NEW HIGH PERFORMACE RESIN FOR THERMOPLASTIC LINERS

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ABSTRACT
Corrosion enhanced abrasive wear is a common cause of failure in sucker rod systems. The combination of high side loads caused by deviation and the presence of corrosive chemicals creates a very difficult environment for operators. The cyclical loading nature of sucker rod systems adds to the problem, leading to premature failures in rods and tubing. Operators are turning to many technologies to increase mean time between failures (MTBF) in these challenging wells.

Thermoplastic liners are one of the many options to extend run life in deviated wellbores. Liners are extruded from specialty compounded resins, each with its own set of advantages and disadvantages. To maximize the benefit of lined tubing, a new resin is now being extruded to fill the void between 210° and 250° F, without high cost of higher temperature resins. This paper summarizes the properties of the new resin in comparison to the other resins currently on the market.

INTRODUCTION

Reciprocating rod pump is the most popular method of artificial lift due to many technical and practical advantages. Rod pumping is often able to achieve lower bottom hole pressures than other methods of artificial lift, and in many situations, rod pumping is the most efficient form of lift. Furthermore, rod pumping has a logistical advantage of being well understood by engineers and field staff and having readily available parts when maintenance is needed. However, the reciprocating nature of rod pumping naturally causes problems in deviated wellbores and corrosive well fluids. Rod on tubing wear is one of the main failure mechanisms for rod pumping systems in deviated wells. Corrosive environments further complicate the issues by accelerating the rate at which both the sucker rods and tubing wear.

Traditionally rod guides have been the common method of addressing deviation related failures in rod pumped wells. The effectiveness of rod guides, however, greatly varies. Guides add friction to the system, which leads to higher loads on the rod string and surface equipment. Rod guides also cause a flow restriction in the tubing which can lead to turbulent flow in the area around the guides. Corrosive elements are more likely to break out from the fluid in these turbulent flow areas, often leading to corrosion enhanced wear occurring near the guides. In severely deviated wells, it is common to have sections of six or eight guides per rod, which significantly increases the cost of the rod string. For these reasons, operators have begun to seek alternative to rod guides in their deviated wellbores.

THERMOPLASTIC LINER HISTORY

Thermoplastic liners have been used in downhole oil and gas application for over twenty years. Although originally developed to protect against corrosion in water injection and disposal wells, the technology quickly gained acceptance in beam pumped wells to reduce the rate of rod on tubing wear. The initial liners were manufactured from a high-density polyethylene (HDPE). HDPE is a very versatile plastic that provides a moderate level of protection against corrosion and abrasive wear, but the maximum continuous operating temperature of 160° F limits its potential applications.

As the industry became aware of the benefits of lining production tubing in rod pumped wells, a few different resins began to be extruded into thermoplastic liners. A raised temperature HDPE was developed which increased the maximum continuous operating temperature to 210°F. This raised temperature allowed lined tubing to be introduced to many new production environments. However, many operators use hot oil treatments at temperatures approaching 250°F, and this resin would not be an option for these wells. HDPE tends to melt when its temperature rating is exceeded, which can cause very expensive failures in rod pumped wells. If the liner melts around the sucker rods, it is unlikely that the rod string will be able to be pulled without pulling the tubing at the same time.

High-performance resins are now being extruded to address the challenges seen with early resins. Not only do high-performance resins provide higher working temperatures, they also perform better against corrosion, have lower coefficients of friction, and stand up better to abrasive wear. Polyphenylene sulfide (PPS) and polyether ether ketone (PEEK) have been the two primary high performance resins used in thermoplastic liners for production tubing. PPS liners have a maximum continuous operating temperature of 350°F, while PEEK liners can withstand temperatures to 500°F. These resins offer terrific performance in a wide range of operating conditions, however, the cost of these liners has prohibited them from displacing technologies such as rod guides. As oil prices have fallen in the last couple of years, many operators have discontinued the use of high-performance thermoplastic liners simply due to economics. Cross-linked polymers and additives such as fiberglass have been used in some cases, but these resins face similar challenges to other high-performance resins. A new thermoplastic liner is now being extruded to meet the needs of rod pumped wells in a low-cost environment.

