Wide Range Temperature, Pressure, and Fluid Resistant Hydraulic Cylinder Sealing Systems

Joel Johnson
Ben Westbrook
Simrit Division of Freudenberg-NOK

Noriyuki Matsui
NOK Corporation

ABSTRACT

Excessive temperature and fluid compatibility often create problems for hydraulic cylinder sealing. Overall, new materials and designs are necessary to meet the increasing requirements of the industry. Smaller packages with higher pressures combined with hotter ambient temperatures (often directly linked to new environmental standards) continue to drive the demands for better performing seal systems. The new advancements presented in this paper help the fluid power engineer design a more robust cylinder that can be used in a wide variety of applications while providing longer life and lower warranty.

INTRODUCTION

Failure analysis indicates that the main sealing challenges for cylinder makers today are excessive temperature and fluid compatibility (including hydrolysis and glycolosis). The latest demands (listed below) exceed the capabilities of most off-the-shelf sealing solutions.

- Capable of 42 MPa (6000 psi) @ 0.5mm diametrical extrusion gap
- Handle continuous 110º C or 120º C temperatures
- TR_{10} of -30º C; - 40º C actual application capability
- Compatible with biodegradable and standard hydraulic fluids
- Hydrolisis and glycolosis resistant
- Retrofit in existing standard grooves

The changes to the temperature range are especially concerning as they affect a broad range of applications. Bench testing has shown that increasing the system temperature by 10º C can decrease the seal life by 5 times (or greater). To narrow the scope of this paper, we chose to use our best-in-class sealing system (fig. 1: buffer seal + asymmetrical rod seal + vented rod wiper) produced in our Disogrin 9250 (urethane) as a baseline.

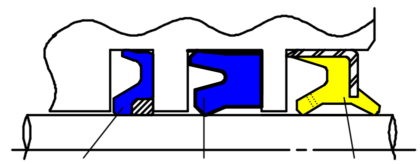

Figure 1. Baseline Sealing System

This system in Disogrin 9250 has decades of proven field experience, but an upper temperature limit of 100º C and is not hydrolysis or bio-fluid resistant. This paper centers mostly on materials, and will show the results of several new urethane and elastomeric blends in designs equivalent to our baseline sealing system.

It should also be noted that many of the results concentrate on the residual interference that remains after test. This is a measurement of the remaining interference the seal has with the bore and shaft, which takes into account not only wear but also the physical state of the material. This is a strong indicator of remaining life as a design is as dependant upon the material resiliency to ensure that it seals at low (or no) pressure as it is the material strength to ensure that it does not extrude at high loads.

MAIN SECTION

For several years we have supplied a proprietary blend of urethane into the market (NOK U641) that is capable of handling 110º C. As part of the material development, the baseline configuration was successfully lab tested to 500km (0.5million cycles) at 32MPa / 0.4mm/s / 110º C without leakage. Our experience indicates that the results of this accelerated test correlate well with actual field results. In this case the NOK U641 change allows our sealing system to provide similar hours to what was provided by Disogrin 9250, but at an elevated temperature (see figure 2). NOK U641 was also developed to be hydrolosis and glycolosis resistant.

