PERFECTING PERFORATIONS

FRANK PREISS, DYNAENERGETICS, GERMANY, PRESENTS A CEMENTING TECHNOLOGY DESIGNED TO LOWER ABANDONMENT COSTS.

A poorly executed cement operation may result in free pipe or a partial cementation, leading to unwanted vertical channels where zonal isolation is not guaranteed. To date, the leaking zones would have been perforated and cement squeezed. Alternatively the casing could be section milled and newly cemented to create an impermeable barrier for abandonment purposes. Unfortunately, conventional perforating may miss some channels and may have to be repeated multiple times, while section milling is very time consuming and expensive.

Today bad cement jobs may be salvaged and wells may be safely abandoned with the DynaSlot™ system, which uses an array of rectangular shaped charges configured to achieve a definite overlap from slot to slot. Regaining a well's hydraulic integrity through this technique is more reliable than conventional perforating, cost-effective and less time consuming than multiple perforation and squeeze attempts or section milling.

In scenarios where limited entry perforation for multiple casing strings is required, a DynaSlot puncher can be used. Here the penetration is restricted to the inner lying casing only with no damage to the outer casing.

To date over 100 systems have been used, with the primary usage being in Canada for surface casing vent flow (SCVF) and gas migration operations.

Well abandonment

Ultimately every well that has been drilled will have to be abandoned at some point in time. When permanently abandoning a well, each individual reservoir of the well will have to be vertically and horizontally sealed covering its full cross section. With a lot of wells this will not be a problem if they have been well planned, drilled, completed and maintained. Other wells though, have experienced problems during their lifetime, which result in crossflow between production zones or leakages to surface. The main reason for these problems is a bad cement sheath between two casings or between the casing and the wellbore.

There are several reasons for cementing a well. The casing or production tubing is held in place, the borehole is stabilised and – most importantly – the various zones in the wellbore are isolated from each other. This is especially important for wellbores that pass through freshwater aquifers. A poorly executed cement operation may result in free pipe, or a partial or patchy cementation. This may lead to unwanted vertical channels where zonal isolation is not guaranteed. Achieving a permanent seal is especially significant, given the fact that operators are responsible for an abandoned well in perpetuity. In the event of a seal failure and leakage, the operator remains liable for the problem and costly workovers and re-entries can be the result.

Well abandonment, at the end of the lifetime of a well, involves complicated procedures where the wellbore must be shut in, permanently sealed and the surface footprint returned to its original state and use. Downhole it is essential that the various zones, in particular freshwater aquifers, are pressure isolated. Unwanted vertical channels or voids in the previously cemented wellbore annulus can produce pathways, resulting in migration of fluids or gas. This can result in a cross flow and cross-contamination between zones or along the outside of the casing up to surface causing various environmental issues.

To date, the leaking zones were first perforated using conventional BH or high shot density shaped charge gun systems and then cement was squeezed into the perforations to intersect the unwanted channels. Alternatively the zones were section milled and newly cemented to eliminate the unwanted channels and to create an impermeable barrier. For both well abandonment and squeeze job applications, it is essential that the formation and the wellbore are completely isolated so no communication can occur. Unfortunately, perforating with conventional gun systems may miss some channels, resulting in the need to re-perforate and re-squeeze. In contrast section milling will give an assured 360˚ circumferential coverage, but is very time-consuming and expensive to perform.

The ideal situation would be a fast and efficient perforation that will intersect all microannuli and behind-pipe channels, allowing a reliable cement squeeze to create an impermeable barrier. This would increase the rate of success and uncertainty and lower the abandonment cost while assuring the sealing of any vertical fluid or gas vents.