NEW HIGH PERFORMANCE RESIN

A raised temperature polyolefin ketone (POK) or polyketone is now being extruded into thermoplastic tubing liners at a much lower price than other high performance resins. POK was originally commercialized by Shell chemical as a replacement for HDPE in offshore applications where higher performance was needed. Shell discontinued the production of the resin in 2000, and the technology began to be investigated by Hyosung in late 2003. For the next decade, Hyosung worked to test the viability of POK as a high-performance resin. In 2012, a large-scale pilot plant was completed, and by 2015 Hyosung had completed a commercial scale plant. Since this time, Hyosung has worked to develop a new strand of raised temperature POK which is being used in multiple industries, and the resin is now being extruded for thermoplastic liners for the first time.

POK has a maximum continuous operating temperature of 115°C (240°F), and the resin shows much greater resistance against corrosive fluids and abrasion than other low cost resins. Laboratory testing has been done to compare POK to other similar resins in a variety of properties. Table 1 shows a summary of the relevant properties of the resin. Field trials are currently underway to validate the performance of the resin in real world conditions.

Physical Properties

Polyolefin ketone has a density 1.24 g/cm^3 of melting point of roughly 220°C. The melting point of POK is roughly 90% higher than HDPE. POK exhibits 30 to 40% crystallinity and is insoluble in most organic solvents. Physical testing of polyketone shows that the resin is strong and relatively stiff as shown by its high modulus and yield stresses(1). Mechanical testing has been done on both flat samples and round samples of extruded pipe. Typical ASTM testing is performed on flat samples, but testing on curved extruded samples showed similar yield values. Elongation at break was reduced in the curved samples(2).

Chemical Resistance

Polyketone polymers have very few known solvents. The polymer is particularly resistant to salt solutions, hydrocarbons, and most other chemicals present in oilfield applications(3). Multicomponent crude exposure testing was done over an eight-month time period over a temperature range from 20°C to 80°C. The modulus, yield stress, and elongation properties will relatively unchanged after this test. A separate eight-month test exposed POK to a fluid from a North Sea sour gas environment at 105°C. Table 2 shows that tensile properties stabilized after two days of exposure and remained relatively unchanged for the remainder of the testing period.

Figure 1 displays laboratory testing showing that POK exhibits much less swelling than HDPE when exposed to multicomponent crude condensate at various temperatures(4). POK absorbs about 0.5% moisture under 50% relative humility, which has negligible plasticization effects. POK resists hydrolysis, dissolution, and other reactions in a broad range of chemicals and temperatures common in oilfield applications.

Collapse and Permeation Resistance

Thermoplastic liners tend to collapse when pressure is reduced abruptly inside the liner in the presence of an annular pressure. This can occur in oil wells when the tubing is pressured up and bled off rapidly. The tendency to collapse is much greater if the permeability of the liner is high. Laboratory testing shows that a 5-inch pipe lined with POK has twice the collapse strength at room temperature than a pile lined with HDPE. At 80°C, the collapse strength of POK is 5 to 6 times greater than the strength of HDPE in the same pipe(1). POK is less permeable than HDPE and other oilfield polymers for CH_4, CO_2, and H_2S at various temperatures. These results indicate that the polymer will be less likely to collapse under a rapid pressure drawdown. The impermeability of POK will provide the steel tubing greater protection in a corrosive environment than HDPE. Furthermore, POK can be extruded to a thinner diameter than HDPE while still providing permeation resistance.

FIELD TESTING

Polyketone is currently installed in several high failure wells in the Permian Basin. The low cost of the resin compared to PPS or PEEK polymers has made it an attractive option in corrosive wells or wells that require hot oil treatments where HDPE is not viable. Field trials are still in the preliminary stages, as the earliest POK installation has only been operating for seven months. Mean time between failures has already been extended on two separate installations, however, and to this point there have been zero failures in pipe lined with the raised temperature POK resin. Further work will be done to provide case studies as the field trials progress.

CONCLUSION

Polyketone possesses many properties that potentially make it very well suited for use as pipe liner in corrosive environments. Testing has shown that POK pipe liners are very strong, resistant to common oilfield chemicals, have low permeability, and perform well in raised temperatures. These properties all compare favorable to HDPE and other low cost resins typically used in oil and gas. The combination of the performance and the cost of polyketone makes it an attractive choice to replace HDPE, PPS, and PEEK liners in many environments. The resin also has the potential to replace IPC coatings, Teflon, and boronized tubing in many environments. Pending successful field trials, the adoption of polyketone liners in deviated wellbores and corrosive environments would be expected.

