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MATERIAL CHARACTERIZATION OF WATER-SWELLING AND OIL-SWELLING ELASTOMERS

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ABSTRACT
Developed in the last couple of decades, swelling elastomers are special polymers that increase in volume when exposed to water or oil, and are highly suitable for use as sealing elements in downhole applications. Swelling elastomers have been successfully deployed for applications such as isolation of water-producing zones, partial replacement of cementing in well completion, sidetracking in old wells to bypass damaged reservoir zones, etc. Performance estimation and design improvement of elastomer packers cannot be accomplished unless reliable data is available about their material response under specific field conditions. This paper reports the results from a series of tests that were performed to find out the behavior of two commercial swelling elastomers, one water-based and one oil-based. One set of samples was tested with one day of acid exposure, and the other set without any acid induction. Changes in volume, thickness, and hardness of elastomer samples were recorded after different periods of swelling, for a total testing time of one-month. Actual conditions from a regional well were selected as testing parameters. Results reported here can be used for prequalification purposes: which elastomer should be selected for a particular downhole application under a specific set of well conditions. Information obtained from the current study can also be used to predict seal behavior under different field conditions through numerical modeling and simulation.
Keywords: Elastomer packer, water-swelling, oil swelling, acid exposure, volume change, thickness change, hardness change

1. INTRODUCTION

Swelling elastomers are a new breed of modern polymers. They can swell upon contact with water or oil, and are therefore a very attractive choice for sealing elements in petroleum applications. Swelling elastomer packers (SEPs) have put many abandoned wells back into production, through strategies such as workovers, sidetracks, redrills, sand control, etc [1, 2]. Openhole swell packers have been used in HPHT well completion for subsea horizontal wells [3]. Other successful applications of swelling elastomers include cementless completions [4], well completion together with cement jobs [5], zonal isolation in openhole completion of foam-drilled horizontal wells [6], etc.

Two critical issues for field and application engineers are prediction of elastomer seal performance under actual well conditions, and improvement of seal design for increased efficiency and productivity. This is not possible without reliable information about material response of different candidate swelling elastomers. Kashkoush et al. [7] examined the effect of H_2S on mechanical and chemical properties of elastomers commonly used in the petrochemical industry. Kubena et al. [8] investigated how different drilling fluids affect the performance characteristics of certain types of elastomers used in drilling equipment. Al-Yami et al [9, 10] studied the resistance of water-swelling and oil-swelling elastomer seals to differential pressures at a given temperature. Material response of an EPDM-type water-swelling elastomer was studied earlier by the authors [11, 12]. Ertekin and Sridhar [13] reviewed the performance and compatibility of some elastomeric materials to gasoline mixtures containing various concentrations of hydrocarbons. The current paper summarizes the results of a series of tests performed to determine the swelling behavior of a water-swelling and an oil-swelling elastomer, with and without acid induction. Volume, thickness, and hardness of elastomer samples were measured before swelling and periodically after swelling over a one-month period. Test temperature, brine concentrations, acid strength, and crude oil samples were selected in line with actual field conditions.

2. EXPERIMENTAL WORK

To replicate actual seal behavior of elastomer mounted on pipe, plate samples were used (30 mm thick elastomer mounted on roughly 50 x 50 mm steel plates of 3 mm thickness). Disc samples (34 mm diameter, 6 mm thickness) were used to emulate free swelling. Brine solutions of 35000 ppm (3.5%) and 85000 ppm (8.5%) concentration were used for the water-swelling elastomer. Actual crude oil was used for the oil-swelling elastomer. Test temperature was kept at 60°C for both elastomers. For one set of samples, acid testing in 15% HCl solution was carried out for one day, after 3 days of water or oil testing; samples were then returned back to water/oil swelling. Readings were taken before swelling and after 1, 3, 7, 15, and 31 days of swelling.

3. ANALYSIS OF RESULTS

Because of space limitation, only a few representative graphs are shown here.

3.1 Volume Swelling

Figures 1 and 2 present the change in volume of disc and plate samples (respectively) against number of days of swelling in 35000 ppm (3.5%) brine solution and in oil. As expected, swelling in lower-concentration salt-solution is higher than in higher-concentration brine. Swelling slows down or decreases during acid exposure (day-4), and then increases again when elastomer is put back into the brine. Total volume swelling of acid-affected samples at the end of the one-month period is higher in both solutions.

3.2 Thickness Change

Figures 3 and 4 show thickness change in plate and disc samples against swelling time in 8.5% salt solution and in oil. Variation trends are the same for thickness-change as for volume change. Predictably, thickness swelling is higher for lower salt concentrations. Total thickness change generally goes up after acid induction.

Swelling amount for disc samples is far higher than for plate samples in all cases. This is very much in line with standard behavior; plate samples are restricted to swell from one major side, while disc samples are free to swell in all directions. Amount of swelling in the case of water-swelling elastomer is considerably more than for oil-swelling elastomer. This should provide an important guideline for field engineers: *Annulus between swell-packer and casing for oil-based elastomers should be significantly smaller than for water-based elastomers if a proper amount of sealing pressure is desired*.

3.3 Hardness Change

What happens to the hardness of an elastomer as it swells can be of significance in determining seal stability after prolonged exposure. Figures 5 and 6 summarize the change in hardness for disc and plate samples as they swell in 8.5% salt solution and oil respectively. Hardness of the original samples (before swelling) on the Shore-A scale was in the range of 53-55. It is interesting to observe that within a relatively short period of time (3 days for water-based elastomer; one week for oil-based elastomer), hardness drastically drops down to below 30, and then changes very little with further swelling. Final hardness is almost the same with and without acid induction for water-swelling elastomer, while it reduces significantly for oil-based elastomer.