Today bad cement jobs may be salvaged and wells may be safely and cost competitively abandoned with built-for-purpose shaped charges that

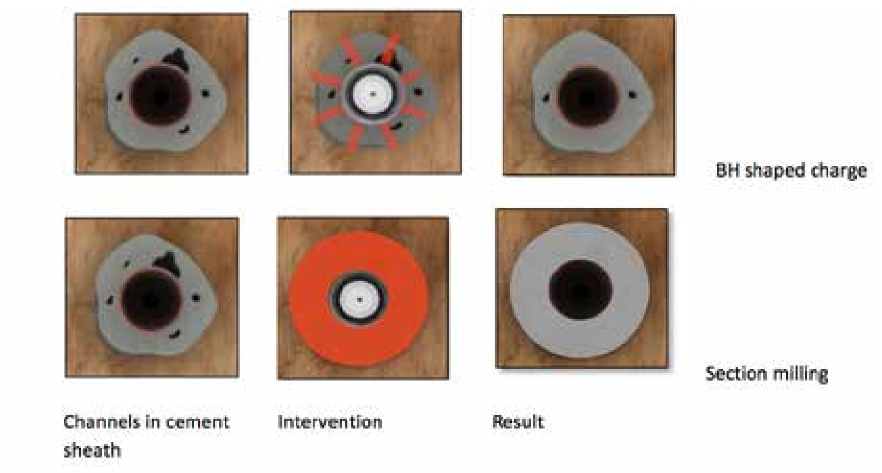

Figure 1. Present abandonment techniques.

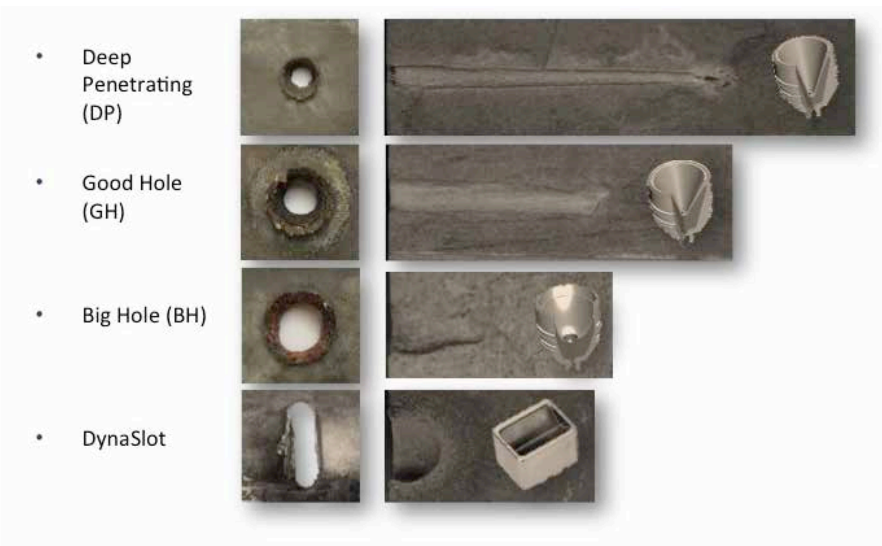

Figure 2. Effects of shaped charges on casing and formation.

punch slots in the casing, through which cement slurry is squeezed to fill voids in the cement sheath.

DynaSlot is a perforating gun system that uses rectangular shaped charges instead of the standard round axial-symmetric shaped charges. These rectangular shaped charges make a linear cut and perforating channel as opposed to the standard round tunnel. The significance of this is that greater horizontal coverage in the casing is possible. The perforating system uses an array of these rectangular shaped charges configured in a helix along the axis of the perforating gun in such a way that a definite overlap from slot to slot is achieved. Within a complete helix of shaped charges the overlap provides a 360˚ circumferential access to the area behind the tubing or casing. The system integrates with standard perforating hardware for a convenient and easy solution and can be run on wireline or TCP.

The slotted shaped charges penetrate through the casing and cement into the formation intersecting any gaps and voids between casing and cement, within the cement sheath as well as between cement and formation. Once the perforation has been carried out, a regular cement squeeze can be conducted. The use of friendly acid may be considered dependent on the situation.

Hydraulic integrity

Regaining a well's hydraulic integrity through this technique is very cost-effective because more costly and time consuming section milling and slot cutting using abrasives can be avoided.

As stated earlier, over 100 systems have been used, with the primary usage being in Canada for eliminating surface casing vent flow (SCVF) and gas migration. Initial jobs have been run in the US and jobs are pending in China.

