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Deployment of Swelling Elastomer Packers in Shell E&P

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Abstract

In Shell Exploration & Production, swelling elastomers have been deployed in a variety of applications: as a means to establish zonal isolation in liner completions, as a production separation packer, and as an integral part of an expandable open hole clad. In these applications, the elastomers have been run in various open hole, casing, and tubing sizes. A total of around 60 deployments in Shell have been recorded, all of which were technically successful.

Case examples of each of the three mentioned applications will be presented from Shell operations in the North Sea, the Middle East, and the Far East.

Introduction

In most areas where Shell operates, especially in the more mature oil field environments, there is a high focus on well cost reduction. Various technology applications have been identified to meet this business need and allow the operator to drill wells cheaper and smarter, making the most of existing infrastructure.

One technology that is experiencing a rapid uptake is the application of swelling elastomer packers. These packers, which swell naturally when exposed to the appropriate swelling agent, have successfully been used as a replacement for traditional mechanical packers and cement. The business case for using swelling elastomer packers is different per application and can include time savings as well as direct tool cost savings.

Shell implemented swelling elastomers in combination with the deployment of a Solid Expandable Tubular (SET) system called Open Hole Clad (OHC) in July 2002. First application of swelling packers for zonal isolation was in the South Furious field in Malaysia in June 2003. Since then, over 60 deployments have taken place in operations in Malaysia, Brunei, Nigeria, Gabon, Oman and the UK.

Theory and Definitions

A swelling elastomer packer, or swelling packer, is a rubber element vulcanised onto pipe. The main property of the rubber is that it swells significantly when exposed to either aromatic hydrocarbons or saline water through a process of absorption.

An oil swellable packer is a swelling elastomer packer, which swells primarily through the absorption of hydrocarbons. This is a diffusion process. Typical operating temperatures for oil swellables are 80-130°C.

A water swellable packer is a swelling elastomer packer, which swells through the absorption of (saline) water. This is an osmosis process. Typical operating temperatures for water swellables are 50-90°C.

The three main design parameters of swelling packers are life-span, pressure rating, and swelling time. Because of the relatively recent development of swelling packers, our understanding of these parameters is still growing and a full theoretical treatment of the subject is beyond the scope of this paper. The main factors to consider in determining the three design parameters are temperature and the geometry of the pipe, packer and borehole.

Pressure ratings have been tested up to 3500 psi, although higher ratings have been recorded in the industry. Swelling times in our operations range widely from 5 to 50 days.

The case examples provided in this paper show three distinctly different uses of the swelling elastomer packer: the liner completion, the production isolation packer, and the expandable open hole clad.

A liner completion is defined as a liner system with slots or perforations to allow access to the producing formation. The swelling packers are used in combination with blank liner joints to isolate oil bearing zones from water zones, where conventionally a cement column would be used.

The production isolation packer is defined as a seal between a production tubing and a production liner in order to isolate the various perforated sections. Swelling packers are used to replace conventional hydraulically or mechanically set packers.

An expandable open hole clad is defined as an expandable tubular used to seal off water bearing formations or water producing fractures in a barefoot well section. Swelling elastomers are used to provide the seal between formation and tubular.

Applications

Three different types of application of swelling elastomer packers are presented in this section. A case study is provided for each application to serve as an example.

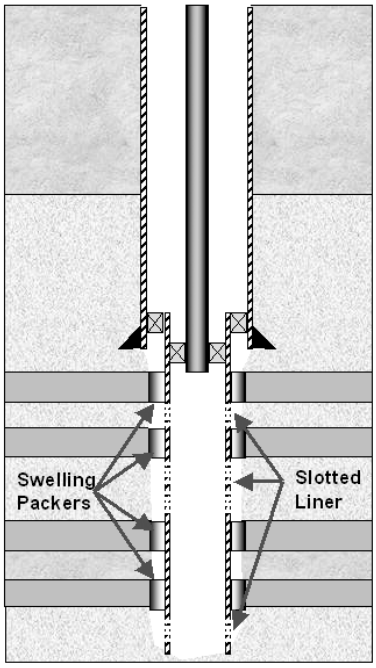
Liner Completion.

