AN OVERVIEW OF CURRENT BEST PRACTICES IN OIL AND GAS WELL CEMENTING

Alexander Anya
Texas Tech University

ABSTRACT

Oil well cementing has come a long way since the first verified use of cement in oil wells in 1903 by Union Oil Company. The years that followed have seen a remarkable amount of research and technological innovation in fluid flow mechanics, cement rheology, cement additives and cement job procedure. Given its purpose, well cementing is perhaps the most crucial stage in the development of any oil or gas well and as such proper procedure and guidelines as well as adherence to regulations are necessary to ensure success. This paper presents a summary of recommended best practices for all the stages of a cement job, from slurry design and lab testing, to job design, execution and evaluation.

INTRODUCTION

The importance of an effective cement sheath around the casing throughout the life of a well cannot be understated as the quality of the cement sheath is directly related to the productivity of the well. Cementing casing has many purposes depending on the type of casing. For instance, conductor casing can be cemented in order to prevent the flow of drilling fluid outside the casing and the subsequent erosion of the surface. Surface casing is cemented to seal off fresh water zones, while intermediate casing is cemented to seal off zones that are abnormally pressured. Production casing is cemented to isolate productive zones for future development and prevent fluid migration to permeable zones in order to ensure optimum productivity. Cementing also provides a significant amount of structural integrity to the well and protects the outer wall of the casing from corrosion. It is then obvious that a primary cement job has to be designed and executed employing the best practices in order to prevent or at least minimize the need for a costly remedial cementing operation that wastes valuable time and may not be effective. A cementing operation involves the job design and the execution of the job. A short description of the procedure involved and associated recommended practices associated are discussed below.

CEMENT JOB DESIGN

Cement Slurry Design

Cement systems are designed specifically for the prevailing conditions in the well for which the job is to be executed. The factors to be considered when formulating a cement slurry include but are not limited to temperature, pore pressure gradient, formation pressure gradient, formation compatibility, density, rheology, thickening time, free fluid, fluid loss control, stability, strength, static gel strength development and fluid migration control. Every one of these factors must be accounted for in designing a cement slurry mix in order to achieve optimum operational efficiency during cement placement and an effective cement sheath.

Slurry density is directly influenced by formation and pore pressure gradients and cement composition. Although compressive strength does depend on slurry density, strong cements can also be designed at low densities by controlling the particle size of the slurry ingredients. Furthermore, compressive strength requirements vary from location to location and depend upon the specific application of the cement. However, recommended compressive strength of cement before drillout and perforation is 500 psi and 2000 psi respectively. Free fluid in oil well cements must be minimized by all means. Free water is an indication of undesirable solids settling and is a big impediment to cement circulation in the wellbore. The target for free water when designing a slurry system should be zero. This is because free water will lead to the creation of water channels in the set cement. Fluid loss for instance alters the viscosity, density and friction pressure of the slurry. Field results have indicated that a fluid loss rate of 50 ml / 30 min is desirable. The desired values of the other cement properties mentioned earlier for different jobs will be different for each job and each well and are achieved using many different additives. The use of additives is necessitated by the need for cements that ensure operational success, exhibit rapid compression strength development, and contend with fluctuations in temperature, pressure and tectonic condition during the life of the well.

Additives are generally classified as accelerators, retarders, extenders, weighting agents, dispersants, fluid loss control, lost circulation control agents and other specialty additives. Accelerators reduce the setting time of cement thereby increase the rate of compressive strength development. Retarders do the exact opposite by delaying the cement setting time. Extenders lower the density of the cement system while weighting agents increase the density. Dispersants are used to reduce the viscosity of cement slurry in order to design a system with a desired rheology. Finally, fluid loss control additives are used to control the loss of the aqueous phase of cement slurry into the formation while lost circulation control agents as the name implies prevents loss of cement slurry into weak formations. Please see table 1 for a list of additives under these categories. It is important to note that although technological advances have been made in additive formulation and design and the use of additives to affect cement behavior is very attractive to operators, the chances for cement slurry instability and incompatibility with spacer systems and the well environment also increase as the number of additives used increases. This is where the concept of multifunctional additives come in handy. Multifunctional additives offer a remedy to the problem of an increased chance of slurry instability due to multiple additive use. The use of multifunctional additives also simplifies slurry design, reduces your chemical foot print, simplifies field logistics and operations and improves operational economics.