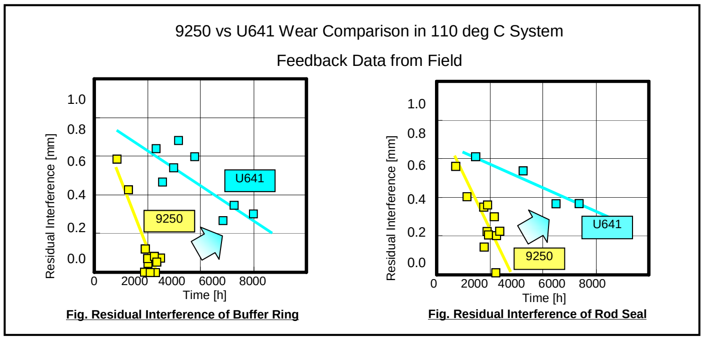

Figure 2: NOK U641 field data

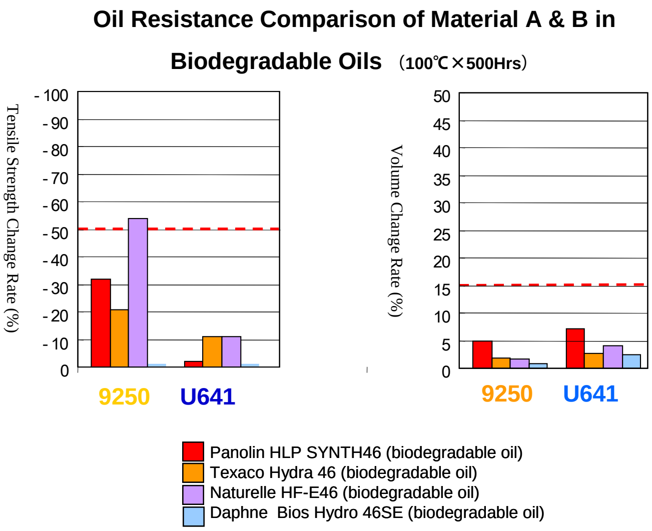

Figure 3: Bio-Oil Fluid Resistance

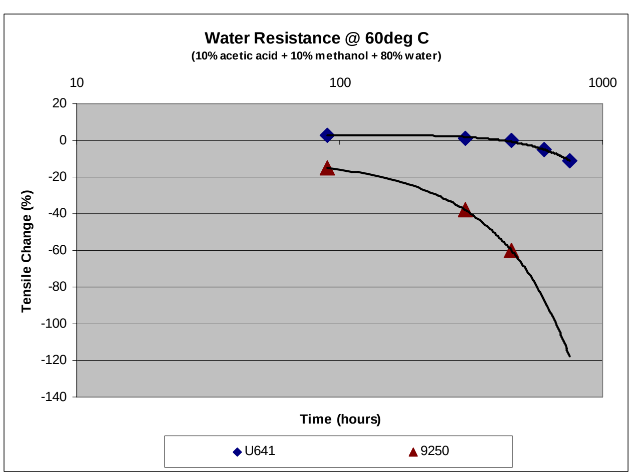

Figure 4: Water Resistance

NOK UH05 – 120º C Urethane.

In many cases NOK U641 is all that is needed to meet the application needs. It does not meet our initial high and low temperature requirements though, therefore NOK UH05 was developed.

NOK UH05 improves our cold temperature resistance, while increasing the high temperature capability (see figure 5). The trade off with NOK UH05 is that it is more difficult to process, and therefore only suitable for the thinner cross section of the buffer seal.

	High Temp (deg C)	Low Temp (Tr10)	Hydrolisis Resistant	Bio Fluid Compatible	PSI Resistance @ 0.4mm dia Gap	Process-ability
Disogrin 9250	100	-30	No	No	6000	None
NOK U641	110	-17	Yes	Excellent	6000	None
NOK UH05	120	-25	Yes	Good	6000	Buffer Only

Figure 5. Urethane material property comparisons

ELASTOMERS: G928=120ºC HNBR; A505=110ºC NBR

As a complement to urethanes, we develop specially formulated elastomers for use in pressure applications. The advantage elastomers can offer is that they take less of a compression set than urethanes (see figure 6), but they require back up support to prevent extrusion at pressures above 12MPa (see figure 7). Lower compression set equates to improvements in residual interference which is advantageous where longer life is required. Extrusion is not an issue as we have successfully used filled / reinforced PTFE back up rings to reach 40+MPa.

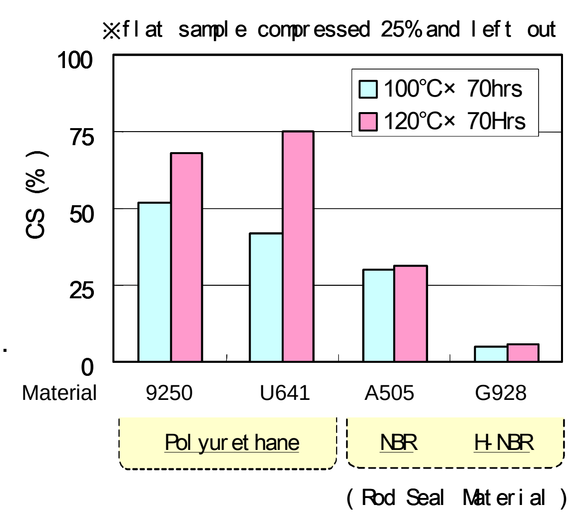

Figure 6. Compression Set Data

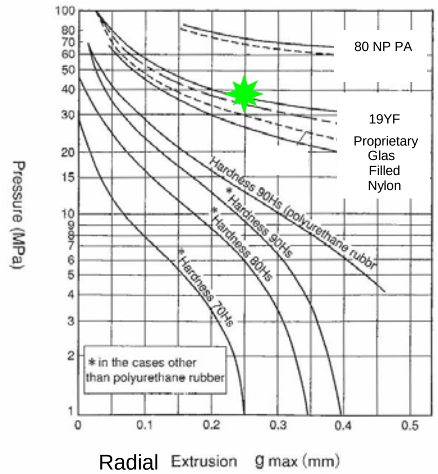

Figure 7. Back Up Ring Data

ELASTOMERIC ROD SEALING SYSTEM

We have successfully used combinations of urethane and elastomer in Asia for numerous years. A U641 buffer with A505 NBR rod seal system (fig. 8) meets all of the design goals except for the 120º C upper limit (max is 110º C). To meet the 120º C requirement, we substitute UH05 for the buffer seal, and HNBR G928 for the rod seal.

