Fluid/Elastomer Compatibility Evaluation for Progressing Cavity Pumping Applications

2008 SPE PCP Technical Conference

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Outline

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Introduction - PC Pump Elastomers

• most critical element in a PC pump but often also the most misunderstood

• unique characteristics are what distinguishes a PC pump from other artificial lift systems but also what limits its application range

• prone to interaction with the wide variety of downhole fluids which can change its dimensional and physical characteristics

• understanding and adjusting for the elastomer/fluid downhole interaction is essential to maximizing the performance and longevity of a PC pumping system
Introduction - Elastomer Selection

- pump suppliers used to have only a couple of general purpose elastomers for which they published only basic use guidelines.
- pump suppliers now have many more elastomers and publish a variety of technical data but it is often only qualitative and not standardized across the industry complicating interpretation.
- the PC pump application range has significantly expanded to include lighter oils, more use of chemicals and higher temperatures.

selecting elastomers for the wide variety of PCP applications has become more challenging.
Introduction – Rotor Sizing/Fit

- Stators are normally manufactured to a standard size & rotor sizes adjusted for the application.

- The fit between the rotor and stator controls its:
  - Ability to form a pressure seal >> volumetric efficiency
  - Sliding/rotating and hysteretic friction >> torque
  - Elastomer strain and stresses >> fatigue life

- Most common industry method for rotor sizing/fit is through performance bench testing:
  - Tests normally not representative of application
  - Rely on “estimate” of target standard test required to yield acceptable performance in downhole application
  - Targets refined through trial and error
Introduction – Rotor Sizing/Fit (cont)

- stator/rotor interference fit can be calculated but requires accurate stator measurements
  - often done during initial pump design but less common for application rotor sizing
  - to use effectively for applications need to understand dimensional and physical changes that occur to elastomers downhole

rotor sizing for certain PCP applications has become more difficult

<<< Before
After >>>
Reasons for Fluid/Elastomer Evaluation

• new application screening
  - increasing important as difficulty increases

• evaluation of fluids introduced downhole including diluents, production chemicals, reservoir treatments
  - often options in terms of fluids & programs

• elastomer selection
  - more choices makes decisions more complex

• rotor sizing
  - quantify potential elastomer changes downhole

• aid in application review and/or failure analysis
  - reactive but still useful
Fluid Evaluation

- most basic technique is review of available data
  - API gravity – can be misleading
  - MSDS sheets – often many ingredients proprietary

- **Aniline Point**
  - simple low cost test available in most labs
  - provides a temperature that estimates aromatic hydrocarbon content

- **Hydrocarbon Analysis (Chromography)**
  - more complex higher cost test less readily available
  - provides hydrocarbon components (C30+) breakdown in mole, mass and volume percent
  - standard practice is to consider total aromatics

➤ only assess fluid therefore elastomer compatibility must be done indirectly by interpreting results
Fluid/Elastomer Compatibility Testing

• process of exposing elastomer samples to fluids under controlled environmental conditions and measuring changes to the elastomer

• results are used for vendor selection, application screening, elastomer selection and rotor sizing

• commonly done by pump suppliers and laboratories

• no standards for fluid collection, test equipment, testing conditions, sample preparation/geometry, measurements or result interpretation/application

• certain procedural variables can dramatically alter test results leading to inappropriate comparisons or conclusions
Fluid Collection and Handling

• perception that a pressurized downhole sample is required
  - flowline sample is what the pump sees
  - pressurized samples introduce significant cost and complexity and very few hydrocarbon components flash off at surface temperatures

• collect sufficient volume (2-4 litres)

• store in sealed container not prone to fluid attack

• accurately complete paperwork to enable shipment

• store samples in appropriate area and/or cabinets

• handle samples under fume hood with proper PPE
Test Equipment - Basic

• Open Container
  - fluid in container into which elastomer samples placed
  - no ability to control temperature or pressure
  - normally no mixing
  - potential safety hazard
  - not recommended