Lab Testing and Job Simulation

The importance of laboratory testing in the cement job design process cannot be under stated. The chemical and behavioral complexity of cement additives and slurries demand that any system to be applied needs to be evaluated by measuring very specific properties of the slurry and the set cement under simulated downhole pressure and temperature conditions. The components of the slurry should also be tested for compatibility and effectiveness under well conditions. The API is the governing body that is in charge of developing standardized testing procedures for evaluating well cement slurry performance. API Specification 10A contains the chemical and physical requirement of eight classes of the cements and specific procedures and equipment for testing the cements neat with no additives. API Recommended Practice 10B outlines general recommendations for testing cement slurries and cementing related materials under the simulated well conditions. These recommendations and specifications can always be modified by the engineer to match field conditions and mixing modes. There are corresponding ISO standards for API Specification 10A and API R 10B as well as additional ISO standards for more specific areas of well cementing. It is important that up to date equipment and analysis methods are used in laboratory testing. Finally, when possible, test results from different laboratories should be compared to improve confidence in and certainty of the cement system's performance.

Computer simulation of cement jobs is now common place in the petroleum industry. A pre-job simulation can be used to make predictions concerning the behavior of the cement slurry to be used as well as the bottomhole and surface pressures to expect during the job. It is important that accurate well data is used for input into the simulator. Very often, actual field results deviate from the results of simulations. However, simulations provide a very good approximation of the conditions that are likely to prevail during the execution of a job. Today, there are a number of commercial simulators on the market that offer a comprehensive suite of applications that handle different wellbore configurations and cement slurry rheological models.

CEMENT JOB EXECUTION

The execution of a cement job can be broadly divided into hole cleaning, mud removal and cement placement. Each of these aspects of a cement job are equally important and very crucial to the performance of a cement sheath. This stage of a cement job is very crucial to its success and is affected by numerous factors that are connected to the quality of the well as well as the different components involved in the mud removal process. The factors that affect the effectiveness of a mud removal operation include wellbore geometry, wellbore depth, casing centralization, spacer fluid properties and spacer fluid – mud compatibility. Typically, the hole is conditioned before and after the casing is lowered, spacer or pre-wash fluid is pumped and then finally the cement follows.

The key objectives of mud removal are to completely remove all mud from the wellbore and remove all filter cake deposits on the borehole wall. Poor mud removal leads to the formation of permeable voids in set cement that allow the migration of fluids in the cement and weaken the integrity of the cement sheath. Poor filter cake removal prevents the cement from bonding to the borehole wall and results in the formation of a micro annulus along the cement – formation interface that allows gas migration along the interface. One of the most challenging problems that is a culprit in poor mud displacement jobs and poor cement placement is casing eccentricity. An eccentric annulus causes an irregular velocity profile around the annulus and leads to unequal mud displacement and cement flow on both sides of the annulus. As a result, large voids and mud channels are formed in the cement and the narrow sections of the hole can be completely without cement. It is paramount that an adequate number of centralizers are used on the casing in order to achieve optimal centralization. These days, the adequate number of centralizers for any given casing job can be calculated using very specialized modeling software. Another piece of equipment of high importance are casing scratchers. These aid in the mechanical removal of filter cake where spacers and washes may fail or are inadequate and just like centralizers should be used adequately in order to achieve a good a result as possible. Spacers and washes/preflushes must be lab tested and designed to ensure that they are compatible with the mud and with the cement. They must be designed and pumped so as not to damage or invade the formation.

A comprehensive approach is recommended as a means to achieve the best possible mud displacement results. Drilling mud should be designed for optimal filter cake deposition (usually a thin filter cake), solids suspension, cuttings removal and hole conditioning. While circulating the mud the following practices are recommended:

- The pipe should be rotated and reciprocated to aid in cuttings removal.
- Simulation and circulation models should be employed to optimize mud properties for increased circulation efficiency.
- Use fluid calipers to measure circulation efficiency.
- Maintain borehole pressure between pore and fracture pressures.
- Maintain annular velocity below the maximum value during the drilling of the hole.

