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**Davorin Matanović*, Katarina Simon*,
Nediljka Gaurina-Međimurec*, Borivoje Pašić*, Matija Malnar***

CONTRIBUTION IN TESTING SWELLING PACKERS BEHAVIOR

1. INTRODUCTION

The ultimate goal of swelling elastomer packers is the creation of a down hole barrier against pressure and flow. The swelling enables to benefit from a smaller profile for running into the well while maintaining the benefits of a full-size packer after swelling, with perfect seal in irregular borehole geometry, cracks, micro fractures, voids in cement, etc. Much more this permits the tubulars to be run at higher speeds with less risk of surges, piston effects, and swabbing effects, when passing through restrictions.

Swell packer technology comprises standard oilfield tubulars with layered rubber chemically bonded along their length or mechanically fixed. Once exposed to hydrocarbons or water from the reservoir or oil/water based servicing fluids, the rubber element (depending on swelling mechanism) swells to form an effective annular seal. Oil swelling packers depend on thermodynamic absorption process to became activated. The process involves hydrocarbon molecules cross linking with the rubber molecules. This cross linkage causes the rubber molecules to stretch. The stretch permits oil to enter the structure, which swells the packer and ensures the packer will remain swollen or continue to swell if the space geometry has changed, unlike less stable polymers. Mere trace amounts of hydrocarbons are sufficient to initiate the thermodynamic absorption process. The wellbore fluid's viscosity and temperature (typical operating temperature is from 80 to 130^{o}C [1]. are key variables in determining the time required for the packer to absorb the hydrocarbon and ultimately set. Swelling of the packer is homogenous along the element length. Also the swelling elastomer packer has the characteristic of being able to autonomously swell multiple times, as long as the appropriate media is present to feed the swell if the wellbore environment has changed. Although the hydrocarbons will not degrade the rubber, they will alter the mechanical properties, reducing the hardness, tensile strength, and Young's modulus. The change in mechanical properties is a function of the volume change of the element.

* University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Republic of Croatia

(differential pressure depends on the length of the rubber element, initial rubber thickness; the pressure retention capability varies inversely with wellbore internal diameter). Maximum care must be taken to ensure that the rubber elements of the packers are kept away from contact with ambient fluids prior to deployment.

Swelling in the presence of water results from the principle of osmosis. To swell in water based servicing fluids rubber (elastomer) seal must contain salts, super-absorbent fibers, and water absorbing polymers. If so there will be a greater salinity inside the packer than the outside. Due to the higher salinity of the packer seal compared to the surrounding water-based servicing fluid, a diffusion of water into the sealing element occurs as the water balances (or "evens out") the concentration of salt inside and outside the packer. The result of the water diffusion into the sealing rubber element is swelling of the elastomer. Investigations of swelling in such fluids have shown that swell speed is dependent upon temperature (typical operating temperature is from 50 to 90^{o}C) [2] , salinity of surrounding fluid, the level of acidity (pH) and polymer and packer element design. Much more, to ensure that the system can successfully be run to the desired depth, the swelling time must be engineered.

The length of the swelling time is critical to success and needs to be reliably controlled so that all required operations can be successfully completed before the packer sealing element contacts the wellbore wall. The swelling time is determined by the type of rubber compound, bottom hole temperatures, the viscosity of the swelling media (oil based), or difference in salinity (water based). It is possible to delay the swelling time long enough by use of a proprietary delaying mechanism that can extend swell profile for days, weeks or even months if needed. The swelling time for an elastomer in different bore diameters is shown in Figure 1.

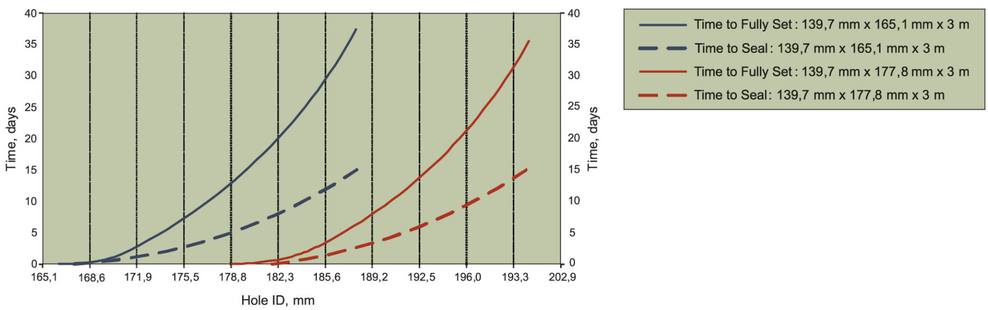

Fig. 1. Swelling of elastomer in different bore diameters [3]