There is significant reduction in hardness due to swelling for both elastomer types. The main question is *what happens to seals formed by these relatively soft swollen elastomers if subjected to high pressure differentials over extended period of time?* Without actual long-duration tests under varying conditions of temperature, pressure, and swelling medium (saline water, oil, acid), any estimates of seal life would be just estimates.

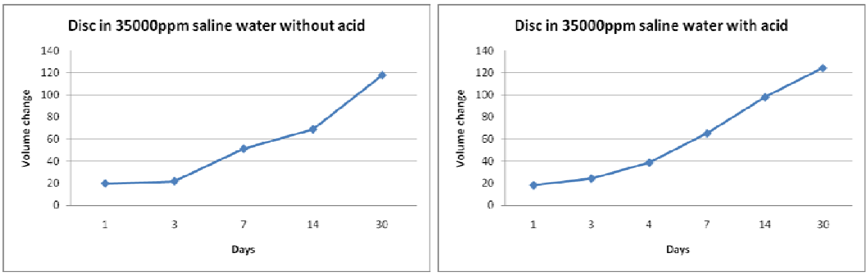

Figure 1. Volume change in disc samples against time; 3.5% brine solution; with and without

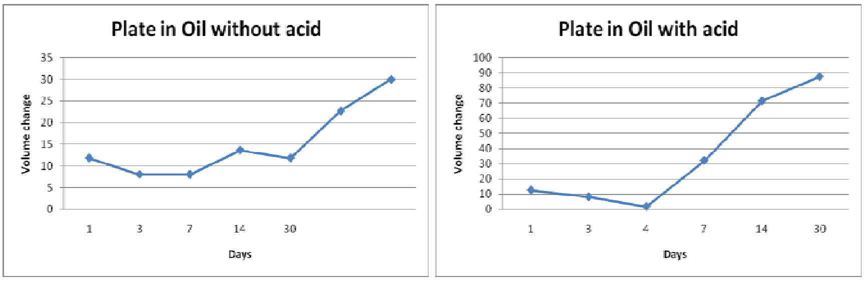

Figure 2. Volume change in plate samples against time; oil; with and without acid

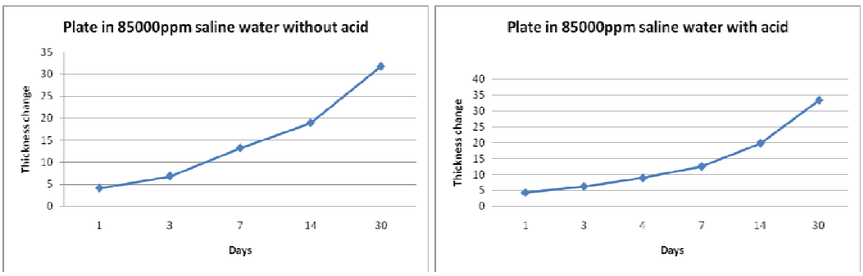

Figure 3. Thickness change in plate samples against time; 8.5% brine solution; with and without acid

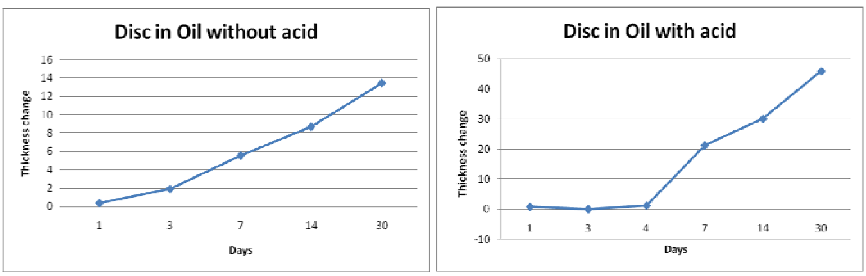

Figure 4. Thickness change in disc samples against time; oil; with and without acid

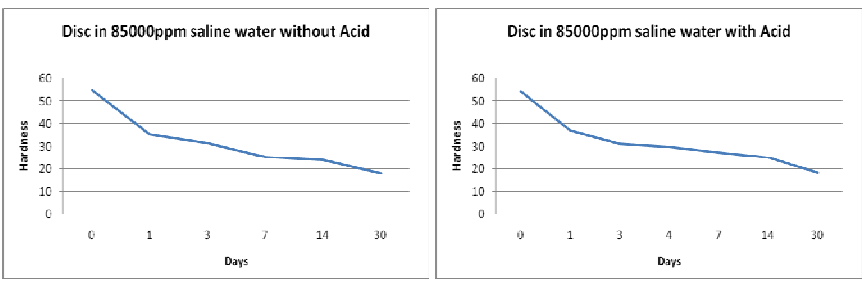

Figure 5. Hardness change in disc samples against time; 8.5% brine solution; with and without acid

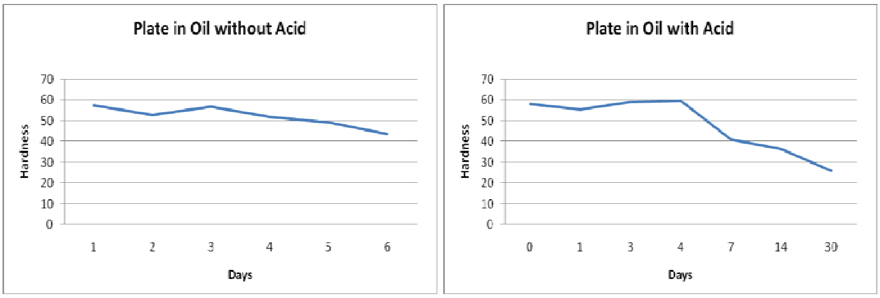

Figure 6. Hardness change in plate samples against time; oil; with and without acid

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