CONTROLLING CEMENT CIRCULATION LOSSES AND FORMATION DAMAGE DURING CEMENTATION IN CBM FIELDS OF EASTERN INDIA

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ABSTRACT
Completion of CBM wells is a major technological challenge in the fields of Eastern India due to the inherent characteristics of underpressured formations with fractures and the requirement of long cement column to cover multiple coal seams. This paper discusses the application of a developed high performance lightweight cement slurry systems in CBM wells of Eastern India where earlier practice of stage cementation with conventional slurry was causing non achievement of the desired annular fill and damage to the fractures from which methane is produced. Unmatched production quality cement properties of these lightweight slurries besides achieving long cement column, also resulted in improved bondage as compared to the earlier multistage cemented wells with conventional slurry. Also in some CBM wells having severe loss circulation problems requiring sub hydrostatic mud weight during drilling, this lightweight cement systems in conjunction with a dispersible synthetic fibers resulted in achievement of the desired fill. Implementation of this innovative technology has solved the perennial field problem of cementation and opened up new avenues for better completion of CBM wells in eastern India.

KEYWORDS
CBM, Cleats, Fracture gradient, Formation damage, Hydro-fracturing, Cement rise, Stage cementing, Cement job simulation, ECD, Particle Packing Technology, HPLW cement slurry

INTRODUCTION
Worldwide, completion of CBM wells is a major technological challenge due to the inherent characteristics of coal seams from which the methane gas is harvested. The most critical difference between gas bearing coal seams and conventional oil and gas reservoirs is the cleat system of the coal. Cleats are a network of natural fractures within the coal which facilitates gas production in CBM wells. The cleats not only act as the drainage path for the gas during hydrocarbon exploitation but also are conduits for undesired cement fluid filtrate loss / whole cement loss during cementation operations. Loss of cement filtrate and especially whole cement into the cleat system causes productivity damage. Since most CBM wells produce hydrocarbons at rates far below conventional gas wells, this loss of hydrocarbon production can make a sizable hole in the bottom line of the venture.

The fractured structure of coals demands the use of light weight drilling muds to minimize formation damage. A column of cement has higher density than drilling mud and exerts greater hydrostatic pressure on the formation. This pressure often forces cement into the cleats, plugging the very
fractures that were supposed to provide free channels for methane to flow into the wellbore. Over and above this factor, cementations in CBM wells are very challenging because multiple coal seams are commonly completed in the same well which requires long cement column rise to cover all the zones. The requirement for multiple stimulation treatments which are carried out during the production stage to increase the permeability of coal seam also emphasizes the need for very good zonal isolation from the primary cement job.

Earlier in the CBM fields of ONGC, in the absence of suitable technology, conventional normal density cement slurries through stage cementing procedures were employed for cementations by availing the services of contractual cementing service provider. Worldwide, stage cementing is not a preferable cementing technique for completion against producing interval because of the problems of stage collar failures. However, use of normal density conventional slurries in stages also had resulted in losses which besides improper zonal isolation had also resulted in formation damage due to cement invasion inside the cleats.

Finding a feasible solution by developing lightweight cement slurry having adequate compressive strength was being investigated at the Institute of Drilling Technology (IDT) in ONGC and a range of low/ultra lightweight cement slurries having adequate compressive strength and other improved slurry properties have been developed. This paper focuses on the development and case studies of field implementation of a new lightweight cement slurry system developed at Institute of Drilling Technology of ONGC for CBM wells cementation to fulfill the cementing requirement viz. lightweight to prevent losses and cleat damage during cementing as well as adequate set cement compressive strength to withstand the blistering pressure of fracturing during the production stage. These new cement systems are designed to provide successful isolation where conventional cement densities or placement technique would not work.

BACKGROUND

In 1994, exploration for coalbed methane was initiated in ONGC. Preliminary studies of Gondwana coals indicated that the best quality coal resources are available in Damodar Valley Graven. Hence the CBM exploration was initially focused in this area. The first two wells DUAA and DUAB were drilled in Durgapur depression in Raniganj basin. In DUAA prefrac test indicated very poor permeability. Hydrofrac job was not recommended because of expected low post fracture production. DST and conventional test of object-I resulted in production of negligible water and no gas. In DUAB due to very poor cementation behind casing, production testing of the well could not be carried out. Henceforth the focus shifted to the more prospective Jharia basin. In Jharia basin the first well JHAA was drilled in Parbatpur block. This is the first well in the country that flowed methane gas from Barakar coals. The success in the well provided necessary lead that resulted in drilling of three more R&D well viz JHAB, JHAC and JHAD in the same Parbatpur block.