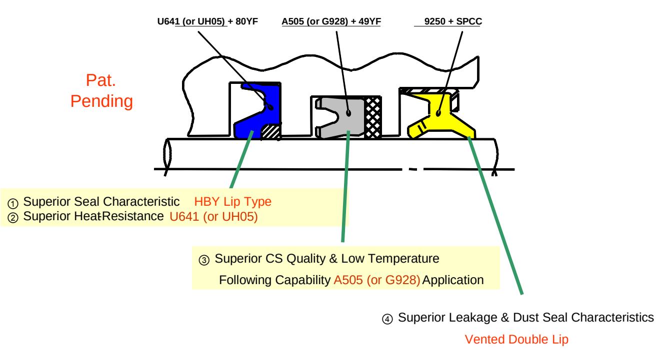

Figure 8. Elastomeric Rod Sealing System

BIODEGRADABLE OIL COMPATIBILITY

Immersion testing was conducted for 500 hours at 100º C and 110º C in numerous biodegradable oils to determine their effect on all previously mentioned materials. Panolin HLP Synth46 was chosen as our baseline biodegradable oil, and lab testing was conducted on the systems shown in figure 8 at 80º C, 100º C, 110º C, and 120º C for 125km @ 42MPa. The results are shown in figure 9. All materials performed well, with U641 starting to take a set at its upper limit of 110 deg C (as expected).

After Test Residual Interference						
80 deg C	Buffer	NOK U641	56%	Rod Seal	NBR A505	85%
	Buffer	NOK UH05	59%	Rod Seal	NBR A505	87%
100 deg C	Buffer	NOK U641	55%	Rod Seal	NBR A505	73%
	Buffer	NOK UH05	77%	Rod Seal	NBR A505	73%
110 deg C	Buffer	NOK U641	30%	Rod Seal	NBR A505	71%
	Buffer	NOK UH05	82%	Rod Seal	NBR A505	69%
120 deg C	Buffer	NOK U641	28%	Rod Seal	HNBR G928	85%
	Buffer	NOK UH05	51%	Rod Seal	HNBR G928	84%

Figure 9. Bio Oil Lab Testing

SYSTEM FOR N.A. AND DIN STANDARDS

The JIS standard groove sizes allow for a back up ring independent of the rod seal material, where as the North American and DIN standard groove sizes do not. This creates a problem with retrofit of the new solutions into existing grooves. We have developed a design that integrates the back up into the seal (referred to as an IUY design – see figure 10) as a solution to this.

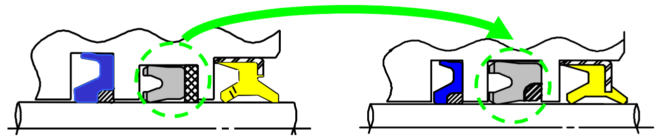

Figure 10. IUY design (patent pending)

The IUY system was tested at 110º C and 120º C for 500km @ 32MPa (0.4mm/s) against a NOK U641 rod seal (both using a NOK U641 buffer), and the residual interference results are shown in figure 11.

Material / Temperature	Residual Interference	
	G928	U641
110℃	74.2%	23.5%
120℃	67.6%	9.1%

Figure 11. Rod seal residual interference

Although neither of the systems actually leaked, the HNBR G928 has significantly higher residual interference overall (especially at 120º C). This can be directly correlated to longer system life.

CONCLUSION

NOK U641 is a hydrolisis / glycolosis resistant option for 110ºC systems with standard and bio hydraulic oils provided 100% sealing at extreme cold temperature is not needed. If 100% sealing at extreme cold temperature is needed, A505 NBR can be used in combination with a back up ring for the rod seal.

NOK UH05 (buffer) in combination with G928 HNBR (rod seal) is a hydrolisis / glycolosis resistant material option for 120ºC systems with standard and bio hydraulic oils. The HNBR rod seal does require a back up ring to prevent extrusion though. Base on our testing, this is the best sealing solution for long life at any temperatures.

Field test show that the A505 (NBR) system can go 8,000 hours in and excavator application, and based on the improvement in seal residual interference we expect the G928 (HNBR) system could last 5X longer even at elevated temperatures. The life of any system is influenced by factors such as contamination, rod damage, and oil degradation which greatly effect seal life in actual applications. Every system should be tested in the actual application.

CONTACT

Joel Johnson, Vice President Technology – Simrit (Joel.Johnson@Simrit.US), 847.428.1261 x81222

Simrit Division of Freudenberg-NOK, 2250 Point Blvd., Suite 230, Elgin, IL 60123

Standard Design Validation Test Fixture Example

Design Validation Test Set Up