There must be an adequate use of centralizers as determined by specialized software to ensure that there are no tight or narrow sections along the length of the hole that will impede the flow of mud and cement. Scratchers and scrapers should be used in conjunction with pipe movement especially in situations where spacers ad washes may not be very effective. Spacers and preflushes must be lab tested and designed to be as effective as possible in cleaning the borehole wall and displacing the mud while maintaining compatibility with the mud and the cement slurry. Ideally, the displacement fluids should have a lower viscosity than the mud in order to achieve critical pumping rate easily. It is important to implement pipe reciprocation carefully because there is a risk of the casing becoming stuck, as well as swab and surge pressures. These risks are however absent with pipe rotation. Finally, with the help of simulations, pump the job at pre-determined rates that minimize formation damage and prevent lost circulation.

CEMENT JOB EVALUATION

It is necessary to determine whether the objectives of a cement job have been met upon completion of the job. It is important that the objectives of the cement job are clearly defined for the evaluation to be efficient and reliable. Whatever the case may be, it is necessary for the operator to work with the service company to define a list of objectives for the evaluation of the cement job and gather as much data as possible that will be used for log analysis. Different evaluation techniques exist for the assessment of a cement job. These include hydraulic testing, temperature logs, nuclear logs, noise logs, acoustic logs, sonic logs and ultrasonic logs. The limits of the tools used in all the methods listed above as well as the prevalent conditions in the annulus have to be understood and taken into account I analyzing any data.

Use hydraulic testing to test the isolation that is provided by the cement and temperature logs to determine the top of cement, detect leaks and detect channeling. If the drilling mud is treated with radioactive tracers, a nuclear log can be run in order to detect mud after the cement job. By far the most familiar and widely used cement job evaluation method is acoustic logging. In evaluating a cement job using an acoustic method, it is important to know what the anticipated response of the acoustic tool is in different environments. Acoustic logs give insight regarding the quality of the bond between the casing and cement, and cement and formation. Ensure that the characteristics of the formation and data concerning the cement job is known prior to analyzing an acoustic log. Note that the performance of acoustic logs is limited in heavy muds due to wave attenuation. To ensure that the quality of a cement log is good, make sure that the casing is in good condition and the radius and thickness data of the casing is accurate.

CONCLUSION

In the oil and gas industry, time and economics play a very vital role in virtually all decision making processes and rightly so. However, it is important to never place any of those over the safety and longevity of the well. The benefits of adhering to regulations and best practices in well cementing go beyond safety and are economically beneficial in the long run by preventing the need for a remedial cement job. Productivity is optimized when the cement job in a well is effective in preventing fluid migration from the productive zone. A good cement job is especially important if there are plans for future stimulation or secondary recovery installations.

REFERENCES

Morris, W., Criado, A.M, Robles, J., Bianchi, G., “Design of High Toughness Cement for Long Lasting Well Isolations”, SPE 81001, April 27 – 30, 2003.

Rueda, F., Heathman, J. and Serranno, M., “Hole Cleaning and Cement Design for Specific Formation Types”, SPE 84560, October 5 – 8, 2003.

Randi, A., Narvaez, G.G and Bray, W.S, “New Slurry Design Concepts Using Multifunctional Additives to improve Quality and Sustainability of Cementing Systems for Zonal Isolation”, SPE 161352, October 3 – 5, 2012.

Ravi, K., and Darbe, R., “Overcoming the cementing Challenges in Deep Gas Environment”, SPE 132090, January 24 – 25, 2010.

Benge, G., “Cement Evaluation – A Risky Business”, SPE 170712, October 27 – 29, 2014.

Nelson, E.B. and Guillot, D., “Well Cementing – Second Edition”

TABLE 1

Types of Additives and Examples	
Types	**Examples**
Accelerators	Chloride salts, Carbonates, Silicates, Aluminates, Nitrates, Sulfates, Thiosulfates, Ammonium Hydroxide, Potassium Hydroxide
Retarders	Lignosulfates, Hydroxycarboxylic acids, Organophosphates, Cellulose derivatives, Saccharide Compounds
Extenders	Pozzolans, Clays, Sodium Silicates,
Weighing Agents	Barite, Manganese tetraoxide, Hematite, Ilmenite
Dispersants	Sulfonated polymers, lignosulfates,
Fluid Loss Control	Cellulosic polymers, Polyamines, Sulfonated aromatic polymers
Lost Circulation Prevention	Gilsonite, Granular coal, Cellophane flake, Nut shells, Fibrous additives
Strengthening Agents	Glass and polymer fibres, Metallic microribbons, Ground rubber
Antifoam Agents	Polyglycol ethers, Silicones