Bausch + Lomb visualizes cataract surgery with SIMULIA

BAUSCH + LOMB

By Lynn Manning

Bausch + Lomb sought to understand the engineering challenges of complex cataract surgery to improve its products, procedures, and post-surgical visual acuity. With SIMULIA from Dassault Systèmes, Bausch + Lomb can solve large nonlinear deformations and difficult self-contact issues, helping engineers visualize a complex biomedical application that cannot be measured physically.

Use your smartphone to see a simulated lens insertion

ROBERT STUPPLEBEEN
Bausch + Lomb Design Engineer and Analyst

By age 80, more than 50 percent of all Americans develop cataracts; every year, more than 3 million undergo corrective surgery. Modern cataract surgery was first performed in the late 1960s, but because the first prosthetic intraocular lens (IOL) was rigid, the incision required to insert it into the eye was large and outcomes varied widely.

Current surgery success rates approach 95 percent, however, largely due to the development of deformable (flexible) materials, including hydrophobic acrylic and silicone, which have decreased incision size dramatically. Today, lenses are being delivered through incisions as small as 1.8 mm.

Engineers at Bausch + Lomb in Rochester, N.Y. recently set an ambitious goal of enabling incisions as small as 1 mm. Research and development is focused on new lens materials and improved geometry, as well as better insertion tool designs. Finite element analysis (FEA), with its ability to realistically simulate a wide variety of physical phenomena, is critical to this effort.

SIMULATION SEES WHAT CANNOT BE MEASURED

Engineers at Bausch + Lomb are using Abaqus FEA from SIMULIA, the Dassault Systèmes brand for realistic simulation, to test more designs more quickly to arrive at optimized solutions.

The Bausch + Lomb team generally starts with 3D CAD models created in Dassault Systèmes' SolidWorks, and then uses the software's Associative Interface to import the model into SIMULIA Abaqus.

When starting a new product design project, "getting sufficient biological test data can be problematic," explains Robert Stupplebeen, design engineer and analyst at Bausch + Lomb. "With just about any biomedical product or process development, a lot of assumptions need to be made."

In the case of cataract surgery, the Bausch + Lomb product development team is focused on two primary modeling issues that *can* be confirmed by testing: the insertion force required to implant the lens, and the geometry of the lens as it emerges from the inserter. They also are studying what *cannot* be measured in real life, including the geometry and internal stresses placed on the lens by the inserter.

"We validate our model on the things we do know and then utilize the rest of what the model tells us to gain a better understanding of the physical behavior," Stupplebeen says. "Without FEA, all of these things are just unknowns."

THE MODEL: LENS, INSERTER, INCISION

From an ophthalmologist's point of view, the cataract surgical procedure is relatively simple. Take a standard IOL, which consists of a circular lens with four appendages (haptics) that stabilize the lens in the eye; load the lens in the inserter and fill the inserter tube with a viscoelastic lubricant; make a small corneal incision and remove the damaged crystalline lens using an ultrasonic device; then place the inserter in the incision and push the plunger, inserting the IOL. The surgery typically takes less than 10 minutes.

From an engineering perspective, however, the procedure is quite challenging due to the geometry. An industry-standard precision lens has a 6 mm diameter, a center thickness of 1 mm, and four haptics; an average incision is 2.8 mm.

"It's like trying to suck a Frisbee through a vacuum," Stupplebeen says. "During the insertion, the lens can experience strains in excess of 60 percent."

VALIDATING LENS STRAIN AND INSERTER FORCES

By using Abaqus, the team was able to calculate the force applied on the inserter versus the displacement experienced by the lens and then compare it with physical test data. The analysis yielded results that correlated well with the tests, which validated the simulations.

"Given the agreement between simulation results, physical tests, and observations, the validated model is being used to reduce the likelihood of failure modes, reduce insertion force, and develop the next generation of IOLs and inserters," Stupplebeen says.

FEA BENEFITS ARE CLEARLY VISIBLE

Whatever the product development direction, Abaqus FEA from SIMULIA is helping Bausch + Lomb designers and engineers reliably predict what will work. Since cataract surgery product design cycle time is typically about a year and a half, with an additional year for clinical trials, accelerating prototyping with realistic simulation provides tremendous bottom-line benefit.

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>
> **Robert Stupplebeen**
> *Bausch + Lomb Design Engineer and Analyst*

"We recognize the significant return gained from continued investments in simulation," Stupplebeen says. "Without a doubt, it has helped us shorten our time to market, decrease our development costs, and improve our product performance."

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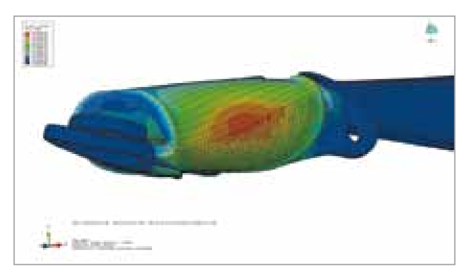

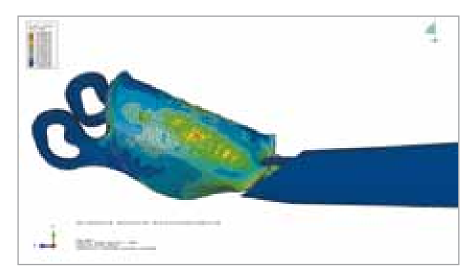

(left) Lens strain is illustrated as the IOL is being pushed by the plunger inside the inserter during a cataract surgery simulation. Rare lens tear has been observed to occur at points of stress where the plunger contacts the IOL or on the trailing haptics.

(right) Strain on the lens is shown as the IOL emerges from the tip of the inserter. The areas of highest stress correlated with the location of rare lens scratching. Values represent 0-60% strain.