Maintenance and Troubleshooting of Progressing Cavity Pumps

Chad Huskey
MOYNO Tech Eng.
chad.huskey@nov.com
The Progressing Cavity Pump and it’s Geometry

- A progressing cavity (PC) pump, or a single screw pump, is a positive displacement pump and therefore a fixed volume is displaced with each revolution of the pump’s Rotor.
- The Rotor forms a single helix (like a corkscrew) and rotates eccentrically in the Stator.
- The Stator has a double helix cavity (like a double corkscrew) double the total volume of the rotor.
- When combined, as the rotor turns, cavities or pockets nearly half of the total volume are formed in the stator which push the product from the suction toward the discharge end of the pump.
Rotor Geometry

- Crest to crest
  - (called Major)
- Circular cross-section
  - (called Minor)
- Machined in a helical shape similar to a corkscrew
Stator Geometry

- Oval shaped cavity cross-section.
- Similar geometry as Rotor but uses a double helix.
- Available in several elastomers, metal, or urethane construction materials.
Cavities

• As Rotor orbits (turns eccentrically) inside the Stator.
• The motion creates cavities and progresses them from suction to discharge.
LOOKING AT END VIEWS OF ROTOR TURNING IN STATOR, AS THE ROTOR COMPLETES ONE REVOLUTION.

This feature results in a continuous, non-pulsating flow because the sum of any two opposing cavities is a constant.
APPLICATION INFLUENCES
“THE BIG THREE”

✓ Abrasion
✓ Temperature
✓ Viscosity
Effects of Abrasion

- **Abrasive fluids = Wear**
  - Wear is proportional to speed; minimize speed to minimize wear.
  - De-rate pressure per stage to limit slip amount ... 87 PSI for no abrasion; 20 PSI for heavy abrasion.
  - Specify oversize Rotor to increase interference fit = longer life.
  - Use abrasion resistant Stator material or softer durometer elastomers: RM 100M, RM 103, Urethane etc.
  - Double chrome rotor for additional Rotor base metal protection.

<table>
<thead>
<tr>
<th>Abrasive Characteristic</th>
<th>Fluids</th>
<th>Press/stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Water, Polymer, Oil</td>
<td>87 PSI</td>
</tr>
<tr>
<td>Light</td>
<td>Milk or Lime</td>
<td>65 PSI</td>
</tr>
<tr>
<td>Medium</td>
<td>Sludge, Clay or Gypsum Slurries, Chocolate, Drilling Mud</td>
<td>43 PSI</td>
</tr>
<tr>
<td>Heavy</td>
<td>Emery Dust, Lapping Compounds, Grout, Sand, Granulated Sugar</td>
<td>20 PSI</td>
</tr>
</tbody>
</table>
Effects of Temperature

- Stator Elastomers swell from 70 to 130°F (physical Rotor dimensions require adjustment above this 130°F temperature) and Elastomers shrink with Lower temperature (Below 50°F).
- Metal parts such as the rotor and drive train tend to expand and contract at a negligible rate than elastomer counterparts.
- Since Stator is bonded to a metal tube, the rubber can only swell inward on the rotor, or shrink away from the rotor.
- This changes the compressive fit between the rotor and stator. Again, to keep a standard fit, the Rotor requires under sizing above 130°F, and over sizing below 50°F.
- Under extreme heat or cold, elastomer Stators may not be appropriate.
- Metal Rotor and Stator combinations can be used for extreme temperature applications because they swell or shrink at the similar rates.
Effects of Viscosity

- The more viscous a fluid, the slower the pump will have to run in order to permit the fluid to flow into the cavity.
- Even at reduced speeds, the pump may not develop 100% volumetric efficiency and this must be accounted for in the selection process.

Loss of Fill (volumetric) Efficiency starts at

- 1 CPS = Above 1800 RPM
- 1000 CPS = 150 RPM
- 10,000 CPS = 30 RPM
- 1 CPS = 700 RPM
## Effects of Viscosity

