began by working in his garage, later moving his research to the University where help from his students plus government and private grants kept the momentum going.

Analyzing “reams of data,” Alexander determined that there were three main impact zones in the classic trampoline design (which dates to the 1930s) that needed to be arranged so the user wouldn’t impact them: the springs connecting the bounce mat to the frame, the metal frame itself and, of course, the ground.

Many prototypes later (starting from 1989) Alexander arrived at his final, innovative solution: move the frame below the jumping surface, create a soft edge to the mat, and surround the whole thing with tensioned, ultraviolet-resistant netting that would bounce users back towards the center if they went off-kilter. The result was the Springfree™ Trampoline (see Figure 1), first produced in 2003 and currently selling at a rate of some 40,000 per year around the globe.

So if trampolines are your thing, the Springfree would certainly make a safer, healthy, eye-catching addition to the backyard. Yet it’s what you don’t see that’s most unique: the high-tech cleats under the mat’s edge—60 or more per trampoline, depending on the model. Made from fiberglass-reinforced polypropylene and shaped like a wide letter ‘T,’ these have a rounded, midline socket into which the balled top of each fiberglass support rod fits (see Figure 2). The lower ends of the rods connect to the metal base of the trampoline.

“The plastic edge fitting of my design had always been the most complicated bit of the eight or nine different versions I came up with,” says Alexander. The cleat, which is inserted into a reinforced pocket in the mat, harnesses the downward tension of each jump, ensuring that the ball at the top of the rod stays wedged into the socket as it moves up and down.

Once the Springfree was commercialized, word about its benefits began to spread. Parent- and safety-association awards followed, sales bounced upwards and production swung into high gear. The company’s New Zealand-based injection molding supplier, Action Plastics, was kept busy manufacturing cleats at a rate that has now reached some 2.5 million units per year.

As the molding tool used to manufacture the cleat drew near the end of its lifetime in 2013, “we had some pretty significant inducements to build a new tool and we realized it was a great time to look at optimizing and improving the cleat component,” says Hamish McIntyre, engineering manager at Springfree New Zealand Ltd. “Because the cleat was so complex in terms of loading and mechanical properties we decided we needed an engineering consultant to help us out. We located Matrix Applied Computing, through a Ministry of Science and Innovation expert search program, and selected them based on their advanced capabilities.”

Of particular interest to McIntyre was Matrix’s familiarity with realistic simulation using Abaqus finite element analysis (FEA) software from SIMULIA, the Dassault Systèmes’ **3D**EXPERIENCE application.

Figure 2. Closeup of the innovative support structure of a Springfree trampoline shows how white rods connect via cleats to the upper, soft-edged jumping surface. Lower end of rods attach to the secure metal frame that sits on the ground. Protective netting not shown.

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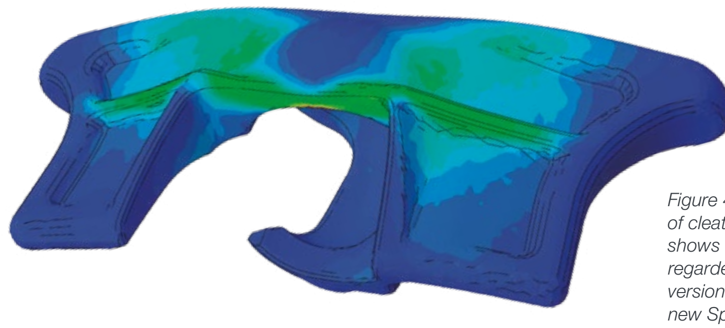

Figure 4. Abaqus FEA model of cleat optimized "by hand" shows the two ribs that were regarded as most effective. This version is now in production on new Springfree trampolines.

"I had worked closely with FEA teams at Airbus in the U.K. and knew how powerful Abaqus was," he says.

"The fact that Matrix used Abaqus was one of the things that drew me to them because I'd seen the software in action on advanced aircraft design."