REFERENCES

1. Kau, J. C., Vieth, C., & Vanderschuren, L. (2000, January 1). Polyketone Polymers: A New Liner Material for Corrosion Control in Oil and Gas Industry. NACE International.

2. Polymer Solutions Inc. (2017, January 13). Physical Testing of Pipe Liner, Project Report AQ-32824.

3. Exposure testing conducted by Shell Canada with multicomponent crude condensate and by Shell Amsterdam in Nelson Fluid (a typical North Sea sour gas environment).

4. CARILON® Polymers – Chemical Resistance Guide, Shell Chemicals Publication # 2420-98.

Table 1 – Properties of polyolefin ketone (POK)

Physical Properties		**Test Method**	**Unit**	**Value**
Density		ASTM D792	g/cm3	1.24
Water Absorption	23°C, 50% RH	ASTM D570	%	0.5
Mechanical Properties		**Test Method**	**Unit**	**Value**
Tensile Strength at Yield	23°C	ASTM		
Nominal Strain at Break	23°C	ASTM D638	%	270
Flexural Strength	23°C	ASTM D790	MPa	49
Flexural Modulus	23°C	ASTM D791	MPa	1300
Thermal Properties		**Test Method**	**Unit**	**Value**
Melting Temperature		ASTM D3418	°C	222
Heat Deflection Temperature	18.6 Kg/cm2	ASTM D648		90

Table 2 – Tensile Properties of POK after exposure to Nelson Fluid at 105°C

Exposure Time, day	**Modulus, Mpa**	**Yield Stress, Mpa**	**Yield Strain, %**	**Break Stress, Mpa**	**Break Strain, %**	**Volume Change, %**	**Weight Change, %**
0	1,699	62	22	84	322	--	--
2	718	52	36	62	217	7.0	5.3
34	754	53	30	61	218	6.4	4.7
92	676	55	34	57	49	6.4	4.6
230	754	57	39	56	114	6.5	5

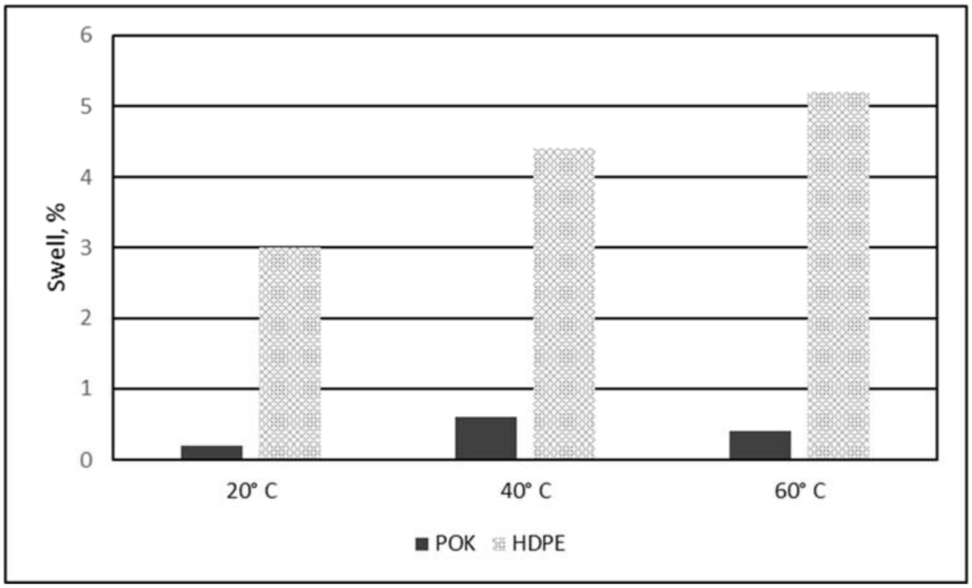

Figure 1 – Swell of POK and HDPE after Exposure to Multicomponent Crude Condensate at Various Temperatures