Introduction. In the last two years, swelling packers have been used in various parts of the world as part of an open hole completion to provide zonal isolation. So far, Shell E&P has recorded 6 applications in Africa, 2 in the far East and 1 in the North Sea, with a further 5 global implementations expected before the end of 2004. All of the applications used oil swellable packers because of the operating parameters.

The business case for using swelling elastomer packers for zonal isolation is mainly based on the fact that the traditional cementation and potentially a perforation run are eliminated.

A generic schematic of the completion is shown below.

Figure 1: Swelling packers in an open hole completion



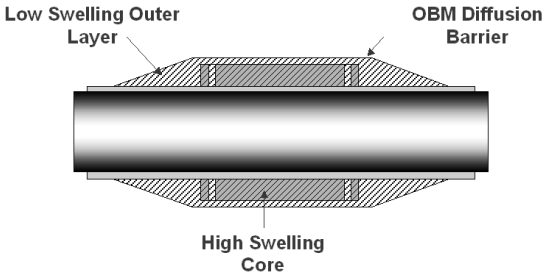
First TTRD application in the North Sea. In December 2003, the last well in a five well through tubing rotary drilling (TTRD) campaign was drilled in the North Cormorant field in the UK sector of the North Sea. The North Cormorant field is highly compartmentalized and the reservoir is characterized by many interbedded shale sections, isolating the various oil and water sands.[1] The main challenge in completing the North Cormorant wells is isolating the more dominant water producing sands while selectively producing from the oil bearing ones.

The first four wells of the campaign had been completed by running 2 7/8" liners, cementing them in place and perforating them across the oil bearing sands. Cementation in a slimhole reservoir section through a small size liner has always been difficult in past experience and was the main cause of non productive time (NPT) during the 2003 North Cormorant campaign. It was mainly for this reason that the alternative of using swelling packers in combination with a pre-perforated liner was considered. Additional to the direct cost savings associated with leaving out the cementation, further time and cost were saved by eliminating a clean-out run and a coil-tubing perforating operation. Furthermore, the use of the swelling packers in combination with pre-perforated liner would mitigate against the NPT incurred during the completion operations in the first four wells.[2]

After successfully drilling the reservoir with a 4 ½" sidetrack of 2424ft in length, the last well was completed with a selection of pre-perforated and blank liner joints and 12 swelling packers, spaced out to seal against the various interbedded shales. The packers were 10ft and 16ft in length and had an original outer diameter of 4.2". The top packer was set inside the original production tubing. Above it, a separate liner top packer was placed.

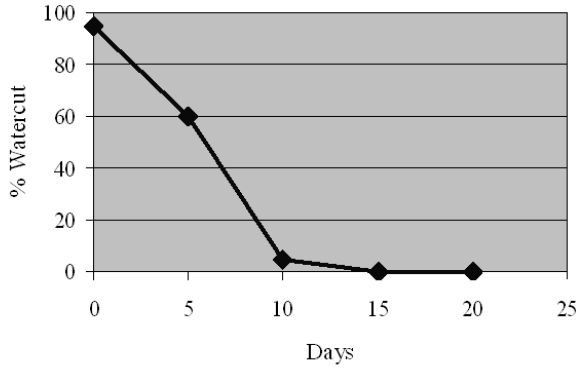
The swelling packers were all run with a thin diffusion barrier and a low swelling outer layer to prevent premature swelling. Typical swelling types for oil swellables are around 15 to 20 days. The well was brought on-line in excess of 20 days after running the liner, due to operational circumstances.

Figure 2: Composition of an oil swelling packer for North Cormorant



Wells can be brought on line before the packers are fully swollen as well, but this introduces the additional risk that the formation around the packer washes out. Nevertheless, this approach was taken in Malaysia in the South Furious field and the graph below shows clearly how the watercut in one of the wells decreased as the packer sealed against the formation, isolating the water zones.

Figure 3: South Furious well watercut against time



The last North Cormorant campaign well was the first ever TTRD well to run swelling elastomer packers in the completion and almost a year after bringing the well on-line, it can be concluded that the use of swelling packers has been a success. The well is producing better than expected and the water-cut is similar to the other wells in the field that were completed conventionally. Differential pressures held by the packers are estimated to be around 2300 psi, well below the 3000 psi, for which they were tested.