PROBLEMS THAT LEADS TO THE DEVELOPMENT
In completion of CBM wells, the requirement of long cement column rise because of completion of multiple coal seams in the same well and the need for very good zonal isolation for multiple stimulation treatments is the main objective from cementation. Several techniques to achieve these objectives including the use of Perlite to reduce the slurry density (#DUAB), use of lost circulation material mica flakes in the cement slurry (#JHAA) and the use of multistage tools (#JHAB,JHAC,JHAD) was not proven to be very effective. Even with cementation in stages with conventional slurry losses were observed. In an open and permeable cleat system, cement enters the cleats, causing formation damage, if the hydrostatic head exerted by cement slurry column is greater than the reservoir pressure of the coal. Possibly due to this factor in spite of cementing in stages, losses were observed in the second stage cementation of well # JHAC and first stage cementation of well # JHAD. This had resulted in incomplete zonal isolation due to uncovering of one zone of interest at well # JHAC and two zones of interest in well # JHAD.

In view of the above difficulty in achieving quality cementation jobs with conventional slurry in CBM wells, the Institute of Drilling Technology (IDT) of ONGC had developed a new slurry system for coalbed methane wells based on packing technology to fulfill the cementing requirement of CBM wells i.e. lightweight to prevent losses and cleat damage during cementing as well as adequate set cement compressive strength to withstand the blistering pressure of fracturing. The unique feature of this development is that slurry performance is decoupled from the slurry density. As a result of this, inspite of low density the formulated low weight slurries developed compressive strength comparable to or in some cases more than that of normal density conventional slurries. The slurries also have inherent properties of low fluid loss, zero free water, improved rheology and high stability as compared to conventional slurries (table-1). The application of the developed light weight slurry in CBM wells besides elimination of stage cementing had also resulted in minimizing cleat damage resulting from cement invasion and increased well deliverability.

**CASE HISTORIES OF FIELD IMPLEMENTATION**

**DESIGN OF CEMENTATION PROGRAM**

The production from a CBM well mainly depends on a properly executed hydro-fracturing operation to increase the permeability by interconnecting the cleats in the coal seams. The success of a fracture job highly depends on the degree of isolation achieved in the annulus by cementation. Considering this importance of cementation jobs in a CBM well, a cement job simulator was used as a design tool for finalizing the cementation program. Using the simulator prior to actually conducting a job one can identify any anticipated problems (such as lost circulation or fluid invasion) and modify the placement schedule. The fracture gradient data which have been generated through DSI log and Pre-frac well test analysis of the four CBM wells drilled at Jharia Block was used as input data for simulation studies.

Prior to the cementation job computer simulation studies were performed with field data and permissible slurry density and displacement rate were determined to prevent losses and cleat damage during cementing. A simulation study of production casing cementation job at well BKAA in East
Bokaro coal field using the developed slurry system for CBM well is shown in figure -1. The result of the simulation shows that with the new slurry system for CBM well (density 1.47), raising a cement column of 250m from surface at the highest displacement rate of 1.0m$^3$/min is achievable at #BKAA without causing the ECD to cross the fracture limit of the weakest coal seams in the open hole section.

FIELD APPLICATIONS
Based on the findings of the simulation studies the field application of the developed lightweight slurry system for CBM well was carried out in the wells of east Bokaro coal field area of CBM-BPM basin.

CASE HISTORY 1
The first field trial was carried out at CBM well # BKAB having drilled depth of 1198m. The bottom hole temperature recorded in this well was 65$^0$C and 51/2” production casing was lowered upto 1162m. The well was having two casing policy and the first casing having 95/8” size was lowered at 320m. The average hole size in the cemented interval was 9” and the uppermost zone of interest was at 560m. The cement rise was planned 400m from surface. The average fracture gradient was 0.6psi/ft with the minimum having 0.55psi/ft in some places in this field. In the initial trial the objective was to demonstrate that the lightweight slurry could replace the stage cementing process by raising the required cement column in single stage without incurring any losses during cementation.

The job was done by pumping in batches through batch mixer 22.0m$^3$ of lightweight slurry of 1.46 density. The cement slurry was displaced by 15.0m$^3$ of water @ 1.0m$^3$/min and no losses were observed during the job. The top of the cement column was found at 385m and excellent cement bondage was achieved throughout the cemented interval.

CASE HISTORY 2
In this well there were 8 zones of interest and the top most zones was at a depth of 300m from surface. Well parameters were as follows.
Well depth = 1067m
Casing size and lowered depth = 51/2”, 930m
Previous casing size and shoe depth = 95/8”, 210m
Average hole size = 8.875”
WBM in hole = PHPA, 1.08 sp.gravity

A viscous pill was placed in the open hole section below the casing shoe prior to lowering the casing at this well. The job was done by pumping 18.0m$^3$ of 1.46 density lightweight slurry and which was displaced by 10.94m$^3$ of water @ 1.2m$^3$/min. No losses were observed during the job. The CBL/VDL taken after the job shows excellent bondage (2-5mv) against all the zones of interest and the cement rise was found 250m from surface thereby fulfilling the objectives of covering all the objects in single stage with the developed lightweight slurry.

CASE HISTORY 3
In this CBM well total loss conditions were observed during drilling below 411m. The well was planned to be drilled upto 1050m as the target depth. The loss was not controlled even after several application of all the known LCM. Drilling could be resumed only after reduction of mud weight to
0.85-0.95 sg to control the losses and the well was drilled upto 1056m. Requirement of long cement column (cement rise 300m from surface) having good strength for hydro-fracturing was a challenge for cementing in this well which could not sustain mud weight more than 1.00 sg during drilling. The objective could be achieved by application of advanced cement based LCM systems which consists of lightweight cement slurries containing dispersible synthetic fibers during the 51/2” casing cementation in this well. Cement could be raised as per the requirement with full return during the job.