As Guido Quesada, CAE Design Engineer at Matrix, recalls, "We were already familiar with Springfree trampolines and knew it was a very technical product. Sometimes a potential customer calls with some funny toy or crazy idea that's hard to take seriously. This was definitely not the case with Springfree. From the start, we knew we had a significant challenge with this cleat design project."

There were two main drivers of the challenge, according to McIntyre: "We wanted to improve the strength, the ultimate load capability, of the cleat. And we didn't want to introduce significant additional cost into the component. The quantity we buy each year is expanding along with our sales growth. Just a couple cents less for materials per cleat ends up as a significant cost savings. We saw this as an opportunity to tweak the component and get the most out of it."

And so the tweaking began, starting with some good old-fashioned field research. Both Matrix principal engineering analyst Don Campbell and Quesada took informal walks around their neighborhoods, watching people jumping on Springfree trampolines in order to visualize what was happening to the cleats as the mats went up and down and the rods bent in tandem.

Then it was back into the physical testing lab, where a device was built to apply the load from a rod to the center of a cleat, supporting it at the sides like the socket would. SolidWorks CAD models were made of the rod and cleat components set up in the testing apparatus. The CAD models were meshed with Abaqus FEA, and data captured through the physical tests served as input for the computer simulations (see Figure 3) that predicted how changes in cleat geometry would affect strength and durability.

"Right from the outset we worked closely with our moldmaker [Sean Dryer of Action Plastics] to ensure that what we came up with was manufacturable," says McIntyre. Matrix imported Moldflow software results into their Abaqus models to incorporate the effects of the orientation of the glass-fibers in the cleat and the residual stress from the manufacturing process itself.

The final cleat design the team arrived at (see Figure 4) uses slightly less material overall and has two ribs added on one side, to provide extra support where needed and to distribute stresses more evenly. It's now appearing in new Springfree trampolines worldwide.

After the redesign project was complete, Quesada took a further look at the final cleat geometry using SIMULIA's Abaqus Topology Optimization Modeling (ATOM) tool, which automatically finds the optimum configuration (weight as well as shape) of a component while confirming performance with FEA to ensure strength and durability targets are met.

"Our previous workflow, involving detailed CAD modeling, mold simulations, nonlinear simulation and simplified modal analysis was ultimately highly successful," he says. "But when we applied ATOM to the same design, the process became much faster and effective with automatic exploration of the optimal geometry. I was very surprised to see that ATOM helped spot features I didn't think of, including a third rib. It also saved us a lot of CAD work since the ATOM procedure uses the same reference geometry during each optimization round."

A new four-rib design, which enhances the automated optimization by putting in additional engineering and design judgment, is being considered for the next generation of trampolines.

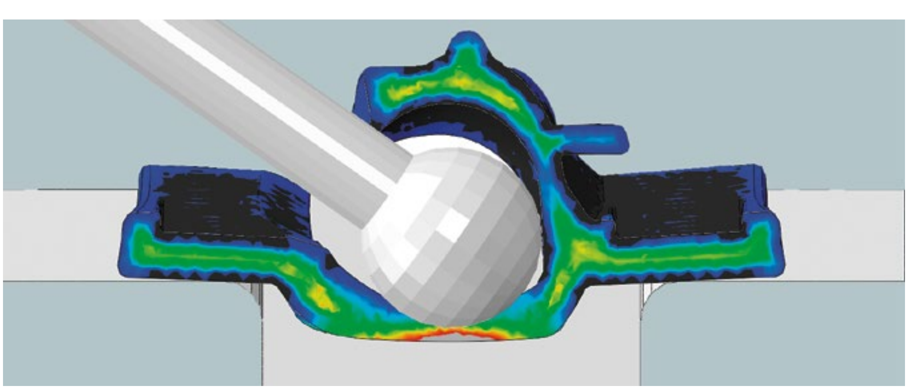

Figure 3. Abaqus FEA analysis of rod ball movement within cleat socket.

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