• Aging blocks
  - fluid in glass tubes into which elastomer samples placed and then tubes submersed in heated water bath
  - tube limits specimen geometry
  - can control temperature
  - can not control pressure
  - normally no mixing
  - suitable for small samples with known homogenous fluids
Test Equipment - Advanced

• **Standard Autoclave**
  - fluid in steel tubes into which elastomer samples placed and then tubes placed in autoclave
  - flexibility with regard to tube size
  - can control temperature and pressure but no mixing
  - suitable for homogenous fluids

• **Agitating Autoclave**
  - same as standard autoclave but adds continuous agitation for fluids prone to separation
  - suitable for all fluids
Test Conditions

• **Temperature and Pressure**
  - temperature accelerates dimensional and physical elastomer changes & can produce different final values
  - pressure normally has limited impact
  - if possible set T&P at downhole conditions

• **Duration**
  - dimensional and physical changes occur with time but since PC Pump applications involve extended exposure periods want to assess equilibrated swell
  - time to equilibrate depends on on T&P, fluid and test sample geometry
  - 168 hrs usually sufficient for preferred sample geometry
  - replicate specific exposure time for treatment chemicals
Test Conditions: Temp. & Time Effect

- distilled water with standard nitrile elastomer
- 0.070” (2 mm) tensile specimens
Test Sample Preparation

- elastomer test sample must replicate what is in stator to ensure lab results are representative of pump
- test samples are normally prepared in molds cured in lab presses at temperatures pressures & time different then stators
- test samples must be cured at equivalent conditions
- verify cure conditions of test samples through comparison to tests on samples from stators
Test Sample Geometry

- wide range of specimen shape, size & thickness
  - round, rectangular and tensile shapes
  - thickness from 0.080” (2 mm) to 0.500” (12.7 mm)

- thicker or larger specimens will exhibit less change and not equilibrate during test

- geometry dictates available measurements

- use multiple (min. 3) samples to improve reliability

- ensure elastomer to fluid volume ratio is not too high

- external labs often just request generic samples from pump suppliers who supply different geometries
  - invalidates comparisons
Sample Geometry: Thickness Effect

- 80% isooctane and 20% toluene at room temp.
- 72 and 144 hour exposures
Test Measurements

- most common are volume and mass change expressed as a percentage
  - measure sample weights before & after in air & water

- normally also hardness change expressed as an absolute unit change (Shore A)
  - done using standard hardness test equipment
  - must ply thin samples to get accurate result

- if tensile specimens are used then can quantify changes in mechanical properties expressed as a percentage or absolute unit change
  - typically tensile strength, elongation, tear, moduli
  - requires specialized elastomer test equipment
PC Pump Fluid/Bond Compatibility Testing

• elastomer to tube bond must also be compatible with fluid for PC pump to be successful

• bond integrity is a function of both the adhesives and the stator manufacturing process
  - ideally test samples from actual stators

• bond samples tested in similar manner as elastomer

• after exposure elastomer is pushed out from tube and load measured and failure mode characterized
  - compare to as manufactured conditions
ISO 15136-1 PCP Standard: Downhole

- standard being rewritten to better reflect industry needs and now includes standards for elastomer specifications & fluid/elastomer compatibility testing

- Annex A includes requirements for elastomers including standard suite of compatibility tests
  - water, IRM903 oil, Fuel B
  - temp’s from 30 to 175C depending on elastomer type
  - zero pressure
  - 168 hour duration
  - standard tensile specimens (ASTM D412 Die C)
  - report volume, mass, hardness, tensile, elong. change

- Annex D includes optional requirements on elastomer and bond testing and selection
Test Interpretation and Application

