MICROSPHERE-BASED CEMENT SOLVES COMMON LOST CIRCULATION PROBLEMS IN THE PERMIAN BASIN AND SURROUNDING AREAS

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ABSTRACT
Operators drilling in the Permian Basin and surrounding areas with low fracture gradients have long strived to achieve zonal isolation and prevent losses in primary cementing. Solutions have generally involved two-stage cementing, water-extended lightweight filler cement, or foamed cements.

Microsphere-based cement provides additional solutions to problems associated with low fracture gradients. The addition of lightweight microspheres to cement slurries can create lightweight cement slurries without the early compressive strength development issues associated with water-extended lightweight slurries. This allows microsphere cement to be placed across zones of interest as production cement without experiencing losses. Eliminating or minimizing losses helps ensure zonal isolation with the primary cementing job, eliminating the need for remedial work.

This paper discusses case histories including both intermediate and production casing strings where these alternative lightweight cementing solutions have been used. Zonal isolation and minimization of annular losses on these wells will be illustrated.

PROBLEM
In portions of the Permian Basin fracture gradients have decreased to the point where conventional cement could not be circulated consistently back up inside the previous casing string. One option that has been tried successfully is using a stage tool and performing the cement job in stages. By separating the job into stages, the fluid cement column height is reduced. Circulating cement becomes possible if the column is made short enough. If the first stage is allowed to set or at least completely gel prior to beginning the second stage, hydrostatic pressure from the second stage will not be transmitted down to any weak zones below the stage tool. This helps increase the probability that the measured top of cement (TOC) will reach the required or design TOC. While often successful, multistage jobs have inherent risks associated with them and as such some operators would rather avoid placing these required stage tools into their wellbores if there is an alternative. The main concerns associated with stage tools are fourfold:

- These tools have holes in them. While these holes are required if a second or third cement stage is to be circulated up the annulus and started somewhere other than the bottom of the casing, it still means having holes in the pipe.
- The tool might not open. If the tool does not open, the second stage cannot be circulated and the TOC is lower than required/desired. The only alternative is to bring a perforating crew out, blast holes in the casing, and then continue with the second stage. While the ultimate result is nearly the same, a lot of rig time may be wasted, not to mention the additional costs.
- The tool opens, but circulation is not possible. Again, when holes need to be punched, time and money can be wasted.
- The tool does not close properly. In this case, the cement job is completed and hopefully the holes are sealed with cement, but they are exposed holes just the same. The alternative to running a multistage cement job is to reduce the cement slurry density to a level at which the circulating pressure in the wellbore will stay below the fracture pressure so cement can be circulated back up inside the previous casing or to wherever the design TOC is required.

LIGHTWEIGHT CEMENTING OPTIONS
When cementing casing through zones with low fracture gradient, conventional cements will often exert too much hydrostatic pressure, which may result in a lost circulation event. If cement is lost to the formation, the resulting

column will be shorter than planned. Remedial work will be required if the top of cement is sufficiently low. To help prevent or minimize losses across these zones, standard cement densities can be reduced. State-of-the-art technology provides three proven methodologies for reducing cement density.[1-4] The original method uses an increased water ratio. With water weighing just 8.33 lb/gal, any additional water added to the cement slurry will reduce the slurry density. To avoid over-thinning the slurry and any associated slurry stability issues, bulk gelling materials are added at a concentration related to the amount of extra water. Examples of this class of additive include: (1) bentonite, (2) sodium silicate, (3) diatomaceous earth, (4) guar, and (5) cellulose. These water-extended designs are the recommended choice when cost is the primary driver in slurry design and reduced set properties are acceptable. To completely hydrate one sack of cement, only 3.3 gal of water is required. Standard mixing water concentrations range from 4.3 to 6 gal of water per sack. Thus, under normal cementing conditions, extra water is already being added to the cement. Additional amounts of water above the 3.3-gal minimum stretch the cement crystalline matrix and thus adversely affect the compressive strength. These water-extended designs are the slowest strength developing slurries used in oil and gas wells. A second related issue is the lower density limit. Somewhere between 10.5 and 12 lb/gal, strength development becomes too slow for use in the petroleum industry. On the positive side, these gelling materials are normally low cost, thus these designs are the lowest cost slurries, in terms of dollars per cu-ft of yield, available on the market. If set time is too slow and rig time is included, or if the reduced slurry properties are not sufficient to perform as required and overall costs are considered, these designs might not be the most cost-effective solution.