When modeling the production from the well with a wellbore damage of 50%, a perforated well will see a somewhat accelerated profile as compared to a pre-drilled liner because of perforating past the damage. However, both completions will still enable the well to produce the same amount of reserves and the acceleration does not generate enough net present value (NPV) to off-set the cost of cementing and perforating.

The cost benefit became even more apparent when it was demonstrated during the TTRD campaign that the mud system actually caused a lot less damage to the formation than previously expected.[3] This neutralised the positive effect of the deep perforations and the two production profiles of the cemented liner and the pre-drilled liner became virtually identical.

All of the above-mentioned advantages of using swelling packers are also true for conventional size wells and thus form the main reasons for using them in the other projects around the world. However, the fact that cementing small size liners is a lot more challenging than conventional size liners and that cementation is the main cause of NPT in drilling TTRD wells only gives a further reason to eliminate this approach by applying swelling packers for zonal isolation. The North Cormorant well has demonstrated the major cost savings involved with the use of swelling packers and they are therefore considered as the base case completion for future TTRD work.

Two (through tubing) coil tubing drilling (CTD) wells are planned to be drilled in the North Sea towards the end of 2004 and these wells will equally deploy swelling packers in their completions.

The main downside of using swelling elastomer packers on a liner completion to establish zonal isolation is the fact that the packers need time to swell. Depending on the completion philosophy, the use of swelling packers will usually delay bringing the well on-line, with the associated deferred production cost. However, as will be seen in the next section, swelling times can be designed to as short as 4 days.

A final point to consider is the proper spacing of the packers downhole. Although a manageable risk, getting the placement wrong can obviously have detrimental results to the well.

Production Isolation.

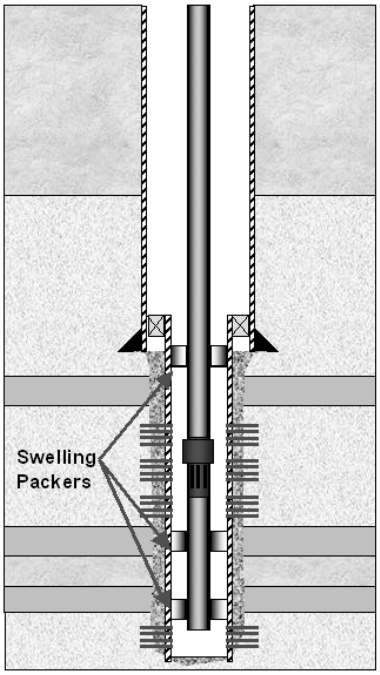
Introduction. Packers that swell by themselves can logically be used as an alternative to mechanically or hydraulically set packers. The main drivers for this are a straight cost saving on the packer as well as the elimination of any extra running or setting trips with the associated risks.

Although the use as a production packer is a relatively simple concept, there are still a few considerations to keep in mind. Thermal effects and subsequent relative movement of the completion strings will exert significant stresses on the packers. Furthermore it may be necessary to run a cable past the packer. Swelling packers allow for cables to be run physically through the rubber element, but the forces on the cable need to be modelled.

So far, the only applications of swelling packers for production isolation in Shell E&P have been in the Saint Joseph and Barton fields in Malaysia. The packers have all been oil swellables, although water swellables have been considered for this application and are likely to be used in the near future.

A generic schematic of the application is shown below.

Figure 4: Swelling packers used for production isolation



Cost saving application in Barton. In the Barton Field in Sabah, Malaysia, a recent deployment of a swelling packer as production isolation packer was run successfully. The well was completed with a 7" liner across the reservoir. The liner was perforated underbalanced across the two pay zones, after which the 3 ½" completion tubing was run in. The completion contained a sliding side door (SSD) across the perforated zones and a conventional packer above the reservoir. The swelling packer was set between the pay zones in order to isolate the production.

The swelling time in this particular application was around 4 to 5 days. The sealing capacity of the packer is more difficult to measure than in the zonal isolation application, but the well is producing as expected and all indications are that the deployment was successful. Thermal effects have are not expected to cause any adverse effects in this well.