- focus is usually on volume change but if available should also review mechanical property changes
- by comparing results with those from standard test fluids or previous test fluids with application experience can evaluate application severity
- result comparisons between elastomers aids in elastomer selection
- result comparisons between chemicals aids in confirming or refining treatment programs
- interpretation of test results for rotor sizing purposes is the most difficult
Laboratory versus Stator Swell

- use of fluid/elastomer compatibility results for rotor sizing depends on ability to relate results to stators but correlation of lab results to stators is complex

- stators are only exposed to fluid from their internal surface but lab samples are exposed on all sides
  - stator dimensional change should be lower

- pump models have different thicknesses and within an individual stator there are varying thicknesses most of which are higher than lab samples
  - stator dimensional change should be lower

- stators constrain volume change due to adjacent material but lab samples are unconstrained
  - stator dimensional change should be higher
Full-Scale Stator Swell Testing

- full-size stator swell test program underway to:
  - understand stator swell phenomena
  - quantify relationship between pump dimensional and performance changes
  - correlate to laboratory scale testing
  - improve rotor sizing practices

- multiple phases with different objectives
  - Phase I: initial trials (1 geo. X 2 elast X 2 fluids)
  - Phase II: elastomer study (1 geo. X 5 elast X 1 fluid)
  - Phase III: geometry study (5 geo. X 1 elast X 1 fluid)

- full-size stators matched with loose fit rotors that generate a low efficiency standard performance test
Fullscale Stator Swell Testing (cont.)

• continuous exposure to fluids at either ambient or elevated temperature but always ambient pressure

• test durations of several months to a year

• stators are removed periodically for evaluation:
  - internal dimensions measured on the minor every pitch and major at both ends
  - standard performance test with initial rotors to quantify change in performance

• parallel fluid/elastomer compatibility tests run in laboratory with varying test sample thicknesses
Fullscale Stator-Dimensional Change

- 25°C 80% isoctane & 20% toluene
- Model 10-900 stator with standard nitrile

![Graph showing dimensional change over exposure duration]

- Decrease (Swell) in Diameter
- Stator Major Absolute Change
- Stator Minor Absolute Change
- Stator Major % Change
- Stator Minor % Change

Tensile Lab Specimen Max Change = 16%
Fullscale Stator Swell–Efficiency Change

- 25C 80% isoctane & 20% toluene with STD nitrile
- Model 10-900 stator with standard nitrile
Fullscale Stator Swell–Torque Change

- 25C 80% iso-octane & 20% toluene
- Model 10-900 stator with standard nitrile
Fullscale Stator-Other Key Parameters

- 25C 80% iso-octane & 20% toluene
- Model 10-900 stator with standard nitrile
Fullscale Stator Swell–Extended Test

- 60C distilled water with STD nitrile
- Model 15 stator: 1.56” minor & 0.68” major thickness
Elastomer Selection/Rotor Sizing Vision

- Laboratory Fluid/Elastomer Compatibility Testing
- Elastomer Selection and Rotor Sizing Design Tool
- Operating Performance Review and Pump Inspection

Feedback and Refinement

- as per ISO 15136
- based on fullscale stator swell testing
Summary

- elastomer selection and rotor sizing is a key determiner in pump performance and life but is usually done primarily based on experience
  - challenging for new or difficult PCP applications

- laboratory fluid/elastomer compatibility testing can provide valuable information but results are highly dependent on the test procedure

- laboratory testing if not properly done can lead to wrong conclusions
  - watch specimen thickness, multicomponent fluids, ensure representative test temp’s

- ISO 15136 includes a laboratory testing standard for PCP’s that will ensure consistent comparisons
• laboratory swell results can not be directly transferred to stator swell due to the significant differences in the elastomer geometries

• stator swell under various exposure conditions can be measured and through performance testing its impact on pump efficiency and torque quantified

• rotor sizing can be done methodically by determining the relationships between laboratory and stator swell for different pump geometries and elastomers
  - reduce the trial and error sizing process
  - improve pump performance and life
  - enable success in more challenging applications