Baker Hughes Refines Expandable Tubular Technology with Abaqus and Isight

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Jeff Wiliams
Project engineer,
wellbore construction group,
Baker Hughes

The unique characteristics of each oil well, gas field, or alternative energy project call for custom-tailored exploration products and solutions that grow out of close collaboration with customers and an intuitive, flexible approach to engineering. Fine-tuning the tried-and-true certainly works in many cases—but applying innovative technology and being open to new ideas is how service companies stay ahead of their competition.

Baker Hughes is one such game-leader. Formed by two companies founded more than 100 years ago, Baker Hughes has a long history of inventions that revolutionized the fledgling petroleum era. At dedicated innovation centers, scientists conduct applied research; at regional technology centers, they collaborate closely with customers; and at product development centers, engineers work on next-generation products and services for drilling and evaluation, completions and production, and fluids and chemicals.

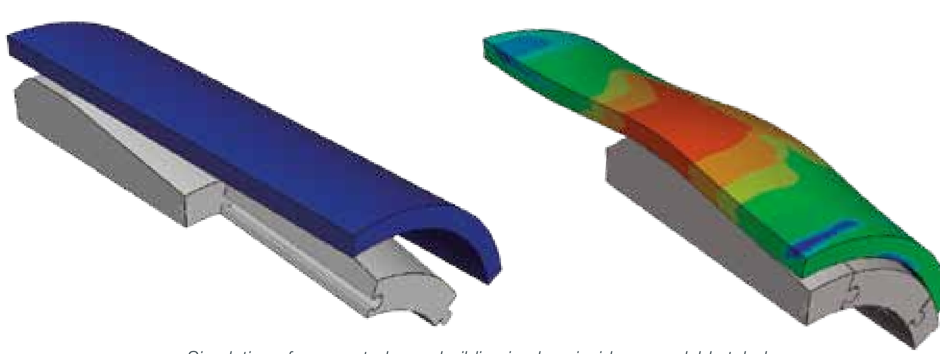
Given Baker Hughes' philosophy of ongoing discovery, it's no surprise that design simulation with finite element analysis (FEA) technology has been a key strategic product development tool. Yet early use of the software was not very proactive, according to Jeff Williams, project engineer for the wellbore construction group (part of the company's Completion and Production division). "Our group's original mentality was to use FEA in a reactionary role. If something breaks, let's go analyze it and see why. But I wanted to take the bull by the horns and use FEA on the conceptual forefront in our downhole expandable tubulars product development process," Williams says.

"Expandables" are a valuable product line in which Baker Hughes has been a leading developer over the last 15 years, with such concepts as the liner hanger packer, screen products, and monobore liners.

"Real-world testing and evaluation of concepts is more expensive in this expandables product line than any other because we are forming metal with materials that aren't just off the shelf," Williams says. "The potential time savings of using FEA for virtual design and testing to prove out our best concept models before prototyping was considerable. With tighter budgets these days, putting real-world testing further along in the product development process also saves money."

Williams has evaluated available FEA software and decided that Abaqus from SIMULIA, the Dassault Systèmes brand for realistic simulation, was the best tool for the expandable tubular challenge. "I knew what our simulation guys were already using, but wanted Abaqus," he says. "With the expansion process, there's obviously a lot of physics involved. There's conservation of volume, a bend/rebend phenomena, and the mechanical expansion of the pipe with the cone device. There's also hoop stress and the Bauschinger effect (post expansion, the tensile yield is stronger, but the compression yield strength is lower). There's so much going on at once. Abaqus is a clear market leader with these kinds of

Segmented expansion cone.



Simulation of segmented cone building in place inside expandable tubular.

Figure 1. Reinforced anchor slip.

Figure 2. FEA of extrudable ball seat.

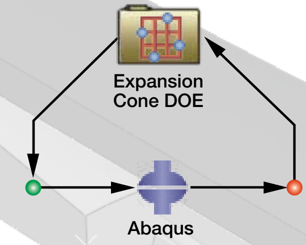


Figure 3. Isight simulation process flow for expansion cone design of experiments (DOE).

nonlinear dynamic events, not to mention the elastomers on which many of our products are based."

An early design problem was a case where an expandable anchor slip was potentially under too much deflection under an emergency release mode thus rendering the running tools (which are used to expand the tubular) irretrievable (Figure 1). The group ran multiple FEA models to determine where to reinforce the slips to avoid this problem.

