Designing Better ThinkPads

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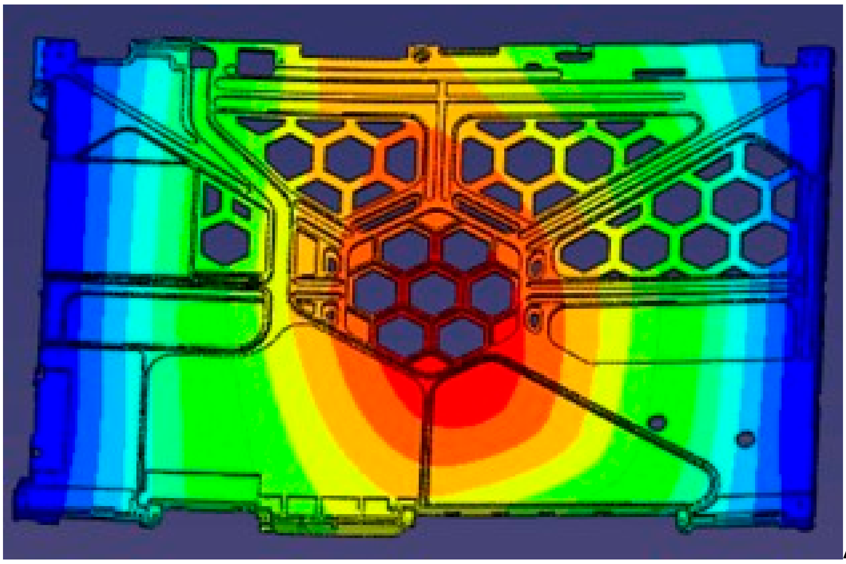
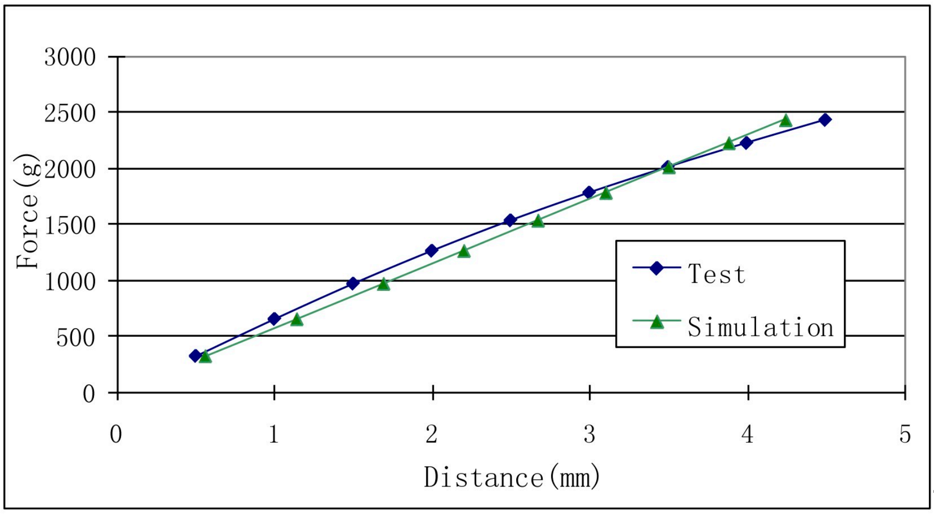
The Lenovo ThinkPad line of laptops is known for its striking aesthetics. The shape of the original IBM design was inspired by Japanese bento lunch boxes (a form still used in ThinkPads today). The 1995 ThinkPad 701, with its unique “butterfly” expanding keyboard, is in the collection of New York’s Museum of Modern Art.

But most laptops don’t sit safely in display cases, or even stay in one place. Consider a typical morning in a coffee shop: A college student strides to his table, bangs a laptop down, flips it open, and begins typing forcefully and enthusiastically. Nearby, another student slams her computer shut, picks it up with a one-handed squeeze, and dashes out at caffeine-induced speeds, bumping it against the doorframe.



At Lenovo, a great deal of design effort goes into ensuring that “portable” doesn’t mean “breakable.” It’s a measure of how seriously engineers take this task that two recent designs for the ThinkPad X300 and the T400 were code-named Kodachi and Shinai respectively—both the names of Japanese martial arts swords. Like those legendary weapons, ThinkPads are widely known for their performance and durability as well as looks—a legacy that Lenovo has continued since it purchased the laptop brand from IBM in 2005. “Our aim is to create a high-quality, reliably strong notebook while keeping cost and product development time down,” says Dr. Zhifeng Xin, senior manager at the Lenovo Innovation Design Center (IDC) in Beijing.

The crucial phase of proving out new laptops is done by Lenovo’s award-winning design center. In the past few years, the IDC has received a US Industrial Design Excellence Award (IDEA), Germany’s Red Dot Best and iF Design Awards, Japan’s international G-Mark Good Design Award for industrial design, and the Intel Innovation PC Award, among others. Engineers at the IDC analyze all of Lenovo’s products, ranging from PCs and notebooks to cell phones and servers. Finite element analysis (FEA) takes place at the concept, development, and failure analysis stages. FEA simulations at Lenovo include modeling drop, shock, vibration, static pressure, and motherboard strain.



The IDC also performs computational fluid dynamics thermal and airflow acoustic simulations. Realistic simulation of notebook computers like the ThinkPad began at the IDC in 2007 and became a formal checkpoint in the product development process shortly thereafter. Abaqus from SIMULIA, the Dassault Systèmes brand for realistic simulation, has been an essential tool for FEA since the IDC first opened its simulation technology center. “With Abaqus, we're able to be more innovative, more quickly, and produce higher-quality products,” Dr. Xin says.