<table>
<thead>
<tr>
<th>Material</th>
<th>Viscosity (centipoise)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water @ 70deg F</td>
<td>1-5</td>
</tr>
<tr>
<td>Blood or Kerosene</td>
<td>10</td>
</tr>
<tr>
<td>Anti-freeze or Ethylene Glycol</td>
<td>15</td>
</tr>
<tr>
<td>Motor Oil SAE 10 or Corn oil</td>
<td>50-100</td>
</tr>
<tr>
<td>Motor Oil SAE 30 or Maple Syrup</td>
<td>150-200</td>
</tr>
<tr>
<td>Motor Oil SAE 40 or Castor Oil</td>
<td>250-500</td>
</tr>
<tr>
<td>Motor Oil SAE 60 or Glycerin</td>
<td>1-2 thousand</td>
</tr>
<tr>
<td>Karo Corn Syrup or Honey</td>
<td>2-3 thousand</td>
</tr>
<tr>
<td>Blackstrap Molasses</td>
<td>5-10 thousand</td>
</tr>
<tr>
<td>Hershey Chocolate Syrup</td>
<td>10-25 thousand</td>
</tr>
<tr>
<td>Ketchup or Common Mustard</td>
<td>50-70 thousand</td>
</tr>
<tr>
<td>Tomato Paste or Peanut butter</td>
<td>150-250 thousand</td>
</tr>
<tr>
<td>Crisco Shortening</td>
<td>1-2 million</td>
</tr>
<tr>
<td>Caulking compound</td>
<td>5-10 million</td>
</tr>
<tr>
<td>Window Putty (glazing compound)</td>
<td>100 million</td>
</tr>
</tbody>
</table>
Summary

How does a MOYNO Pump Work?

- The standard PC pump consists of a Rotor (metal) which rotates within an elastomeric Stator.
  - The Rotor has a circular cross-section and is machined in a single helix like a corkscrew.
  - The Stator cavity is molded as a double helix with an Oval cross-section. The helix geometry is similar to the rotor to create an interference fit.
  - As the rotor turns inside the stator it orbits on an eccentric (at an offset around the center axis), this motion creates cavities that progresses from suction to discharge; moving product and building pressure.
Summary
Progressing Cavity Pump Advantages

- The **MOYNO** design creates a low shear, metered, and pulse-less flow.

- The PC pump is able to effectively handle “water-like” to super viscous fluids including levels of air or gases.
  - It can gently pump large particulates and handle abrasive solids.
  - Provides excellent suction capabilities and does not air lock.

- The **flexible geometry** of the **MOYNO** pump allows.
  - Multiple drive end choices (power) and multiple stages (pressure).
  - **MOYNO** pumps allow **precise** control of the interference fit.

- **MOYNO** can **best** match the pump to your application.
General Maintenance

MOYNO

PUMP MAINTENANCE
Preventative Maintenance

Most of the maintenance needed for a MOYNO pump is based on “look-feel”

DAILY INSPECTION;
• Lip seals on bearing housing
• Packing/Mech seal (flow/pressure/noise)
• Gear reducer (temp/noise).

WEEKLY MAINT;
• Adjust packing (should drip 2-5 times per minute)
• Lube packing (typically 2-3 pumps per week).

YEARLY MAINT;
• Replace packing, inspect shaft wear.
• Replace automatic lubricator (if applicable).
• Pull spool piece to inspect pipe internal condition.
Lubrication Schedule

• Bearings
  Bearings are lubricated and the factory and do not normally need periodic re-lubrication—recommended only when drive shaft is removed for maintenance.

• Packing
  Once a week or more, frequency determined by process.

• Gear Joints
  Only recommended when gear joints are disassembled.
  (example; when replace rotor)
### MOYNO® PROGRESSING CAVITY PUMPS USE TWO LUBRICANT FOR MOST INDUSTRIAL APPLICATIONS. (TEMPERATURES 400° F OR LESS)

DuBOISE CHEMICAL ACG – 2, AND MOBIL-1 NLGI Grade 2

### DuBOISE CHEMICAL. ACG – 2 and MOBIL-1 NLGI Grade 2

ARE RECOMMENDED FOR:
- GEAR JOINTS
- PIN JOINTS
- BEARINGS
- INDUSTRIAL PACKINGS

THE FOLLOWING LUBRICANTS ARE ACCEPTABLE FOR:
- PIN JOINTS
- BEARINGS
- INDUSTRIAL PACKINGS

| 1. | ACG-2 | DuBOISE CHEMICAL (FACTORY INSTALLED) |
| 2. | MOBIL 1 NLGI Grade 2 | MOBIL CHEMICAL (RECOMMENDED) |
| 3. | MOBILUX EP2 | MOBIL CHEMICAL |
| 4. | ALVANIA EP2 | SHELL OIL |
| 5. | MYTILUS 2 | SHELL OIL |
| 6. | SUNAPLEX 992 EP | SUN OIL |
| 7. | ACL-2 | FISKE BROTHERS |
| 8. | TRIBOL 823-2 | CASTROL |
| 9. | STARPLEX SERIES | TEXACO |

FOR MOYNO® SANITARY PUMPS, THE RECOMMENDENDED PACKING LUBRICATION IS FGG - 2 from DuBoise Chemical or Accrolube – 2 from Accro-Seal or equivalent.

