Sealing solutions from SKF for wind turbines
SKF sealing solutions offers for all applications in wind turbines

- Rotor brake (hydraulic)
- Gearbox
- Pitch and yaw slewing bearings
- Main shaft
- Pitch and yaw drives
SKF sealing solutions for wind turbine main shafts

Presented to NextEra
Main shaft sealing solutions from SKF

Key requirements:
- 20-25 years of service life
- Ease of replacement
- Resistant to ozone, UV radiation and sea water

SKF sealing solutions:
- Includer seals: radial shaft seals to prevent lubricant leakage
  - Standard solution: HSS all-rubber reinforced seals
  - High performance solution: HRS polyurethane seals
- Axial excluder seals to protect the main bearing from contamination
  - Standard solutions: V-rings and CT seals
  - High performance solutions: special GR06 and HRCs seals

Radial shaft seals: HSS, HRS
Axial excluder seals: V-ring, CT1, Special GR06, HRC1
Sealing solutions for main shafts: radial shaft seals + axial excluder seals

SKF recommended sealing arrangement:

- Radial shaft seals
  - Manufactured slightly oversized relative to the housing bore diameter and depth
  - A cover plate is used to compress the seal axially for proper fit in the housing bore
- Axial excluder seals
  - Designed to protect radial shaft seals and bearings from contamination

Axial excluder seal
Radial shaft seal
Why radial shaft seals?

Trend change: from labyrinth seals to radial shaft seals

Advantages of radial shaft seals:
• Reduce wind turbine weight
• Increase wind turbine reliability
• Reduce wind turbine maintenance
• Reduce downtime and lost productivity
• Extend bearing service life
• Better lubricant retention
• Better contamination protection

Disadvantage:
• Need to be replaced
Radial shaft seals
# SKF radial shaft seals designs for main shafts

<table>
<thead>
<tr>
<th>Designs</th>
<th>Description</th>
<th>Available materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS</td>
<td>All-rubber seal</td>
<td>• NBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• SKF Duratemp (HNBR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• SKF Duralife (FKM)</td>
</tr>
<tr>
<td>HSF</td>
<td>Fabric-reinforced seal</td>
<td>• NBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HNBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• FKM</td>
</tr>
<tr>
<td>HSS</td>
<td>All-rubber reinforced seal</td>
<td>• NBR</td>
</tr>
<tr>
<td></td>
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<td>• SKF Duratemp (HNBR)</td>
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<tr>
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<td></td>
<td>• SKF Duralife (FKM)</td>
</tr>
<tr>
<td>HRS</td>
<td>High-performance polyurethane seal</td>
<td>• G-ECOPUR</td>
</tr>
</tbody>
</table>

**Preferred designs**
HSF – Fabric-reinforced seals: competitors offer

- The heavy industrial standard seal in Europe and Asia
- Rolled phenol impregnated cotton fabric reinforces the outside diameter
- Multiple leakage paths at the outside diameter due to rough fabric structure
- Prone to volume change/shrinkage when exposed to moisture/water
- The fabric-reinforced outside diameter cannot fill housing bore imperfections, adding the risk of leakage at the static sealing section in the housing
HSS seals – main features

- Seal body in harder grade of SKF Duratemp (HNBR)
- The smooth OD facilitates the seal installation
- SKF Springcover (optional)
- Well-proven, spring-loaded sealing lip in a more flexible grade of SKF Duratemp (HNBR)
- Stainless steel spring
- SKF Springlock
HSS seals – available designs

• Solid designs: recommended when there is access to the end of the shaft (e.g. installation in a workshop)

• Split designs: recommended when there is no access to the end of the shaft (e.g. up-tower installation)
  • Available spring connections:
    - Up to 455 mm: threaded connection (1)
    - Above 455 mm: hook and eye connection (2)

Links to installation video:
https://www.youtube.com/watch?v=v-Cp0xKPb2s

No gluing or additional operation required
HRS seals – Main features

- The grooves help to improve static sealing performance.
- The smooth outer diameter facilitates service and handling operations for easy installation and dismounting.
- A flexible sealing lip helps to cope with large misalignments.
- Stainless steel spring.
- The lip design avoids contact with the seal carrier and can minimize the risk of installation failures.
HRS seals – available designs

• Solid designs: recommended when there is access to the end of the shaft (e.g. installation in a workshop)

• Split designs: recommended when there is no access to the end of the shaft (e.g. up-tower installation)
  • Spring connection: threaded

Links to installation video: https://www.youtube.com/watch?v=v-Cp0xKPb2s
SKF polyurethane seals are made of H-ECOPUR or G-ECOPUR materials that provide:

- Excellent mechanical performance compared to standard elastomeric materials, especially wear resistance and increased stiffness.
  - Wear resistance helps to promote longer service life
  - Stiffness helps to minimize the risk of installation failures (sealing lip bending or spring loss)

- Good chemical properties such as ozone and UV radiation resistance

- Hydrolysis resistance
Excluder seals
**SKF axial excluder seals for main shafts**

<table>
<thead>
<tr>
<th>Designs</th>
<th>Description</th>
<th>Available materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-ring VA</td>
<td>All-rubber seal</td>
<td>• NBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HNBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• FKM</td>
</tr>
<tr>
<td>Special GR06</td>
<td>Special polyurethane seal</td>
<td>• G-ECOPUR</td>
</tr>
<tr>
<td>CT1</td>
<td>All-rubber extruded seal</td>
<td>• NBR</td>
</tr>
<tr>
<td>HRC1</td>
<td>High-performance extruded polyurethane seal</td>
<td>• H-ECOPUR</td>
</tr>
</tbody>
</table>
V-rings from SKF

- Simple, cost-effective axial excluder seals to keep contamination out
- All-rubber and very elastic for easy installation
- New V-rings from SKF are made from SKF developed rubber compounds
- HNBR recommended for wind turbine applications
- Available in different designs and sizes to fit in virtually every application.
Special axial excluder seal GR06

Customized machined seal made of SKF developed high-performance ECOPUR materials to keep contamination out of the bearing housing.