2. PACKER TYPES

Today's application of swelling packers is primary for open and cased hole straddles, production isolation, liner completion, stimulation placement, cement repairs, water isolation, in multilaterals and as expendables in horizontal wells.

The application and design of the swell packer are based on three key variables: open hole size, required minimum differential pressure across the packer, and time to seal. To establish such properties extensive testing on the expansion properties of the elastomers lead to the development of simulators that can predict (simulate, measure) expansion ratio, differential pressure capability, and time to seal for a given base pipe and outer diameter. Such simulations are used to design and size packer for a given application and are key to proper design. The final hole size must be considered carefully in the design phase to ensure that the swell packer is sized correctly to fill the annular space and sustain the required differential pressure.

A key feature of the swell packer is its ease of deployment. With no mowing parts, down hole activation, or surface equipment required, the packer is simply made up as part of the completion or casing string and deployed as a single-trip assembly. Additionally, there is no need for special training. Figure 2 represents commercially available swell packer.

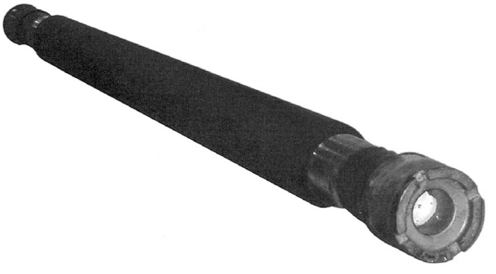

Fig. 2. The swelling packer [4]

Swell packer elements are chemically bonded to a full pipe joint (9 to 12 m) or a pup joint (3 to 6 m) with various element lengths to accommodate for the required differential pressure across the packer. Slip-on sleeve designs are also available (0.3 m).

The core swelling rubber of the swell packer is suitable to run “as is” in a water environment well that will ultimately produce oil and set the packer. However, the packer construction for an oil-based mud system normally uses a multilayered design that delays the onset of swelling while the packer is deployed into the well.

The packer consists of a mandrel (can be perforated), the rubber core that is attached to the mandrel (it is possible to use a high swelling inner core surrounded by a low-swelling outer layer and a diffusion barrier; the low-swelling outer layer and diffusion barrier can be adjusted to delay the packer set time to coincide with the installation program) and end connections that can be welded to the mandrel or contain a set screw assembly to attach the packer to the blank pipe.

3. COMPLETION CONSIDERATIONS

When designing such type of completion there are several driving aspects; minimizing total costs for the life of the well by primary reducing or eliminating intervention costs, while maintaining the ability to control production and to provide adequate means of isolation between producing zones. Other concerns may be: reliable design to afford required longevity, minimize risk exposure associated with new completion technology, provide an easy to install and operate reliable completion that would ensure zonal isolation, minimize the topside footprint, manage H_2S, maximize commingled production rate while controlling production from different layers. Some of today’s applications are shown in Figures 3, 4, 5 and 6.

Fig. 3. Expandable zonal isolation profiler tool with feed-through capability for control liners [5]

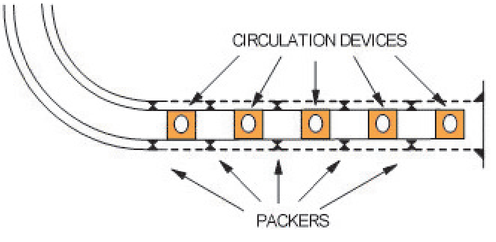

Fig. 4. Completion for the interval switching process [6]

Fig. 5. Swell technology has filled in the un-cemented area [7]

