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SWELLING ELASTOMER APPLICATIONS IN OIL AND GAS INDUSTRY

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ABSTRACT

Swelling elastomers are advanced polymers capable of self healing and volume-increase when in contact with certain fluids. These elastomers are mainly used as sealing elements and packers in different petroleum drilling and development operations. As case studies generally focus on only a single or at most a few related applications, an overall picture of swelling elastomer versatility and scope cannot be found in published literature. The current paper presents an thorough overview of different swelling elastomer applications in the oil and gas industry. Separation of unwanted zones from production zones to avoid the mixing of redundant fluids is known as zonal isolation. Swelling elastomers are considered to be the default material for zonal isolation work. One specific form of zonal isolation is known as water shutoff, used to overcome the problem of water production. Swellable packers have been successfully employed for enhanced oil recovery through relatively low-cost yet long-term and effective water shutoff. Sand control is any method by which sand from a formation is restricted to enter the wellbore, as it can cause plugging and wear of well equipment. Swellable packers are used with sand screens in many applications. The term well completion refers to all the tasks involved in making the well ready for production, including the stage known as cementing. Problem of crack initiation and propagation in the formation is notable when using conventional method for cementing, resulting in mixing of unwanted fluids and loss of circulation. Swelling elastomers have found success in well completion together with cementing, and also as an efficient alternate to cementing. Enlarging of old channels or creation of new ones in the producing zone of well formation is known as stimulation. Stimulation processes require proper isolation of zones, and swellable packers are therefore used for this purpose also. Many other applications are also discussed in the paper. This review can be useful for field engineers as well as research and development personnel.

Keywords: Swelling elastomer, Zonal isolation, Enhanced oil recovery, Well completion, Intelligent well, Stimulation, Underbalanced drilling

1. INTRODUCTION

Swelling elastomers are a new breed of advanced polymers that swell upon interaction with fluids like water, oil, or acid. Swelling results in change of geometry, density, hardness and other properties [1-3]. Water-swelling elastomers swell through the absorption of saline water following the mechanism of osmosis, while oil-swelling elastomers swell by the absorption of hydrocarbons through a diffusion process [4]. Swelling rate depends on the temperature, pressure, type of elastomer and fluid composition. Swelling elastomers have become the default material for certain petroleum applications like zonal isolation. Schematic illustration of the construction of a typical swellable packer is shown in Fig-1. Through different swelling elastomer applications, profitability of old wells can be maintained, production from abandoned wells can be restarted, and production from inaccessible new reservoirs can be achieved economically.

2. APPLICATIONS OF SWELLABLE ELASTOMERS

The self-operating mechanism of swell packers leads to easy installation and execution, thus saving a significant amount of rig time and associated costs. Some case studies about deployment and execution of swellable elastomers in the more important oil and gas applications are discussed in the following sections.

2.1. Zonal isolation

Zonal isolation refers to techniques used for prevention of mixing of redundant fluids from unwanted regions with production fluids. Conventionally, zonal isolation in a well bore is carried out by cementing the production string in place, and by appropriate use of casing plugs and packers. Figure-2 shows the free swelling of elastomer for effective zonal isolation. Asab field Abu Dhabi, a mature carbonate reservoir was drilled in 1985 and horizontally sidetracked in 1999. By 2005, water cut increased from 14% to 25%, significantly reducing the oil production [5]. Water was coming from the fractures due to the failure in the placement of cement plugs at the toe. Swellable packers were used to isolate the unwanted zones and resulted in a huge decrease in water cut from 25% to 0.3%. In Malaysia South Furious field, deployment of swelling elastomers resulted in reduction of water cut, production starting the very next day, even before complete swelling of the elastomer [6]. Enhanced oil recovery (EOR) techniques can be used for higher recovery from dwindling old reservoirs or difficult new ones. The required isolation of oil/gas and water can be successfully achieved through a combination of swelling elastomers and primary cementing. Petroleum Development Oman executed its first EOR plan in the Harweel Cluster Southern Oman using miscible gas injection. Proper isolation of zones was required for improved hydrocarbon recovery. Cementing failed in many applications, leading to the use of swelling elastomers, yielding very good results [7]. Water production management, sand control, reservoir compartmentalization, production separation, inflow profile control, and control of condensate banking are other important applications in which swellable elastomers are used for zonal isolation.