- Engineered customizable cross section to virtually fit in all applications
- High abrasion and hydrolysis resistant material
- Excellent ageing resistance to ozone and UV radiation
- Excellent oil compatibility
- Available in solid and split designs
- Features a stainless steel clamping band
Sealing Solutions for V82 Main Shaft
Vestas V82 (NM design)

Workshop installation

OEM: Standard NBR fabric reinforced radial shaft seals (2, 3 or 4 pcs) + V-rings (2 pcs)

- Standard solution:
  - 700 VA R (407000 USA)
  - 710X760X20 HSS5 H

- Up-grade: polyurethane seals
  - 8029809
  - 710X760X20 HRS11 GP

Up-tower replacement:

Split solutions

- Standard solution:
  - 8029809
  - 710X760X20 HSS8 H

- Up-grade: PU seals
  - 8029809
  - 710X760X20 HRS12 GP
Sealing Solutions for other E.ON wind turbine models
# Sealing solutions comparison

<table>
<thead>
<tr>
<th></th>
<th>Labyrinth seals</th>
<th>HSS H</th>
<th>HRS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material</strong></td>
<td>Steel</td>
<td>SKF Duratemp (SKF special HNBR)</td>
<td>G-ECOPUR®</td>
</tr>
<tr>
<td><strong>Designs</strong></td>
<td>Customized</td>
<td>Solid and split</td>
<td>Solid and split</td>
</tr>
<tr>
<td><strong>Permissible misalignments (mm)</strong></td>
<td>Depends on the gap size between static and dynamic part</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Contamination exclusion ability</strong></td>
<td>-</td>
<td>O</td>
<td>O (+ HRSA design)</td>
</tr>
<tr>
<td><strong>Contamination exclusion with V-rings</strong></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Lubricant</strong></td>
<td>Grease</td>
<td>Grease (Oil)</td>
<td>Grease NLGI ≥ 1</td>
</tr>
<tr>
<td><strong>Ease of installation</strong></td>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Up-tower replacement</strong></td>
<td>N/A</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Recommended installation</strong></td>
<td><img src="Image" alt="Image" /></td>
<td><img src="Image" alt="Image" /></td>
<td><img src="Image" alt="Image" /></td>
</tr>
<tr>
<td><strong>Seal dimensions customization</strong></td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Service life</strong></td>
<td>O with V-ring</td>
<td>O</td>
<td>+</td>
</tr>
</tbody>
</table>
GE 1.5 & 1.6 MW housing rework proposal

From labyrinth

To radial shaft seals

HSS
HRS
GE 1.5 MW: labyrinth + excluder seal upgrades

Workshop installation

• OEM: Standard NBR V-ring – 1 piece
  • Part number: 725 VA R (407250 USA)

• Up-grade: polyurethane seal
  • Drawing number: 8028780

Up-tower replacement: 1 piece

• Polyurethane split solution
  • Drawing number: 8028780
GE 1.6: labyrinth + excluder seal upgrades

Workshop installation

- OEM: Standard NBR V-rings – 1 of each
  - Part numbers: 750 VA R (407500 USA)
  - 800 VA R (408000 USA)

- Up-grade: polyurethane seals
  - Drawing numbers: 8029846 8029632

Up-tower replacement: 1 of each

- Polyurethane split solution
  - Drawing numbers: 8029846 8029632
Siemens 2.3 MW
SKF alternative: customized sealing solutions

Workshop installation

OEM: several sealing arrangements from felt seals to standard NBR fabric reinforced radial shaft seals (2 to 4 pieces)

- Up-grade: polyurethane seals
  - 850X910X30 HRS11 GP
- To replace felt seals with an up-graded solution contact SKF Industrial seals for a customized design

Up-tower replacement:

Split solutions

- Up-grade: PU seals
  - 850X910X30 HRS12 GP
- To replace felt seals with an up-graded solution contact SKF Industrial seals for a customized design
V80 & V90 – 2MW: radial shaft seals
V100 validation in process

Workshop installation
- OEM installation: fabric reinforced seals
- SKF cost effective solution:
  - 500X540X20 HSS5 H
  - 660X700X20 HSS5 H
- SKF high performance solution:
  - 500X540X20 HRS11 HP
  - 660X700X20 HRS11 GP

Up-tower replacement: split seals
- SKF cost effective solution:
  - 500X540X20 HSS8 H
  - 660X700X20 HSS8 H
- SKF high performance solution:
  - 500X540X20 HRS12 HP
  - 660X700X20 HRS12 GP

Approved by Vestas Services