The second way to reduce standard cement slurry density is through the addition of a gaseous phase. Typically, cement slurries are foamed via the injection of nitrogen. For a foamed cement to be useful as a zonal isolation tool: (1) the gas should be added at a downhole volume concentration of less than 45% and normally less than 30% (to avoid permeability issues), (2) proper chemicals should be added that prevent commingling of fluids and promoting the formation of small, well dispersed, stable bubbles, and (3) there should be a properly designed choke to aid in the formation of small bubbles. If a stable foam is created, it can be a very good engineering fluid[6-8] with the advantages of (1) increased elasticity, (2) increased compressibility, (3) the ability to adjust the density on location at the last minute, and (4) increased effectiveness in mud removal. On the other hand, foam cement jobs are: (1) the most complicated way to mix cement, (2) require extra, highly trained people, and (3) require extra, specialized equipment.

The final way to create a reduced-density cement slurry is via the introduction of lightweight microspheres (LWM). Using LWM to create low-density cement slurries can have advantages:

- At any given density, the LWM design can achieve the shortest initial set times. It is common to follow primary cement jobs with rig downtime. When the preparatory work required to get ready for the next rig operation takes less time than the waiting-on-cement (WOC) time, money is being spent WOC. In these situations, reducing initial set time of the cement slurry reduces well construction costs. If rig operations require a day or two before being ready to start drilling or testing cement, reducing initial set does not add value unless it is required for well-control issues
- LWM designs can be made lighter than other designs while still maintaining good set properties. When ultra-lightweight cement is required, these designs are often the best choice. On the other hand, if large amounts of LWM material are required, these slurries can become quite expensive. However, if these LWM slurries can provide zonal isolation on the first try, after factoring in rig time and remedial work, the price is often very economical.

Another consideration is that special care should be taken to help ensure that the cement slurry, when mixed on location, is mixed at the proper cement-to-water ratio. This becomes increasingly important as the density of the bulk material approaches the density of the mix fluid. As the desired slurry density decreases, the concentration of the LWM in the bulk blend must increase. As the concentration of the LWM increases, the bulk density decreases. When LWM slurries are mixed with normal density-based mixing systems and conventional best practices, achieving proper slurry-to-water ratio is not assured. Again, the closer the design slurry density is to the density of the mix fluid, the more serious this problem can become. Some in the industry believe it is hard to mix LWM slurries at the correct density, especially at lower densities. This is a misconception. In fact it is difficult to mix these LWM slurries at the wrong density. To fully comprehend this situation, imagine trying to mix an 8.33-lb/gal cement slurry. If the mix fluid weighs 8.33 lb/gal and the slurry is supposed to weigh 8.33 lb/gal, the bulk material must also weigh 8.33 lb/gal. In this situation, any and every cement-to-water ratio would have the correct slurry density, but not the desired/required slurry properties. With special LWM best practices and special nondensity-based mixing systems, LWM slurries can be consistently mixed at the correct cement-to-water ratio.

SOLUTION

In the Permian Basin, special lightweight water-extended designs have been developed to reduce standard slurry density and circulate up to the required TOC. This is the ideal solution when applicable. These designs are even more economical than conventional cements because they have an increased yield, which means fewer sacks of cement need to be purchased. These solutions work well when the wellbore can handle a 12-lb/gal slurry. Unfortunately, there are areas in the Permian Basin, such as the Delaware and Bone Springs formations, where these water-extended designs are not lightweight enough. In some instances, it is required that 9,600 ft of cement be circulated to get back inside of the surface casing (12,600 ft back to 3,000 ft). In these areas, the more expensive LWM slurry is worthwhile because it can create a better well, eliminate or minimize the need for remedial cementing, and eliminate the need for stage tools. Sometimes both water-extended and LWM slurries will be used on the same job. With this method, costs are minimized while densities are reduced sufficiently to circulate (**Fig. 1**). In Fig. 1., the red curve (slurry density) shows the first slurry in our LWM design, which was pumped at 10 lb/gal; much lighter than achievable with conventional cement systems. The water-extended design was mixed 20% heavier, at 12 lb/gal. In this example, 455 sacks of the 10-lb/gal cement were pumped, achieving 3,300 ft of fill. The wellbore fluid prior to cementing was a 9.7-lb/gal brine. The 3,300 ft of 10-lb/gal cement was sufficiently light to maintain circulation throughout the job.