The main reason for deploying a swelling elastomer packer between the reservoir sections is the fact that the well inclination builds rapidly through the resrvoir section. Inclination at the swelling packer setting depth of 2545 ft is

83°. Setting a conventional plug and prong system would mean running the lower SSD closed and an extra coil tubing run would be required to open it afterwards.

It is the extra coil tubing work and the associated operational cost that makes for a strong business case for using swelling packers. There is a drive to reduce the cost of these relatively shallow wells in Malaysia and the use of swelling packers in both production isolation inside the casing as well as zonal isolation outside the casing has been a strong contributor to the cost saving initiative.

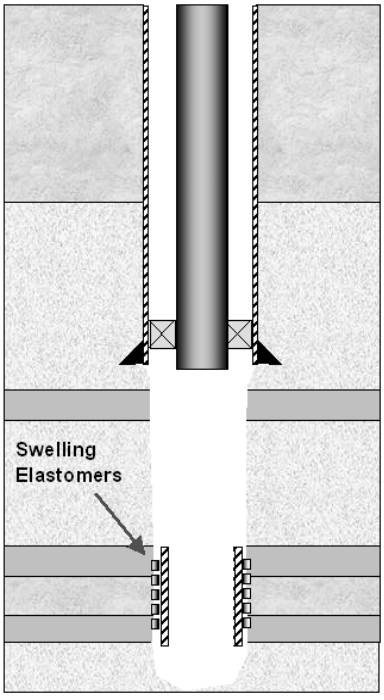
Expandable Open Hole Clad.

Introduction. In order to seal off a water producing open hole section without significantly sacrificing hole size one can consider the use of an expandable Open Hole Clad (OHC) or an Open Hole Liner (OHL). When a water bearing sand or a water producing fracture has been identified it is critical that the clad creates a proper seal against the borehole wall. A long anular seal is provided with up to 70% of the pipe covered with elastomer. Chances of success can be further improved by lining the expandable clad with swelling elastomers.

The application of expandable clads in combination with swelling elastomers has proven to be highly successful in Shell's operations in Oman, where some of the main reservoirs are highly fractured carbonate formations with increasing water production[4,5]. Water swelling elastomers were developed for this application to swell when contacting the reservoir water.

A generic schematic of the open hole clad application is provided below.

Figure 5: Expandables with swelling elastomers for zonal isolation



Yibal: the world's longest expandable Open Hole Clad and Liner. The Yibal field, operated by PDO in Oman, is characterized by highly fractured and faulted carbonate formations. Over the life of the field, the water-cut from the producing wells has increased significantly and it has become difficult to predict which fractures will produce water in the planning phase of a well. Furthermore it is almost impossible in a fractured (and depleted) carbonate reservoir achieve zonal isolation with cemented horizontal liners. A solution PDO has come up with is to drill long horizontal wells and provide zonal isolation by expanding Solid Expandable Tubulars (SET) in combination with swelling elastomers. One such well would replace five vertical wells at the cost of only two vertical wells [6].

The elastomer will provide the seal after pipe expansion and, if necessary, will swell to fill any voids. Because swelling elastomers are self healing and form themselves to fill any wellbore shape or cavity, they are ideal for this sealing application. The swelling effect is, however, only seen as a back-up to the mechanical expansion of the pipe-elastomer combination.

Adding a rubber element to the outside of an expandable liner increases its outer diameter (OD) and its friction coefficient when running in hole. For this reason, significant planning and modelling time went into the selection of the appropriate lengths of clads to be run in the well. After successfully drilling the Yibal well, a caliper was run. The calliper showed the hole diameter to be between 6 1/8" and 6 1/2" with some spots at just under 7". After thoroughly cleaning the wellbore, it was decided to run a 1033ft long OHC for the first section. It was run and expanded successfully. The next section was even more ambitious, running a 2323ft long OHL (tied back to the previous casing shoe), again successfully. This achievement established a world record as being the world's longest OHL with swelling elastomer as a seal.[4]