Another case involved developing an extrudable ball seat that released pump-down balls at precise pressures to activate and deactivate service tools, but also allowed for up to five different balls to pass through without fracturing (Figure 2). FEA was used to help find the best design that would extrude the balls at predetermined pressures.

"For evaluating expandable openhole barrier concepts, Abaqus was crucial," Williams says. Concepts could be quickly simulated and filtered for feasibility, enabling informed decisions about whether or not to fund further development. "The idea that you don't do any real-world testing until you see FEA results has now definitely caught on throughout the company."

Isight: a quantum leap

Then came a further paradigm shift: the engineers were introduced to SIMULIA's Isight process automation and design optimization software, which could be used in conjunction with their Abaqus tools to speed up the design process even further (Figure 3). Isight automatically and systematically alters the variables in a design undergoing FEA. The user's choice of design of experiments (DOE), or other Six Sigma methodology, is linked to the FEA analysis to evaluate simulation results against criteria such as how much each iteration varies from the target, which model provides the best performance, and which design will cost the least to manufacture.

"My mind began racing," Williams says. "I could definitely see multiple applications for the Isight tool immediately. We had been accomplishing a lot manually with FEA, squeezing in as many runs as we could and banging out a lot of iterations over four to six weeks on a typical project. But I saw the potential for a quantum leap in time and money savings with Isight."

Williams' team had just started a pilot project for designing a cone expansion tool to be used with high-torque, gas-tight threaded connections in expandable tubulars. The specialty tubulars are part of a potential wellbore concept that involves one-trip drilling with casing, in which expandable liner packers come along for the ride as part of the bottomhole assembly. The new cone technology needed to work with Baker Hughes' already fine-tuned threaded connector designs and advanced materials. "The only thing we hadn't looked into optimizing yet was the cone," Williams says.

Existing cone geometry, developed five years earlier, had been "manually optimized" through repeated, extensive FEA testing for one type of threaded connector (connection A). But when the same cone design was tried on a different connector (connection B), it did not perform as well, so the design was abandoned and a new one was manually reworked through several more months of analysis. This new cone (BR-6) worked very well on connection B, but not with connection A. The engineers were faced with a quandary: developing a whole new cone geometry for each type of connection would be prohibitively expensive. Could they find one cone design that would work for both?

"Using the Abaqus component in Isight, we could communicate seamlessly with our FEA model behind the scenes," Williams says. "The drag-and-drop function in Isight is easy to use when setting up your simulation process flow. We could create a DOE as needed, picking the cone component dimensions we wanted to change by focusing on those parameters that we knew influenced the post-expanded geometry of the connection." The process did not call for major compute power, as they performed all their Isight runs on a 4-core, Xeon Intel processor running Windows XP.

With all the necessary analyses plugged into the Isight workflow, the team could then automatically run hundreds of FEA-tuned iterations to optimize the cone design. Before Isight, it would have taken at least two months of analysis and testing to develop a single acceptable cone geometry. With Isight, the development period was reduced to two days. "We saw awesome results, with clearly better thread expansion, almost immediately," Williams says.

Surprisingly the final result, deemed the OPTI-Cone, employed some of the old geometry used for connection A that had been discarded in the pursuit of the supposedly ideal BR-6 cone. "The OPTI-Cone uses geometry previously deemed unacceptable," Williams says. "Isight took us down a path we had not foreseen and gave us the confidence to keep an open mind about design. If we hadn't been using the software, the most effective cone geometry would have never been considered."

Subsequent iterations proved out the same size OPTI-Cone for several other thread configurations. And even when mapping over to different diameter expandables that required an alternative cone size, the engineers found that running their new DOE through Isight helped them arrive at the best geometry much faster. "Going forward, this kind of quick adjustment to specific product configurations gives the potential for more rapid, precise customization," he says. "With the OPTI-Cone, we can now attack a market that no one has been able to until now: high-torque, gas-tight expanded connections."

Automating the optimization process with Isight has another, more immediate benefit, Williams points out. "The time we are now able to save is hard to put a monetary value to. It's not just how much quicker the project can go, it's also a matter of, if I can get this done quicker, what else am I going to be able to work on next? We now have both the software tools and more available man hours to pursue new markets previously thought unobtainable."

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