In **Fig. 2**, the results are displayed from a well that required LWM slurry to be used in combination with a stage tool. Simulation software suggested that even the shorter second-stage column of cement required a 10-lb/gal slurry density. In this example, 575 sacks of the 10-lb/gal LWM slurry were pumped, yielding 2,500 ft of fill. Again, full circulation was maintained during the job, indicating that the 10-lb/gal slurry density was sufficiently light to keep the circulating pressure above the wellbore’s fracture pressure.

In another well, a LWM slurry was used in an attempt to circulate cement back to the surface. Full returns were maintained through the job, and cement was observed at the surface. In this example, 450 sacks were mixed, yielding 3,500 ft of fill. One thousand feet of tail was pumped along with 8,500 ft of 12-lb/gal water-extended cement, filling a column from a TD of 12,600 ft back to the surface.

SLURRY QUALITY CONTROL

To avoid the above discussed cement-to-water mixing rate issues, these jobs were batch mixed. Batch mixing is one of the best ways to help ensure field replication of lab developed slurry properties. Batch mixing eliminates most of the quality control problems associated with blending and mixing LMS slurries when batch mixing best practices are followed. In batch mixing LMS slurries, one best practice that normally might not be thought about is blend batch size. With LMS slurry batch mixing, it is critical to blend in small batches. The batch size needs to be tailored to the blender size. Take an example where 180 bbl of slurry are required, and two batch mixers are available for the job. Standard batch mixers have two 50-bbl tubs. Thus, four 45-bbl batches would be mixed to yield the required 180 bbl. If the slurry yield was 2.42 ft^3/sk, 105 sacks of blend would be required to make 45 bbl of slurry. If losses of 5% are a local standard, four separate batches of 110 sk should be blended. If the slurry were designed at 53.4% water, 24 bbl of water should be added to the batch tanks. If then the entire contents of the four separate batches of blend were added to each 24 bbl of water, 180 bbl containing the correct blend and the correct cement-to-water ratio would be the result. If the blends were not perfectly homogeneous at the time of mixing, but contained the correct amounts of additives, and the full batch was added to the correct amount of water, the resulting slurry would be homogeneous. As long as the job volume is small enough or sufficient batch mixers are available, batch mixing is the ideal methodology for providing LMS slurry quality control.

When job volumes are too large for batch mixing to be a reasonable option, other methods are available that provide varying levels of quality assurance. In the most basic operation, slurry volume generated and mix fluid used are monitored. The slurry’s viscosity and weight can be adjusted by changing the amount of water used. This process can be automated so that the slurry and mix fluid rates are continuously monitored and the mix water rate is controlled to maintain the correct cement-to-water ratio. When automated, this process provides a high level of quality control.[9] Another recent development calls for using the LMS as a liquid additive. Blending and density based mixing issues can be minimized or alleviated with this option.[10]

CONCLUSIONS

- Slurries substantially lighter than 12 lb/gal can be used in the petroleum industry.
- These LMS slurries can be easily mixed.
- Quality control is possible when best practices are followed.
- In areas plagued by lost circulation and partial returns, desired TOC can be achieved.