To date a 86 mm (3 ⅜ in.) hollow carrier gun with 13 spm (4 spf) and 20˚ phasing is available for 5 in. and 5 ½ in. tubulars for 360˚ coverage with 50% overlap, guaranteeing an intersection of all channels without section milling. For a complete helix 18 charges are loaded into a perforating gun with 1.8 m loaded interval. If backup is required and multiple helixes are to be perforated the perforating guns are available in multiples of 1.3 m (approximately 4 ft) or can be run in tandem. The average slot size in a 4 ½ in. casing has a width of 35 mm to 38 mm (1.38 - 1.50 in.) and a height of 7 - 9 mm (0.28 - 0.35 in.). The axial pull test of a 4 ½ in. casing, perforated with the system has shown that there is only a 15% loss in yield strength and a 11% loss in tensile strength.

Case histories

Perforated interval 248.0 - 250.8 m

- Job needed acidising to pump cement.
- Well monitored for two months w/o gas migration.

Perforation depth 302 m

- After exceeding anticipated squeeze pressure well was cemented.
- Well monitored for two months w/o gas migration.

Perforation depth at 3000 m

- Perforation depth at 3000 m with BHT 77˚C – Casing 114.3 mm, 17.26 kg/m, P-110.
- Squeeze pressures were normal.

Perforation depth 550 m

- Perforation depth 550 m - Casing 139.7 mm 20.83 kg/m
- Squeeze pressures were normal.
- Gas flow was not repaired.
- A sand slotting process was completed and cement squeezed.
- Gas flow was not repaired.

12 shot 86 mm (3 ⅜ in.) perforating systems have been returned and measured for swell, whereby the maximum gun swell ranged from 93 mm to 96 mm.

In scenarios where limited entry perforation for multiple casing strings is required, a DynaSlot puncher can be used. Here the penetration is restricted to the inner lying casing with no damage to the outer casing independent of the tubing to casing positioning. This ensures zonal isolation within the secondary casing string. The width and height of the slot is equivalent to the regular system.

Recently surface testing has been conducted for operators in the North Sea to evaluate the effect of the puncher charges. The clients assets require a 5 ½ in. 13 Cr tubing punch to communicate to the 'A' annulus while protecting the 9 ⅝ in. casing. The wells are at a high angle and may potentially have scale. Conventional axial-symmetric puncher charges can produce collateral damage and typically produce comparably small holes in the tubing compared to the slotted puncher charge. The test results show slots in the tubing that are uniform in size and dimensions with approximately 95% of the punched slots open to flow. Indentations on the low side of the inner wall of the 9 ⅝ in. casing are visually evident but the casing is not severely deformed or breached. After the test the casing and tubing were returned to the operator for inspection and testing and the mechanical integrity was confirmed.

Presently 4 ½ in. and 7 in. OD DynaSlot perforating systems are being qualified for use in 7 in. and 9 ⅝ in. casing. The first field trials in the North Sea are anticipated to take place in the next months.

The DynaSlot gun system provides a good starting point to a cement squeeze. It is expected that oil and gas companies adopting the system will reduce workover costs, as they will avoid having to re-perforate a second or third time as the previous perforating and squeeze attempts were not successful. As a single-gun system, using this system is significantly less time consuming compared to other 360˚access methods such as section milling and slot cutting with abrasives.

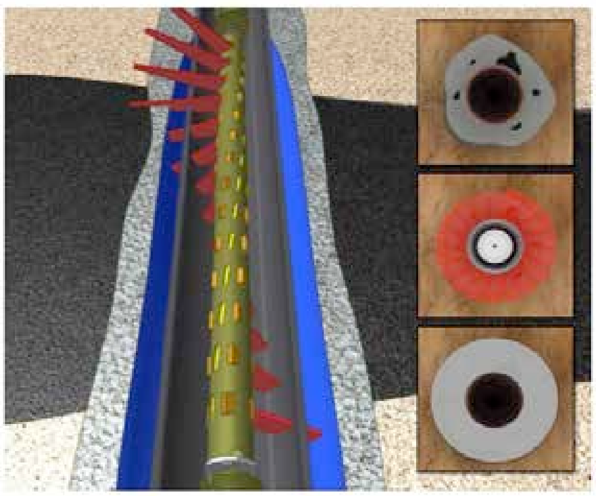

Figure 3. *Perforating with DynaSlot.*