2.2. Well completion

In petroleum applications, all the operations carried out until the well is ready for production are collectively known as *well completion*. Drilling of the hole, running/cementing of casing, continuing drilling the hole until desired depth is reached, and perforation/stimulation of casing, cement and formation makes up well completion. Purpose of cementing is to provide significant hydraulic seal between casing and formation which prevents annular flow and isolation of individual zones. Intelligent well is a special type of well that maximizes or enhances hydrocarbon recovery by installing unique completion and monitoring tools adjustable either automatically or with human intervention. An intelligent well completion with swellable elastomer reduces development costs and optimizes the production as it provides effective zonal isolation which cannot be achieved in conventional perforating and cementing techniques. In the offshore Al-Khalij in Qatar, remediation of corroded and damaged tubulars was carried out using the intelligent well approach [8]. Before initiating the recompletion, use of alternative packer technology was investigated. Reliable hydraulic sealing mechanism can lead to remediation/work-over that is technically and economically feasible for such mature reservoirs. Swellable elastomer packers were used, extending the life of well and enhancing the recovery. Swellable elastomer can also be used with open-hole, cased-hole, horizontal well, and solid expandable tubular (SET) technology as a completion tool [9, 10].

2.3. Stimulation operations

Enlargement of old channels or creation of new ones is sometimes required in the producing zone of a well. Achieved by techniques such as acidizing, formation fracturing, etc any such process is known as *stimulation*. Fracturing is a stimulation method based on opening of new flow channels in the rock structure around a production well, increasing the surface area for formation fluids to flow into the well, and also extending past any possible fractures near the wellbore. Rutger et al. discuss the use of swelling elastomer packers in stimulation operations; Fig-3. Major challenges are down-hole environmental conditions such as average temperature and pressure, shrinkage forces of the pipe, and thermal effects that cause contraction of the seal (this may result in temperature fall due to contact with stimulation fluid). Expandable liner hanger, swellable elastomer packers, and ball drop sleeves were used by an operator in USA for stimulation in horizontal open-hole completions, giving successful results [11]. Hydraulic fracturing, matrix acidization, and multi-stage fracturing are other areas where swellable elastomer technology is successfully deployed.

2.4. Underbalanced drilling

During *underbalanced drilling* (UBD) of oil and gas wells, pressure in the wellbore is deliberately kept lower than the formation fluid pressure; Fig-4. This is done to allow formation fluids to rise to the surface while drilling, preventing damage to the formation being drilled. UBD technique is used to determine possible thief zones so that swellable packers can be placed correctly [12]. UBD combined with swelling elastomer can offer an efficient zonal isolation mechanism. It can help maximize well performance and can lead to ultimate improvement in hydrocarbon recovery. Richard et al. explain the use of underbalanced drilling in Nimr reservoir Oman [13]. Data retrieved by UBD shows that rogue fractures and thief zones play a crucial role in water movement. Swellable elastomers are deployed for water shutoff identified by UBD.

2.5. Evaluation of swellable packers

Swell packers are a new technology replacing conventional techniques in various petroleum applications. There should be some method for assessment of the performance of these new applications. Wireline ultrasonic measurements are used to evaluate zonal isolation achieved using swellable packers. Herold et al. [4] discuss the appraisal of swelling elastomer tools for proper zonal isolation using conventional and latest ultrasonic tools. Ultrasonic imaging tools and ultrasonic scanner is used to measure acoustic impedance (AI), third interface echo (TIE), radii and flexural attenuation. Amongst all, TIE gives more promising results to ensure hydraulic seal and zonal isolation in the case of swelling elastomer. TIE generally measure from cement-formation boundary but for swelling elastomer it gives reflection from elastomer surface. TIE also differentiates between swollen and inert elastomer [14].