**NOTE:** THE ABOVE LUBRICANTS ARE ALL NLGI Grade 2 Greases
Remember…

MOYNO

Always the Right Solution™
FAILURE ANALYSIS
AND
EXAMPLES OF WORN & FAILED MOYNO PARTS
Failure Analysis

Equipment failures are frustrating and inconvenient. That doesn’t mean that a failure is not useful.

Some of the more useful information you will gather as a maintenance professional or operator will come from failure analysis.
Failure Analysis

Was the failure caused by operator error? Is there a process issue? Was there a mechanical shortfall?

Failure analysis will help to determine future preventative maintenance and narrow the decision making for necessary changes concerning process or equipment.
Failure Analysis

Inspecting Rotors

To check any rotor, place 1.000 inch bar across the crest on one side of the rotor. The micrometer reading minus 1.000 equals the rotor crest to crest diameter. Example: 3.646 in. - 1.000 in. = 2.646 in. crest to crest.

Figure 4-4. Measuring Rotor Dimension
Failure Analysis

Inspecting Stators

A worn stator may appear pitted and gauged, or may appear smooth similar to new.

Performance is the best measure of rotor to stator fit. If unable to measure performance adequately, suspected stator wear can be evaluated by a MOYNO sales representative.
Failure Analysis

What is cavitation and how can I tell if my pump is cavitating?

In summary, cavitation is an abnormal condition that can result in loss of production, and equipment damage. In the context of pumps, the term cavitation implies a dynamic process of formation of bubbles inside the liquid, their growth and subsequent collapse as the liquid flows through the pump. It can be **vaporous** or **gaseous**.

Both types of bubbles are formed at a point inside the pump where the local static pressure is less than the vapor pressure of the liquid (vaporous cavitation) or saturation pressure of the gas (gaseous cavitation, also referred to as “air binding”). The noise and pump vibration is caused by the collapse of the air bubble when it gets pressurized.

Typically in a **MOYNO** pump the cause of cavitation is a lack of suction volume. The symptoms are reduced flow, a rumble with vibration or and may include a rapid popping sound.
Failure Analysis

- TYPICAL ROTOR ABRASIVE WEAR PATTERN
- NOTE THE TELLTALE RIDGES
Failure Analysis

- ABRASIVE WEAR ON A ROTOR
  NOTE THE RIDGES OR GROOVES
Failure Analysis

- ABRASIVE WEAR ON A 316ss ROTOR
- NOTE THE DEEP GAUGING GROOVES
Failure Analysis

- TYPICAL ROTOR EVEN WEAR PATTERN
- A LITTLE TOO WORN TO RE-PLATE
- ADJUSTING THE MAINTENANCE INTERVAL MAY LOWER COSTS
Failure Analysis

- CHEMICAL ATTACK TO THE EXPOSED CARBON STEEL BASE METAL OF A CHROME PLATED ROTOR.

- A SYMPTOM INDICATING THE ROTOR BASE METAL IS NOT COMPATIBLE WITH THE PROCESS
Failure Analysis

- CHEMICAL ATTACK UNDERMINING THE CARBON STEEL BASE METAL **THRU** THE CHROME PLATING.
Failure Analysis

• CHEMICAL ATTACK TO THE CARBON STEEL BASE METAL **THRU** THE CHROME PLATING.
CHEMICAL ATTACK TO THE 316 SS BASE METAL UNDER THE CHROME PLATING.
THE INNER SURFACE OF A RUN DRY STATOR IS HARD AND HAS A VERY ROUGH TEXTURE.

AN ORANGE PEEL TEXTURE ALONG SEAL LINES IS A TELLTEALE SIGN OF RUN DRY.

RUN DRY DAMAGE NORMALLY BEGINS AT THE SUCTION END.
Failure Analysis

- CHEMICAL ATTACK AND RUN DRY CAN OFTEN HAVE A SIMILAR APPEARANCE.
- ONCE CHEMICAL ATTACK HAS SET IN RUN DRY WILL EVENTUALLY OCCUR.
- NOTE THE EVIDENCE OF HARDNESS AND ROUGH TEXTURE AND CRACKS THROUGH THE ELASTOMER. THESE DEEP CRACKS THROUGH THE ELASTOMER CAN CONFIRM CHEMICAL ATTACK.

Degeneration of all elastomer and destruction of geometry.
Failure Analysis

THE SURFACE OF THE STATOR IS HARD AND HAS AN ORANGE PEEL TEXTURE.

THE SURFACE BLISTERING AND CRACKING COMBINED WITH A BURNED SMELL AND THE ELASTOMER INTACT IN SURROUNDING AREAS IS CONSISTENT WITH RUN DRY.