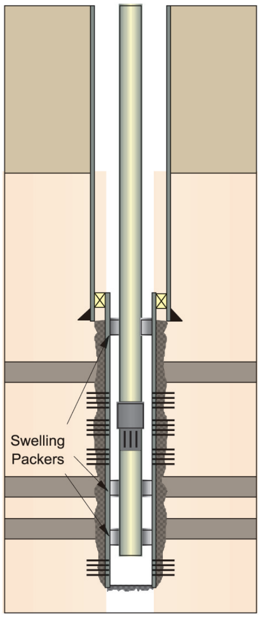

Fig. 6. Swelling packers used for production isolation [1]

Operation of swelling packers is simple [4]. Listed are main steps in handling with swell packers:

- gauging of the operating diameter of the packer,
- making up pup joint for handling,
- running in hole as a part of completion string or liner (casing) system,
- waiting on swelling, or
- producing the well, or
- spotting the fluid to activate swelling.

4. TESTING AND QUALIFICATION

Because of differences in fluid properties and composition, and reservoir conditions (temperature, and pressure) it is necessary to test swelling packers for particular use. To be able to do so one has to define testing procedures and develop testing equipment for such purpose.

At first it is important to test tensile strength of the rubber (elastomer), modulus and elongation at break. Rubber strength is critical for obtaining needed to bear differential pressure. Modulus must be as low as possible to achieve sufficient swelling.

Testing and verification of the swelling speed, maximum swelling and the stability must be tested depending on swelling mechanism (in oil, pure water, water of different salinities (brines) and temperatures. Two types of apparatus will be used in such testing. First one (Fig. 7), that enables the use of different rubber (elastomer) samples, fluids, change of temperature and measurement and recording of swelling in progress.

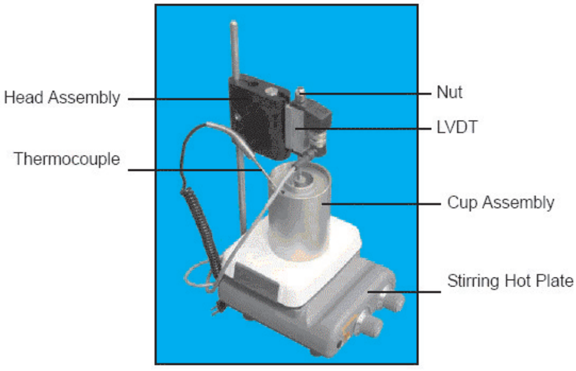

Fig. 7. Dynamic linear swellmeter [8]

Second one (Fig. 8 and 9) will be the variation of equipment used for dynamic seals investigation, that enables to install swellable material in the testing chamber, pump in desired fluid and weight for element to swell.

Fig. 8. Packer seal testing device

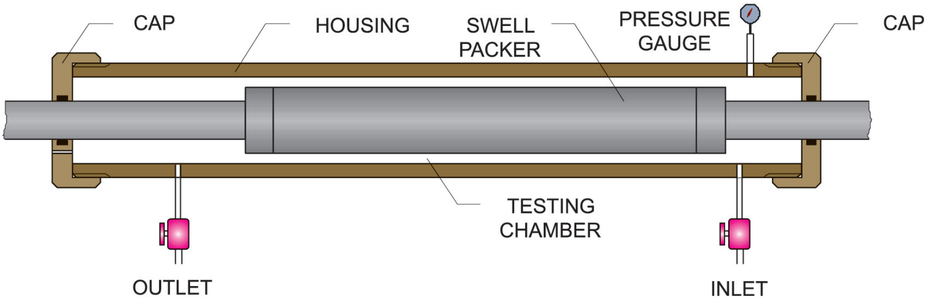

Fig. 9. Testing chamber cross section [9]

It is also possible to heat the system to desired temperature (reservoir temperature), and pressurize to the desired pressure (reservoir pressure). By pushing or pulling the carrying rod it is possible to detect sealing, control is than established through pressure differential between inlet and outlet side by establishing desired pressure differential. The testing device can be in vertical, horizontal or slanted position as well. That enables to perform full scale testing, and long-time stability testing.

5. CONCLUSION

The use of swelling packers is growing, because of simplicity in use and reliability that can be determined before the use. To be sure what to apply one has to perform testing of suitable swelling materials (rubbers, elastomers), because, their behavior in various servicing or producing fluids through adopted testing procedure must be verified for each new project.

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