TECHNICAL ARTICLE

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Advances in Polymer Seal Materials Set to Improve the Efficiency of Enhanced Oil Recovery Operations

Making enhanced oil recovery (EOR) operations more efficient is the aim of a UK Government funded project into advanced polymer sealing materials. John Kerwin, materials technology manager with Precision Polymer Engineering, a polymer technology partner in the MERL-managed project, reports on progress so far.

Extracting oil is becoming more technically and financial challenging as operators are faced with increasingly complex and deeper wells. The lifespan of a well is dictated by production volume versus economic viability. This has led to technologies such as Enhanced Oil Recovery being developed that increase the amount of oil extracted from the well thus improving its profitability.

EOR involves the injection of super critical CO_2, steam or H_2S into the well in order to recover a larger proportion of the oil. The solvating properties of high temperature steam and super critical CO_2 when injected at high pressure reduce the viscosity of heavy oil and enable more oil to be extracted. However, these same solvating effects can affect sealing elastomers, thermoplastic liners and composites that come into contact with the fluids, leading to swelling and a weakening of the polymer's structure. In turn this may result in loss of sealing due to extrusion of the seal under pressure, increased fluid permeation and seal volume loss. As a result, polymer seals on pumps and compressors, for example, need frequent replacement. With a 1% improvement in world oil production efficiency estimated to be worth an additional 20-30 billion barrels, the ability to extend the operational life of seals and other polymer-based components offers significant financial benefits.

The aim of the 'Durability of Polymers under injection conditions for Enhanced Oil Recovery (PEOR) project' is to better understand the effects of EOR environments on polymers used for reinjection and storage purposes in new and existing infrastructure. In so doing, it will identify, qualify and develop new polymeric materials for EOR operations offering longevity and safe operations in these hostile applications.

As the EOR injection process can be used in CO_2 storage and carbon capture by pumping super critical CO_2 into a well and displacing the oil, it can then be re-injected and sealed underground rather than letting it vent into the atmosphere. Part of the PEOR project involves the development of guidelines on the use of polymers in carbon capture applications

PEOR puts polymers to the test

The PEOR project simulates the operating and reinjection conditions for North Sea and other fields around the globe and assesses what effect these conditions have on current and emerging state-of–the-art polymers. The 34 materials evaluated in the project included elastomers such as Ethylene propylene (EP), butyl, hydrogenated nitrile (HNBR), Tetrafluoroethylene propylene copolymer (FEPM), fluoroelastomers (FKM and ETP) and perfluoroelastomer (FFKM) as well as thermoplastics including PEEK, PPS and PVDF.

These polymers were specifically chosen as they have demonstrated considerable success in current field applications and have the potential to be developed and incorporated into cost effective future EOR technologies.

Initial screening of the polymers involved exposure to steam, super critical CO_2 and hydrogen sulphide. The performance of the materials was evaluated by means of visual inspection, tensile testing for steam and H_2S, rapid gas decompression damage evaluation using the NORSOK M-710 oil and gas standard.

Steam (exposure of dumbbells followed by tensile testing) has shown that materials including FKM, FFKM, ETP and FEPM perform well (at 220°C, 150bar 2 week exposure). Other materials including HNBR (Figure 1) do not perform well under these conditions.

Figure 1 - steam swell comparison of HNBR dumbbell shown with un-aged dumbbell.

Super critical CO_2 soaking of O-rings whilst constrained in RGD (rapid gas decompression) fixture - very few materials are unaffected by exposure to super critical CO_2. Swelling is usually followed by damage resulting from RGD (tested according to NORSOK M-710 standard with decompression rate of 20bar/minute). HNBR and FKM (with high fluorine content) have performed well with little damage seen following one decompression (at 110°C from 350bar). Other materials such as ETP (Figure 2) have shown extrusion, while the base resistant FKM O-ring was split into two halves. Blister damage was also common (Figure 3).

Thermoplastic PPS shows slight swelling (PEEK does not under these conditions), and both PPS and PEEK show discolouration, but no blistering was observed.

Hydrogen sulphide testing was conducted in a harsh environment of 65% H2S + 35% CO_2. Interestingly more material grades showed good resistance to H_2S (through tensile testing and swell measurements), including FKM, HNBR, FEPM, BUTYL, EP and FFKM.

Figure 2 - ETP extrusion during rapid gas decompression following super critical CO_2 immersion.

Figure 3 - Blister damage during rapid gas decompression following super critical CO_2 immersion.

Overall none of the materials tested showed good resistance to both steam and super critical CO_2. In practice, however, it is unlikely that materials will see both environments: more likely they will see hydrocarbon exposure followed by super critical CO_2 or steam (as in well conversion).

Full EOR testing

The initial list of 34 polymer materials was reduced to seven material grades (based on FKM, FFKM, ETP, EPDM, FEPM and PPS). These were then exposed to the full test conditions. Each of the polymers was subjected to exposure to steam: 260°C and 250bar, and exposure to 65% H_2S and 35% CO_2: 220°C and 20bar. Rapid gas decompression in 100% super critical CO_2: 150°C and 410bar was also carried out. Just one material, a fluoroelastomer, performed acceptably well in all tests. The next stage of the project with this material is the moulding of a three element packer component for test under steam conditions to ISO 14310.

So far, the PEOR project has succeeded in identifying the strengths and weaknesses of existing polymers under injection conditions for enhanced oil recovery and carbon storage. Further work is now planned for the development of new fluoroelastomers to improve the mechanical performance of the elastomer sealing material.

The PEOR project is managed by MERL Ltd with the assistance of polymer technology partners Precision Polymer Engineering Ltd and Clwyd Compounders Ltd, and off-shore tooling specialist Baker Hughes.

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For more information on the Durability of Polymers under Injection Conditions for Enhanced Oil Recovery (PEOR) project contact John Kerwin, PPE on +44(0)1254 295400 and email: john.kerwin@prepol.com.