3. FUTURE TRENDS

Swellable elastomer is an expanding and evolving technology with a huge potential. However, many challenges are still there to be overcome. Its use in extreme well environments of high-pressure and high-temperature (HPHT) is still questionable. Highly acidic and chemically more reactive aggressive reservoirs are also unexplored areas. Development of new swelling-elastomer materials and designing of improved and innovative applications is a need of the moment for the working envelope of HPHT and aggressive reservoirs.

4. CONCLUSIONS

Utilization of swellable elastomer technology offers feasible alternate solutions in well completion, well remediation, annular hydraulic isolation, and facilitating other applications. It has also proved to be economical in terms of rig time and cost involved. It helps in improving production volume and rate of hydrocarbon recovery, thus decreasing the impact on environment. Swellable elastomer technology in few areas is used for remediation and recompletion after the failure of tubular, cement, or due to excess water-cut. Looking at the vast potential of this technology, it should be considered during the design phase of a well (rather than a purely remediation strategy) in order to save time and money wasted due to well shutoff. This review can be useful for field engineers in selecting appropriate swelling-elastomer tools, and for research and development teams in designing new applications.

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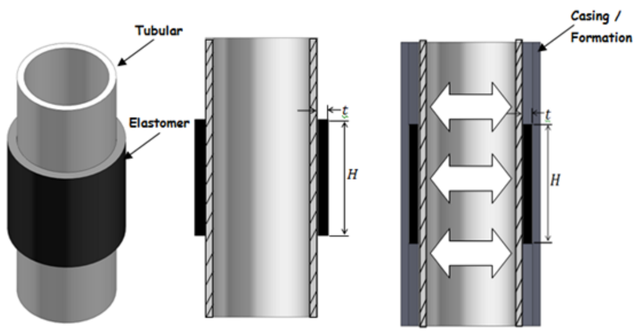

Figure 1. Schematic of a typical swellable packer

Figure 2. Elastomer swelling creates zonal isolation

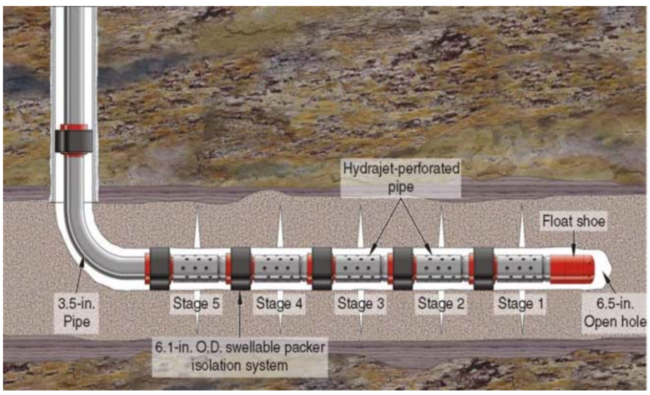

Figure 3. Hydra-jet perforation system

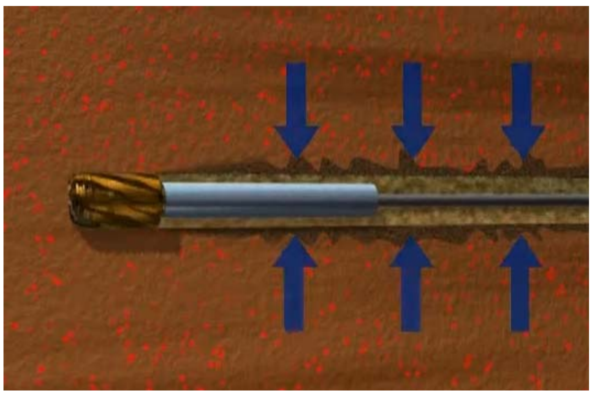

Figure 4. Underbalanced drilling