Mud Condition Effect on Cement Job Performance

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ABSTRACT

The predominant cause of cementing failure appears to be channels of gelled mud remaining in the annulus after the cement is in place. If mud channels are eliminated, any number of cementing compositions will provide an effective seal. In evaluating factors that affect the displacement of mud, it is necessary to consider the condition of drilling fluid before cement job. Model studies reveal that any decrease in viscosity of the drilling fluid increases the displacement efficiency. The drilling fluid removal is affected by two major downhole conditions, namely, the thixotropic properties of the drilling fluid (very closely related to the gel strength) and its filter cake deposition characteristics. This paper looks at a range of specific mud properties which has a bearing on mud removal during cement job.

Keywords: cementing, cement job, displacement efficiency, thixotropic, gel strength.

Introduction

The main objective of a primary cement job is to provide complete and permanent isolation of the permeable zones located behind the casing [4]. To meet this objective, the drilling mud and the preflush (if any) must be fully removed from the annulus, and the annular space must be completely filled with cement slurry. Once in place, the cement must harden and develop the necessary mechanical properties to maintain a hydraulic seal throughout the life of the well; therefore, good mud removal and proper slurry placement are essential to obtain well isolation. Incomplete mud displacement can leave a continuous mud channel across the zones of interest, thereby favoring interzonal communication. Bonding and cement seal durability is also related to the efficiency of the displacement process. This is why mud displacement has been a topic of interest for such a long time in the well cementing Community. It is significant that essentially all published model studies and work credit that the proper mud condition before cement job is the most important driving factor with the success of primary cementing during the critical displacement period [1, 2,3].

Mud Conditioning

Drilling muds have properties which are designed to facilitate drilling operations and provide proper cuttings transport, but are not necessarily conducive to efficient mud displacement [1,2]. Therefore, it may be necessary to condition the mud, i.e., to modify its properties. Prior to placing cement in the wellbore, two mud characteristics can be changed-density and rheology. Anticipating the best conditions for displacement, it is desirable to reduce the mud density to the minimum wellbore density limit. However, the mud density is usually maintained close to the wellbore pressure limit during drilling. Reducing the mud's gel strength, yield stress,

and plastic viscosity is recognized as being very beneficial, because the driving forces necessary to displace the mud are reduced, and its mobility is increased. The mud rheology can be modified by adding water to the mud at the surface. It is necessary to circulate the mud until its rheological properties are within the desired range. This necessitates circulation for at least one hole volume, and ideally should be done before removing the drillpipe. Otherwise, unconditioned mud may have sufficient time to gel during the pseudostatic period (while removing drillpipe, logging, and running casing). Mud circulation is also necessary after the casing is in place [5,6]. Unfortunately, it is very common to condition the mud only at this stage. Circulation is beneficial in the following ways:

- Ensures that gas flow is not occurring,
- Homogenizes the mud after treatment on the surface,
- reduces mud yield stress and plastic viscosity because most drilling muds are thixotropic,
- Erodes the gelled and/or dehydrated mud that is trapped in washouts, on the narrow side of an eccentric annulus, and at the walls of permeable formations.

Gelled or dehydrated mud, which is eroded while running the casing, can lead to an excessive pressure buildup when circulation is resumed. Therefore, it is often desirable to circulate the annulus at intermediate intervals before the bottom of the hole is reached. The mud mobility factor has an inverse function of the filter cake characteristics and the maximum gel strength of the mud. It has been demonstrated that as the value of this factor increased, by decreasing the filtrate loss or the 10 min gel strength, the displacement efficiency of the drilling fluid increased dramatically [1,2].

Effect of Gelled Mud and Mud Cake on the Circulation Process

The theoretical results for mud displacement during cement job have not considered the effect

