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Performance Analysis of Swelling Elastomer Seals in Petroleum Applications

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Abstract

Swelling elastomers (or gels) are being increasingly used in many fields ranging from bio-engineering to the oil and gas industry. In particular, swelling elastomers are used as sealing elements in many applications in the petroleum industry. Pre and post-swelling material characterization and performance analysis under varying field conditions is very important before their actual deployment. Currently, placement of such seals is mostly based on a few laboratory tests and trial-and-error approach. It is very difficult to test all the parameters under all field conditions experimentally. Analytical or numerical techniques are therefore needed to predict the behavior of such elastomers and seals.

No comprehensive investigation of this nature is currently available. This work focuses on performance analysis of swelling elastomer seals, using all three investigation methods available: experimental, numerical, and analytical. The work consists of various integrated but independent studies. Experiments are conducted to determine mechanical, structural, and chemical properties before and after swelling for different elastomers exposed to brine solutions of various concentrations. Experimental results are used for performance analysis, as an input for analytical and numerical modeling, and for validation of predicted results. Comparative evaluation of hyperelastic material models has been conducted to identify the best available model that can be used for simulation of swelling elastomers. Effect of swelling on mechanical and structural properties of different elastomers has been investigated, both experimentally and numerically, using the best available material model. Performance evaluation of elastomer seals (such as determination of seal contact pressure) has also been carried out using current best material model. As none of the existing models captures the real behavior of swelling elastomers, a new (analytical) material model has been developed. Apart from the hyperelastic nature of such materials, this new model also takes into account thermodynamics of mixing, diffusion effects, and changes in network entropy. A MATLAB code has been written for model solution. Compared to numerical solutions based on current hyperelastic models, predictions from the new model are significantly closer to experimental results.

Major contributions and applications of this work include an insight into the behavior of swelling elastomers and an understanding of swelling phenomenon; performance analysis and optimal selection of swelling elastomers for a given set of field conditions; and design improvement of swelling elastomer packers and other sealing applications. With suitable adaptation, the new model can also be usefully implemented for analysis of soft materials (such as tissues, cartilage, etc) in the field of biomedical engineering.