Figure 6: Solid expandable pipe with swelling elastomer elements

Both clads were 5 ½" OD when running in and they were covered with 0.2" of swelling elastomer except for the top 328ft of the second clad, which only had 0.16" elastomer. In both expansions, the observed overpressures indicated a good seal of the elastomers against the formation. This was further confirmed by subsequent production logging tool (PLT)

readings. When the well was brought on-line, the water-cut was higher than expected, but it was concluded that this was for reasons other than the elastomer seal.[4] In a subsequent 'sister' well, placed parallel with the same length, the installation was repeated and this well is producing as expected.[6]

The application of swelling elastomers on expandable tubulars has been applied in over 40 installations now. The value drives are:

- Fracture shut off with annular sealing along the entire length of the clad or liner
- Replace a horizontal cemented liner with a SET system with swelling elastomers to improve zonal isolation
- Replaces vertical liners set in a lost circulation environment with a SET system with swelling elastomers to reduce time spend on loss curing prior to cementation and to improve the zonal isolation.

The main issues to consider when running the expandable clad with elastomer elements are the dogleg severity limitation of 14°/100ft and the risk of the wellbore being overgauge. Furthermore, it is essential to know where the water influx takes place in order to accurately place the OHC.[5]

Conclusions

Swelling elastomer packers and elastomer elements have been successfully deployed in different applications and in various operating environments around the world. The case examples in this paper have provided an overview of some of the achievements related to the use of swelling elastomers. Production data has supported the isolation established by the swelling packers in all cases.

The understanding of the boundary conditions for the deployment of swelling elastomer packers is still growing. Better definition of the longevity of the rubbers, the operating environment of the various compounds and best practices on the operational deployment of the swelling packers will support future applications.

The uptake of the swelling packer technology is now very rapid and in some parts of the world the swelling packers are already considered the default design for zonal isolation.

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Nomenclature

CTD = *Coil Tubing Drilling*
NPT = *Non Productive Time*
NPV = *Net Present Value*
OD = *Outer Diameter*
OHC = *Open Hole Clad*
PDO = *Petroleum Development Oman*
PLT = *Production Logging Tool*
SET = *Solid Expandable Tubular*
SSD = *Sliding Side Door*
TTRD = *Through Tubing Rotary Drilling*

References

1. Brekelmans, H., Davey, S., Lamens, J. and Slager, S.: "Brownfield Excellence in North Cormorant by Integrating Advanced Seismic, Static Modelling, and Simulation Techniques," presented at the 6th Petroleum Geology Conference, London, Oct. 7, 2003.
2. Kleverlaan, M. and Lawless, A.:"Through Tubing Rotary Drilling: A Cost-Effective Method for Sidetracking Wells in Mature Assets," paper SPE 91005 presented at the 2004 SPE Annual Technical Conference and Exhibition, Houston, Sept. 27-29.
3. Franks, T. and Marshall, D.S.:"Novel Drilling Fluid for Through Tubing Rotary Drilling," paper IADC/SPE 87127 presented at the 2004 IADC/SPE Drilling Conference, Dallas, Mar. 2-4.
4. Noort, R. van, Shell International Exploration and Production; Rivenbark, M. and Jones, M., Enventure Global Technology, 'Using solid expandable tubulars for open hole water shut off', SPE 78495 presented at the 2002 Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, 13-16 October 2002
5. J.C.M. Braas, SPE, C.O. Aihevba, SPE, M. Shandoodi, Petroleum Development Oman, R.H. Van Noort, M.N. Baaijens, Shell International Exploration and Production "Water Production Management – PDO's Successful Application of Expandable Technology" SPE 81489
6. Al-Balushi, H.M., Al-Rashdi, M.H., Al-Shandoodi, M.H. and Van Noort, R.H.J.:"World Longest Expandable Open Hole Clad & Open Hole Liner with Swelling Elastomer Deployed in Yibal Horizontal Well," paper IADC/SPE 88026 presented at the IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Kuala Lumpur, Sept. 13-15, 2004.
7. Marketz, F., Van Noort, R.H.J. and Baaijens, M.T.:"Expandable Tubular Completions for Carbonate Reservoirs," paper SPE 88736 presented at the 11th Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, Oct. 10-13, 2004.