# ENSURING A GOOD BOND

New **Baker Hughes** electromagnetic–acoustic transducer (EMAT) technology provides a more accurate method of assessing the bond between the cement and casing in an oil well. Baker Hughes engineers used ANSYS Mechanical to maximize the reliability and reduce the time to market for this technology by 20 percent; the key was designing the complex linkage assembly to successfully deploy the transducers inside the wellbore for measurements.

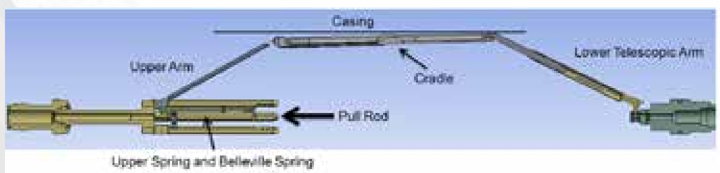
By **Saeed Rafie**,
Senior Reliability Manager,
Baker Hughes
Wireline Services,
Houston, USA

**Smart and Integrated Surface, Subsea and Downhole Technology**
ansys.com/downhole

One of the most critical steps in preparing a well for production involves pumping cement into the annulus between the drill bore and the casing — the tubing that is set inside the drilled well to protect and support the well stream. Cementing the well provides a number of benefits, the most important of which is isolating the surrounding geological environment from flowing production fluids. The integrity of the cement, and particularly the strength of the bond between the cement and the casing, is critical for delivering the highest-possible level of protection to ensure reliability and safety of the well.

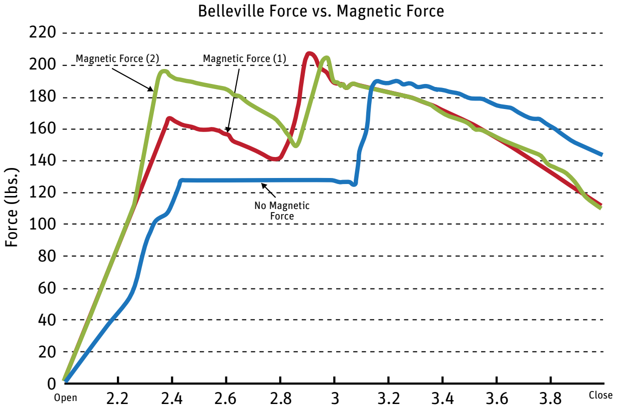
Traditionally, measuring cement bond integrity relied on acoustic transducer instruments that are lowered into the well. The instruments sent an acoustic energy (pulse) into the casing. The amount of acoustic energy that leaked into the cement indicated the cement's compressive strength. A solid bond resulted in less energy being reflected back to the instrument. In challenging conditions, such as when the cement becomes contaminated with borehole mud or when low-density cement is used, acoustic impedance of the cement is decreased and traditional acoustic-based cement evaluation is not possible. However, using a new capability called the Baker Hughes Integrity eXplorer™ wireline cement evaluation service, electromagnetic–acoustic instruments are lowered into the casing to assess the integrity of cement bonds. The acoustic shear wave generated by the electromagnetic-acoustic transducers (EMATs) provides a new foundation for cement evaluation by responding to the cement's shear modulus, which is a true indicator of solid cement behind the casing.

When developing this new instrument, engineers needed to design the linkage, a mechanism that carries the sensors downhole so the device would open to deploy the instruments and then close to move the linkage to a new location. Repairs cannot be performed downhole, so if the linkage does not operate properly when deployed, it must be brought to the surface for repairs. This is an expensive process. In a worst-case scenario, the linkage becomes lodged in the hole, which requires even more expensive




^ Schematic of linkage of Baker Hughes electromagnetic–acoustic transducer

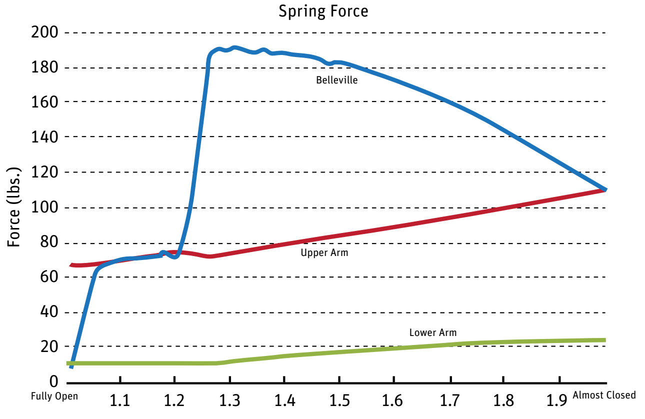
^ Contact force due to friction between telescopic parts remedies. The design of the linkage is particularly challenging because, for accurate measurements, the sensors must maintain the contact between instrument and casing. The hole and casing are not always straight, so to ensure that the sensors maintain contact when a bend occurs, each sensor is attached to a spring-loaded telescopic arm that extends to maintain contact with the casing. The linkage also must operate properly in a wide range of wellbore diameters. It was critical that engineers optimize the design of the linkage because of the high cost of building and testing prototypes, and the even higher cost of a downhole failure in a well being readied for production. Baker Hughes engineers estimated that traditional design methods, which rely on building and testing prototypes to evaluate the performance of proposed linkage designs, would have required three or four prototype iterations to meet the design specifications. This approach would have taken about three years to develop the product.




^ Resultant forces from simulation when the linkage is fully open and fully closed

Instead, Baker Hughes engineers used ANSYS Mechanical to evaluate multiple linkage designs and simulate their performance under a wide range of conditions. Engineers began with a SolidWorks® model of the initial concept design. They defined several types of joints and springs used in the linkage, the spring constants, the torque function of the motor driving the linkage, and the coefficients of friction of the telescopic arm and joints in the linkage. Concern about the friction between telescopic parts due to potential deflection of the lower telescopic arm led Baker Hughes engineers to define the arm as a flexible model by incorporating a finite element mesh, material assignment and solver setup.

ANSYS Mechanical provided a complete picture of the linkage's performance, including contact friction forces, flexing, twisting and deforming of the lower telescopic arm. For example, it calculated the frictional forces generated as the telescopic arm was deployed and the joints in the linkage rotated, and the forces generated by the springs as they were displaced. The simulation results showed several opportunities for improvement. For example, in the initial concept design, the springs that retract the telescopic arm did not generate enough force to overcome the frictional forces.




^ Spring forces when the linkage is fully open and fully closed

Baker Hughes engineers addressed these and other issues revealed by the simulation by changing design parameters in the model and rerunning the simulation. They solved the telescopic arm problem by adjusting the spring constants. Engineers used ANSYS Mechanical to evaluate many different alternative linkage designs. This ensured that the linkage would successfully perform the critical deployment and withdrawal operations. By calculating component loading, the team optimized components and ensured that they would survive downhole.

Based on the simulation results, Baker Hughes engineers identified a design that met the requirements and commissioned a prototype. Testing of this prototype showed it performed exactly as predicted by the simulation, so the company began production without additional prototype iterations. Baker Hughes engineers estimate that the use of simulation on this project saved about 6 months or about 20 percent of the total of 30 months required for this project from concept through completion.

The Baker Hughes Integrity eXplorer™ wireline cement evaluation service was introduced in 2015. The service earned an Offshore Technology Conference (OTC) Spotlight on New Technology award for 2016. This OTC award is presented to selected exhibitors for the most innovative hardware and software technologies for offshore exploration and production.