**RESULTS AND DISCUSSION**

In all the wells, CBL / VDL results shows excellent cement bondage. These single stage cementations were carried out with the IDT formulated lightweight cement slurries and long cement column could be raised as per plan without inducing losses. A comparative result of cement rise with the lightweight slurry system and the earlier practice of cementing in two stages with conventional cement slurry is presented in Fig-2 which clearly depicts the technical advantages. In addition to achieving long cement column as per plan without inducing losses and subsequent formation impairment, the developed lightweight cement slurries also resulted in improved bondage as compared to the earlier cemented wells with conventional slurry (Figures 3 & 4).

Besides the technical advantages derived from improved cementation, longer cement column rise, elimination of stage cementation and less damage to the network of fractures or cleat system in the coal seams, the cementation with lightweight slurry in CBM well is also financially very attractive (Table-2). The savings are in the tune of minimum Rs. 9–14 lakhs per well depending on job contracts / services availed from branded service providers. This cost savings on cementation is a definitive advantage for CBM well where cost of completion plays an important role in deciding economic viability of CBM field development. It needs to be realized that exploitation of hydrocarbon through CBM wells is a thrust area in ONGC and numerous wells are to be drilled in future for development of any CBM field. The cost savings achieved in initial trials show the tip of the iceberg as cumulative savings will be phenomenal.

**CONCLUSION**

Implementation of this innovative cutting edge technology has opened up new avenues for better completion of CBM wells. For the first time in ONGC, in-house expertise in light weight cement slurry designing for cementation of CBM well & successful implementations for solving perennial field problem has been achieved.

The technical advantages of the innovation for CBM wells are:

- Improved cementation
- Longer cement column rise
- Less damage to the network of fractures or cleat system in the coal seams
- Elimination of stage cementation
- Self reliance in cement job execution dispensing contractual cementing services
- Saving on cost of cementation

**REFERENCES**


ACKNOWLEDGMENT

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TABLES:

Table – 1: Performance of the lightweight slurry system for CBM wells

<table>
<thead>
<tr>
<th>TYPE OF SLURRY</th>
<th>HPLW_A</th>
<th>HPLW_B</th>
<th>HPLW_C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DENSITY (gm/cc)</td>
<td>1.47</td>
<td>1.45</td>
<td>1.35</td>
</tr>
<tr>
<td>TESTING CONDITIONS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHST/BHCT (°C)</td>
<td>60/40</td>
<td>60/40</td>
<td>60/40</td>
</tr>
<tr>
<td>Dispersant (%BWOB)</td>
<td>-</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Retarder (%BWOB)</td>
<td>0.1</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Fluid loss agent (%BWOB)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SLURRY PROPERTY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickening time (mins)</td>
<td>180</td>
<td>210</td>
<td>305</td>
</tr>
<tr>
<td>Compressive strength (PSI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. 24 Hrs</td>
<td>1763</td>
<td>1378</td>
<td>1184</td>
</tr>
<tr>
<td>b. 48 Hrs</td>
<td>2360</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>c. 96 Hrs</td>
<td>2390</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>d. 144Hrs</td>
<td>2531</td>
<td>2236</td>
<td>2039</td>
</tr>
<tr>
<td>Fluid loss(ml)</td>
<td>416</td>
<td>832</td>
<td>588</td>
</tr>
<tr>
<td>Free water (%)</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
</tr>
<tr>
<td>---------------</td>
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</tr>
<tr>
<td>(P_v) @ BHCT (cp)</td>
<td>90</td>
<td>50</td>
<td>58</td>
</tr>
<tr>
<td>(Y_p) @ BHCT (lbf/100ft2)</td>
<td>15</td>
<td>17</td>
<td>8</td>
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</tbody>
</table>

Table-2: Comparison of effective cementation cost in CBM well

<table>
<thead>
<tr>
<th>With Conventional (2 Stage) Cementation earlier Carried Out</th>
<th>With IDT’s formulated Lightweight Slurry now implemented in Well # BKAB &amp; # BKAA</th>
<th>With Light Weight Slurry Of International Service Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rs. 18.625* LAKHS</td>
<td>Rs. 9.25 LAKHS</td>
<td>Rs. 23.15 LAKHS</td>
</tr>
</tbody>
</table>

*Remedial cost if stage collar fails is not included in the cost analysis

FIGURES:

![Figure-1: Pre job simulated result of ECD at Well #BKAA](image-url)
Figure-2: Planned Vs actual cement rise

Figure-3: Comparison of CBL/VDL of BKAB & BKAA (Object I &II) Vs earlier cemented wells in Jharia field
Figure 4: Comparison of CBL/VDL of BKAB & BKAA (Object III&IV) Vs earlier cemented wells in Jharia Field