Elastomer totally burnt by run dry, THE SURROUNDING AREAS STILL HAVE INTERGRITY.
Elastomer totally burnt by running dry. Note that surrounds areas are perfect.

This results in a different diagnostic process and narrows the focus when evaluating the loss of performance.
Failure Analysis

- The stator has become soft and tacky as a result of run dry.
- The elastomer is smeared and sticking to the rotor.
- The stator will smell like burned rubber and have a melted appearance.
Failure Analysis

- **Elastomer swelling is evident on the ends of this stator.**
- **Significant swelling or shrinking is a clear sign of chemical attack.**
CHEMICAL ATTACK HAS CAUSED THIS NITRILE STATOR TO SWELL. NOTE HOW THE RUBBER BULGES OUT PAST THE END OF THE STATOR TUBE. THIS TYPE OF CHEMICAL ATTACK (SWELLING) COULD OCCUR WITH ANY STATOR ELASTOMER.
DELAMINATION IS THE RESULT OF THE ELASTOMER MOLECULES NOT KNITTING PROPERLY DURING THE MANUFACTURING PROCESS. THE ELASTOMER MAY THEN COME LOOSE IN LAYERS WHILE PUMPING AGAINST HIGH DISCHARGE PRESSURE.
Hysteresis (fatigue)

Action: Cycling loads on elastomer increases internal temperature and causes a secondary vulcanization.

Result: The elastomer loses its elastic properties, becomes very hard and cracks arise in the surrounds areas of cycling loading

*LARGE CHUNKS TYPICALLY WILL BREAK LOOSE*
Failure Analysis

WORN TEETH

NORMAL
Failure Analysis

WORN TEETH

NORMAL
Failure Analysis

Failure Analysis

- Failure

- Twisted

- Normal

Twisted splines/broken connecting rod typically indicate high torque.
Failure Analysis

TYPICAL CIRCULAR PATTERN INDICATES TORQUE FAILURE

THE TWIST INDICATES THIS CONNECTING ROD WILL FAIL SOON!
Gear joint seals should be inspected for damage when the pump is serviced.
Pin Joint Dynamics – Point Contact in Connecting Rod

The “hour glass” shape necessary to transfer motion, results in large thrust loads to be transferred to the pin in a point contact.
Failure Analysis

- Typical pin wear patterns
Failure Analysis

- Typical connecting rod wear pattern
Failure Analysis

• Excessive rotor head wear
Questions?
A customer reported repeated failures of a connecting rod. Application is a G2 (open throat housing) pumping 7% solids from a filter press.

MOYNO replaced the 1\textsuperscript{st} connecting rod under warranty. Then the 2\textsuperscript{nd} connecting rod.

When the customer had a 3\textsuperscript{rd} failure, and using customer supplied information concerning the failed parts, engineering changed the material to 17-4 ph (heat treated stainless) with a strength of 145,000 psi.

Engineering also developed a hollow tube version of the connecting rod to withstand higher torsional loads, without the higher expense associated with 17-4.

When the 17-4 con-rod broke Moyno sent a team to investigate the issue.
Failure Analysis Case

We looked at the broken parts
Noted an irregular break pattern.
Noted no twist in the splines.
We looked at and evaluated the normal wear parts for damage or anything that could cause binding.
Failure Analysis Case

When nothing was obvious we further evaluated the type of failure and began to carefully review the operational information.

The type of failure pattern is not consistent with a torque failure and is consistent with a fatigue failure.

Then the operational information; how the system operates and conditions when operating were closely reviewed.

The system has high levels of whey from a cheese producer, which results in significant pipe build up.
Failure Analysis Case

The system is run by the flow rate (maintain a certain flow), so if the pipe buildup results in restriction the pump speeds up. The max speed by design is 419 rpm, which is faster than we would prefer for a 2 meter open throat.

The system is protected from high pressure using a pressure ring switch assembly and analog gauge.

Plant maintenance reported that pipe buildup regularly restricted the internal pipe dimension to 2” or less.

High pressure safeguard is set to shut off at 80psi, but heavy buildup can stop the switch and the pressure gauge from properly reading = malfunctioning.

The restriction would also lower the flow rate resulting in faster, and faster pump speeds to keep up.
Review of the VFD settings revealed the system is enabled to run over the design speed at a max 78Hz which translates to 544rpm max.

The system failures/breakages generally occurred on third shift when the system was not closely monitored.

The conclusion after reviewing all the information was the pipe internal buildup needed to be addressed by more frequent maintenance or a process change.

But more importantly the speed needed to be restricted to at or below the original design speed.
Failure Analysis Case

Questions?