of gelled mud and/or dehydrated mud on the circulation process. Such modifications may not only take place when the mud is static, but also while the mud is being circulated, because wellbore ovality, irregularities (washouts), and casing eccentricity can induce zones where the local velocity of the fluid is zero. This mud is commonly called the immobile mud when allowed to remain static; most drilling muds develop a structure which is usually characterized by its gel strength. This parameter represents the minimum shear stress value necessary to induce flow. Drilling muds are designed to exhibit such thixotropic properties, because they must be able to suspend cuttings and the weighting agent when circulation is stopped. Unfortunately, the mud gel strength is partially responsible for the wellhead pressure peak when circulation is resumed. In addition, it can strongly affect the efficiency of the circulation process, especially when the pipe is not centered. Once the mud has been allowed to gel, the force required to overcome it is no longer equal to the yield stress, but to the gel strength. Thus, for fluid exhibiting gel strength the minimum friction pressure to achieve flow on the narrow side of an eccentric annulus might be result in formation fracturing. The presence of a mud cake at the wall of permeable formations is another factor which affects the circulation process. When mud is not flowing across a permeable zone, it is subjected to static filtration. Without sufficient fluid-loss Control, an excessively thick filter cake can grow and reduce the size of the annulus. Mud cakes as thick as ½ in. (1.2 cm) have been measured by a caliper with poorly treated muds. This partially dehydrated material is difficult to mobilize when circulation is resumed, because both its density and viscosity (especially at low shear rates) are much higher than those of the original mud. Predicting how much mud cake will be eroded when flow is resumed is difficult, because most mud cakes are compressible, and their characteristics vary as a function of distance from the formation. The loose cake

furthest from the wall can most probably be eroded by the flow, but removal of the hard cake against the formation is much more difficult.

Mud Displacement

Despite what has just been said about mud circulation efficiencies, it should not be assumed (as is sometimes the case) that the interface profile between two fluids can be derived directly from the velocity profile of one of the two fluids. Mud displacement is much more complicated than mud circulation. In addition to the parameters regard to the mud condition which has been mentioned earlier, mud displacement is dependent upon the relative properties of the fluids involved (density and rheology), their relative flow regimes, and their eventual interaction when mixed together. If mud has not been conditioned before cement job the mud displacement process has been affected drastically and has led to cement job failure. In this section, the displacement of such muds is considered. As mentioned earlier, a mud which has been altered by gelation and filtration is difficult to mobilize during circulation. As with mud circulation, the process is not well understood, because gelled or dehydrated muds are so poorly characterized. Using some simplifying assumptions to describe the buildup and breakdown of gel strength, it has been shown the displacement efficiency to be strongly affected by gelation. The effect is qualitatively illustrated in Figure. 1. When the drilling mud exhibits low gel strength, the best results are obtained at low displacement rates, provided the density of the displacing fluid is higher than that of the mud. Under the same conditions, if the mud exhibits high gel strength, turbulent flow is preferred; however, high-gel-strength muds are difficult to remove regardless of the displacement rate. After performing displacement experiments, the direct relationship between flow resistances of gelled mud on the narrow side of an eccentric annulus to the gel strength of the mud has obtained.

In view of these contradictions, which in fact may be due to a poor characterization of the rheological properties of drilling muds, this area certainly requires more attention before even qualitative conclusions can be drawn.
The situation regarding the effect of the mud cake is even worse. Very little is known about the erosion of mud cakes by displacing fluids, although it is generally admitted that mud cakes are eroded by displacing fluids at high Reynolds numbers. It is characterized the ability of a mud to be displaced by a single parameter, the mud mobility factor, which considers mud gelation and mud dehydration.

$$\textit{Mud Mobility Factor} = \frac{1}{FL\,vol \times gelstrength\ (10\ \text{min})}$$

Which:
FL vol: Fluid Loss Rate (ml/ 30 min)
In the experiments, the muds were allowed to gel prior to the displacement. A good correlation was found between the efficiency of the displacement and the mud mobility factor multiplied by the square of the average velocity of the displacing fluid Figure. 2[5,6]. These results confirm the intuitive idea that removal of the immobile mud requires much more energy than that for removing mobile mud. The problem with this approach, sometimes called the “pump as fast as possible method,” cannot always be adopted because of fracture pressure limitations; therefore, other solutions for removing the immobile mud have been developed such as casing movement coupled with various types of casing hardware is effective. Spacers and washes are also useful.

Spacers and Washes

During a cementing job, the cement slurry must displace all of the drilling mud from the annulus. However, contact between the drilling mud and cement slurry often results in the formation of an unpumpable viscous mass at the cement/drilling mud interface. Under such circumstances, the drilling mud and the cement slurry are said to be incompatible. When

incompatibility exists between fluids being displaced in the annulus, the displacing fluid (i.e., the cement slurry) tends to channel through the viscous interfacial mass, leaving patches of contaminated mud sticking to the walls of the casing and formation. This may lead to insufficient zonal isolation, necessitating expensive remedial cementing prior to stimulation treatment of the formation [1, 3].