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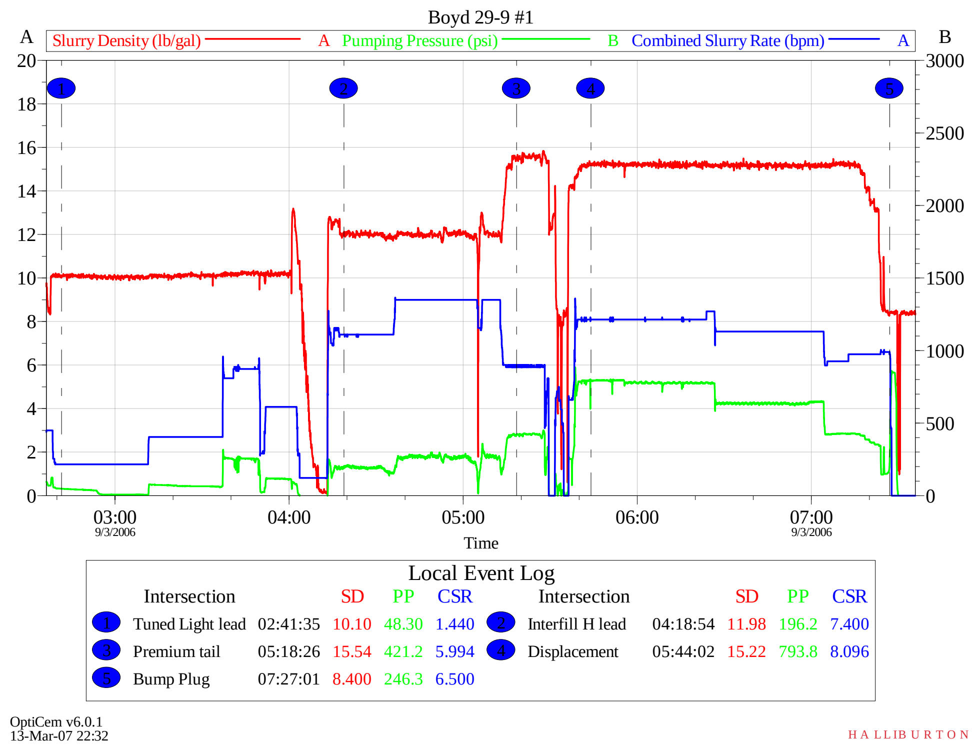

Figure 1—LWM slurry with water-extended slurry; real-time data job plot.

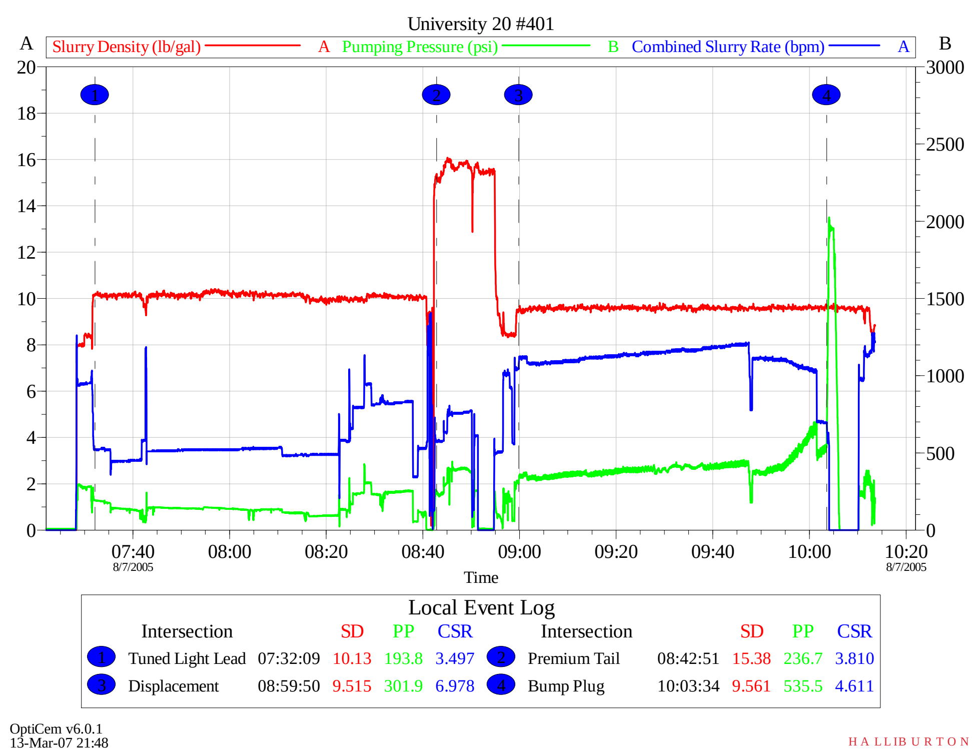

Figure 2—LWM slurry used as the second stage; real-time data job plot.