Engineers use Abaqus early in design process to verify product strength, choose between different versions, and identify and improve problem areas. The process involves pre-processing from CAD to meshed model; establishing loads, boundaries, and part interactions; running the analysis; and creating the reports.

Flexible analysis, rigid results

FEA is especially central to eliminating flex, an objective vital to making the ThinkPad more reliable. A number of forces—such as carrying a closed notebook one-handed—can potentially deform the laptop frame and bend the motherboard, which could damage the soldered connections or the liquid crystal display (LCD).“Notebooks face demanding loads and forces even when they’re just being carried from place to place,” says Dr. Xin. “It’s important for the covers to be stiff enough, with minimal deformation, so that the rear cover will protect the display, while the base cover protects the motherboard."

During recent work on a new model, simulation of flex was instrumental to the goal of reducing weight without loss in strength or rigidity. A base cover that used carbon fiber reinforced plastic (CFRP) with an aluminum shield would offer support to the motherboard. The LCD screen would be protected by a rear cover with CFRP and graphite-fiber reinforced plastic (GFRP).

Analysts simulated the physical tests that were performed on a magnesium LCD frame, an LCD panel assembly, a rear cover made of PC/ABS, and a CFRP base cover with its aluminum shield in place. "We applied loads of 400 to 3200 grams, and we compared the resulting deformation to physical test results," says Dr. Xin. "In each case, simulation had a close correlation with real-world behavior during physical testing."

In a whole machine analysis, engineers evaluated the performance of laying-up composite CFRP for the rear cover; this kind of composite material could enhance much of the strength for the entire machine. "In this instance," Dr. Xin says, "the nonlinear capabilities of Abaqus were valuable to us because of the complex performance properties of the materials, complex geometry deformation and complex contact behavior." Engineers also evaluated two alternatives for the array of CFRP: horizontally versus vertically orienting the fibers. The analysis found that horizontal lay-up of the fibers resulted in smaller deformation. The engineers were also able to prove out the strength of a (now-patented) joint line for combining CFRP and GFRP. Due to composite CFRP being limited by part geometry shape, the rear cover is made of both CFRP and GFRP through the patented joint method.

Analysis weighs alternatives
The Kodachi (ThinkPad X300) project proved that the simulation tool has the ability to provide accurate results, allowing engineers to predict the strength of the structure and offer suggestions to CAD designers, on the project codenamed Shinai (ThinkPad T400s), for example. Analyzing deformation of the closed notebooks under a press load revealed that the Light Emitting Display (LED) stress was much lower than in the Kodachi design. During press load on the rear cover of the whole machine, the Kodachi LED contacted the track-point—the cursor tracking button in the ThinkPad keyboard—potentially creating as much as 8.4 MPa of stress. By contrast, the LED on the Shinai contacted the palm rest on the base, yielding a much lower stress of 2.2 MPa.

The analyses also showed that four areas on the magnesium frame of the Kodachi design exceeded specifications for material yield strength and created deformation of the rear cover of 5.8 mm, resulting in higher overall deformation than on the Shinai, which only exceeded specs of material yield strength in one area. The data from the simulation guided revisions to the Shinai frame, helping the development team speed up the project schedule. “Because of our work with Abaqus,” Dr. Xin says, “we were able to fix the Shinai design quickly and easily.” In both cases, FEA results were quite similar to physical test results.

FEA gets in touch with keystroke feel
Keyboard design is a strong selling point for the ThinkPad. The notebooks have long been known for their sturdiness and their pleasing signature “feel”—the physical response of keys being pressed. In the case of a new keyboard, the engineers wanted to reduce the thickness of the assembly (thereby making the overall notebook slimmer) but still keep their traditional keystroke feel.

“‘Feel’ may sound like a vague term,” Dr. Xin says, “but with FEA, it is actually quantifiable.” To confirm that the feel remained the same from the old keyboard to the new, engineers simulated the effects of keystroke pressure on the original dome-shaped rubber spring, the central component that provides each key with its resistance and spring-back. Because the rubber dome was axisymmetric, they were able to model a 2D half-section of the spring and run the analysis on that. The nonlinear simulation enabled the engineers to establish values—on a feeling chart—for how far the rubber dome traveled downward (compressed) as keystroke force increased. (Typical typing force is between 0.6 to 1.2Newtons.)
The engineers then used Abaqus to evaluate a new rubber dome design for the thinner keyboard in order to match the keystroke behavior of the old rubber dome. “The feeling chart of the new simulation showed close correlation with the old one,” Dr. Xin says, “and both simulations matched up well with data from physical testing.”

These are just some of the simulations a Lenovo ThinkPad undergoes on its way from design to reality. The motherboard itself is also analyzed (and physically tested) for flex, and the Ball Grid Array (BGA) components are modeled undergoing strain to confirm that the solder joints will perform well. “As always, nothing validates a simulation like its close conformity to real-world testing,” Dr .Xin notes. “The push-point tests of the motherboard, and the strain tests for the BGA, were based closely on our physical prototype testing, and they yielded similar results.”

All of the simulations at the Lenovo IDC yield the same result: high-performance, quality products that undergo less prototyping, reach production faster at a smaller cost, and perform reliably for users, from museum curators to coffee-fueled college students.