„Microcrystalline Diamond Coated Seal Faces for strong challenging Multiphase Pump Application“

24th Pump User Symposium
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Outline

- The Location
- The Process
  - The Application
  - The Problem
  - Sealing technology
  - The Solution
  - The technology
  - The Result
The Location

- Canada, Primrose, Deer Creek
- End user „Total“
- Twin Screw Multiphase Pump

Deer Creek, OK
The Process

- Heavy oil recovery by steam injection processes
- CSS-process (Cyclic Steam Stimulation) requires only one wellbore. Steam is injected for several weeks to heat the oil, then oil flows into the wellbore and get lifted to the surface.
SAGD-process (Steam Assisted Gravity Drainage) requires two horizontal wellbores. Steam is injected continuously into the upper wellbore, mobilizing the oil to drain to the lower wellbore and get pumped to the surface.

*Courtesy of Petro-Canada*
In the annulus vapor recovery service multiphase boosting systems are used

- Single Mechanical Seals installed at suction side
- A simple unpressurized buffer fluid system supports the seal lubrication at high gas volume fractions (GVF), API-Plan 52
### Operating conditions for the mechanical seals:

<table>
<thead>
<tr>
<th>Product media</th>
<th>Saturated steam and condensed water, small amounts of bitumen and sand; gas including methane, CO2 and H2S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product pressure [p / bar(abs)]</td>
<td>approx. 1</td>
</tr>
<tr>
<td>Product temperature [T / °C]</td>
<td>up to 130</td>
</tr>
<tr>
<td>Rot. speed [rpm]</td>
<td>up to 1800</td>
</tr>
</tbody>
</table>
The Problem: former installation – failed every 2 weeks due to heavy wear of seal faces

Single Seal with unpressurized buffer fluid system – API-Plan 52

Buffer fluid In/Out

Seal face materials: antimony impregnated carbon versus silicon carbide (soft – hard)
Sealing technology: Single Mechanical Seal Material Selection challenge

- Increased **dry-running risk** requires soft-hard seal face material combination

- **Abrasive particles** require hard-hard seal face material combination with the ability to run **without** lubrication and cooling for an unpredictable period of time
The Solution:

- Seal faces
  - in a **hard material** in order to handle solids
  - and
    - can **run dry** for a specific period of time

- **crystalline diamond coated seal faces**
The Solution: Mechanical Seals with two diamond coated seal faces

Installation in December 2006 on site
The solution – Mechanical Seals with two diamond coated seal faces

Diamond Seal Faces properties:

- Unique hardness
- Excellent thermal and chemical resistance
- Low friction coefficient
- Dry running capability!!

→ Thus mechanical seal faces can handle solids and dry running!
The manufacturing process

Pressure, Energy, Gasflow, Gasphase,...

Hydrogen 99%

Methane 1%

Gas atmosphere at vacuum

Activation due to hot filament

Deposition of Diamond (0.2-1.0 μm/h)

T ~ 800°C

T ~ 2000°C
In the reactor with horizontal filaments silicone carbide seal face surfaces are coated with diamond
The tribological performance

Benchmark for hard/hard material combinations

Test condition:
Sliding speed: 2m/s
Contact pressure: 0,3N/mm²
Medium: Dry Nitrogen

Friction coefficient $\mu [-]$

Time [s]
Tribological Performance – Benchmark of friction coefficient (poor lubrication)

Dem. water, $v_g = 7.6 \text{ m/s }, p = 1 \text{ MPa}$

![Graph showing friction coefficient over time with and without diamond coating.](image-url)

- **Without Diamond coating**
- **Diamond coated seal faces**
**Diamond – Comparison Graphite / Crystalline Diamond**

**Graphite**
- $sp^2 = 3$ covalent bonds
- Strong horizontal bonding
- Weak vertical bonding

**Diamond**
- $sp^3 = 4$ covalent bonds
- Strong bonding in all directions
Diamond – Hardness

Mohs hardness

Vickers hardness [kg/mm²]

Carbon graphite

SSiC

DLC

Quelle: Fraunhofer IAF
http://www.cvd-diamond.com/tfdiprth/frames_d.htm
Adhesive strength – Results:

**Adhesive strength diamond-SiC test:**

- Adhesive strength (tensile strength) status 2007: 70-80 MPa
  (diamond layer can not be pulled off, values correspond to maximum tensile strength of the glue!)

![Images of adhesive strength tests](image_url)
Diamond deposition – Flatness measurement by laser interferometer
Diamond deposition - Homogeneous deposition standard seal face

Flatness measurement before and after coating

<table>
<thead>
<tr>
<th>Type</th>
<th>Flatness</th>
<th>Λ</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>Flatness Old @ 2000x</td>
<td>Δ=0,66μm</td>
<td>9,291 μm</td>
</tr>
<tr>
<td>After</td>
<td>Flatness New @ 2000x</td>
<td>Δ=0,50μm</td>
<td>9,140 μm</td>
</tr>
<tr>
<td>After-Before</td>
<td>New-Old Flatness @ 2000x</td>
<td>Δ=-0,16μm</td>
<td>9,009 μm</td>
</tr>
</tbody>
</table>

Due to the high hardness of the coating a final polishing after the coating process is not feasible. Therefore the process was optimized to achieve homogenous deposition rates in order to minimize the change of the ring flatness.
Single Mechanical Seals have proven their ability to seal multiphase mixtures using current seal designs and diamond coated sliding face materials.

Correct installation and operation are the key-factors for a long MTBF-value.