The very viscous cement/mud mixture can also cause unacceptably high friction pressures during the cement job, with the obvious danger of fracturing a fragile formation. In extreme cases, total plugging of the annulus can occur, preventing the completion of the cement job To avoid such problems one or more intermediate fluids (or preflushes), which are compatible with both the cement slurry and drilling mud, are often pumped as a buffer to prevent or at least minimize contact between them. Preflushes, pumped into the borehole in front of the cement slurry, are designed to clean the drilling mud from the annulus and leave the annular surfaces receptive to bonding with the cement. Thus, they must eliminate the mud from the casing and formation walls. To accomplish all of these tasks, the rheological and chemical properties of preflushes must be carefully designed.

Conclusion

Ensuring that a large percentage of the mud is actually in circulation is a key to the success of a primary cement job. In view of the complexity of the problem, there is no doubt that sufficient time should be devoted to the design, execution, and evaluation of the mud conditioning and circulation phases prior to cementing. The following qualitative guidelines can be distilled from the preceding discussion.

- The rheological properties of the mud, mud gel strength, and pipe standoff should be such that the mud is in movement completely around the annulus at an achievable flow rate. This can be done by improving pipe standoff and
- decreasing the mud gel strength, or increasing the flow rate.
- If the above criteria cannot be met, reciprocation or rotation of the pipe should be performed during mud circulation.
- In cases where mud removal is expected to be difficult, such as presence of hole irregularities, mud with high gel strength, mud with poor fluid-loss control, and poor centralization, the pipe should be equipped with scratchers, scrapers, or cable wipers, and pipe movement should be planned.
- Prior to pumping the preflushes, sufficient time should be allowed to circulate at least two annular volumes of mud at the highest rate possible, without losing returns. A better procedure involves using tracers to monitor the volume of circulatable mud, and circulating until this volume represents at least 85% of the hole volume.
- The mud and spacer should be separated by a preflush, which must be compatible with both.

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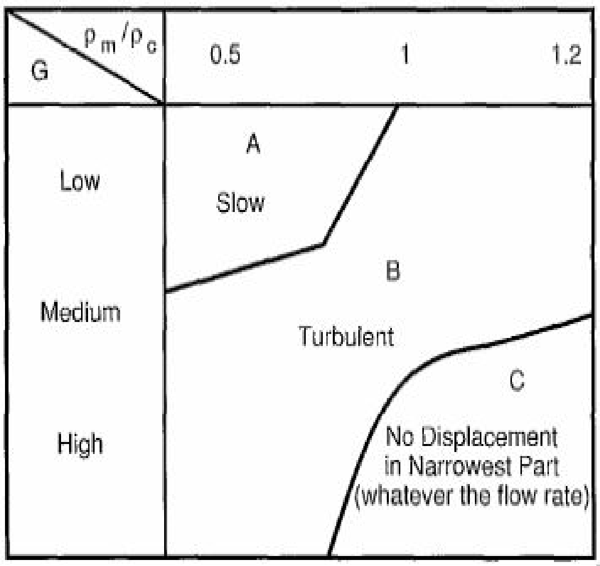

Figure1. Effect of mud gel strength on mud displacement. G is the ratio of the 10 min gel strength to the initial gel strength of the mud

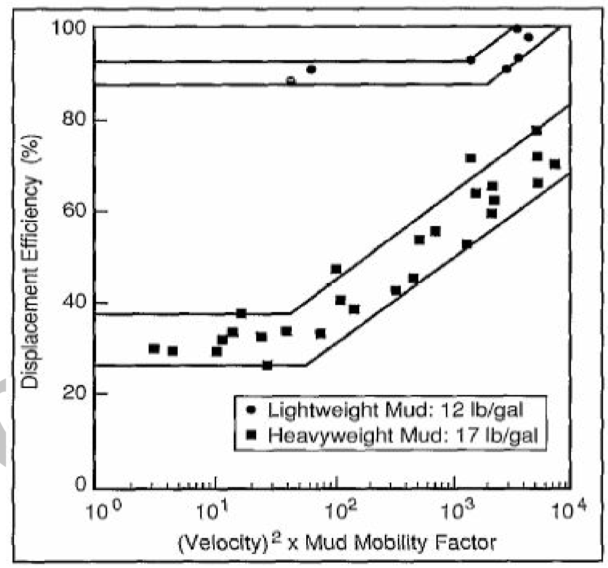

Figure 2. Effect of displacement velocity and mobility factor on the displacement efficiency of muds