VEM

ELECTRIC DRIVES

FOR EVERY DEMAND

Next generation slip ring motors

Technical information

Technical information from VEM Sachsenwerk GmbH

VEM is manufacturer of different kind of Slip Ring Induction Motors for Cement Industry. Many of our motors are cooperation products with partner labeling, others direct VEM branded. Based on our continuous maintenance as well as customer's feedback or feedback cooperation partners, VEM is continuously working on technical improvement of our products.

Main development targets over the past years:

VEM can point to several technical improvements where verified benefits have been achieved. With regard to cement industry motors in shaft heights 800, 900 and 1 000, these concern for example:

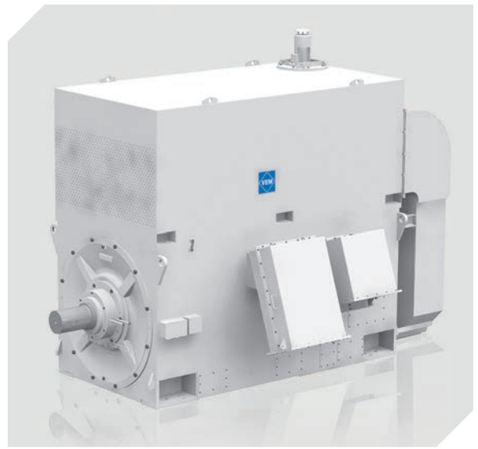
1. Slip rings:
Increased mechanical stability of slip rings
(production standard since 2016 and retrofittable)

2. Bearing lubrication:
Improved lubrication, new old grease path,
bearing temperature reduction (2017, retrofittable)

3. Rotor shafts:
Stiffened rotor shafts to reduce magnetic forces due to gravitational bending and increase rotor bending natural frequency (standard since 2011)

4. Bearing shields:
Increased stiffness of bearing shields, reduced vibration (retrofittable)

5. Winding heads:
Improved containment of winding heads for better protection of the connectors between slip ring and winding heads (production standard since 2014 and partially retrofittable)



The figure shows a slip ring motor of the new generation.

6. Bearing insulation:
Change from internal to external bearing insulation at NDE for better thermal behaviour (retrofittable)

7. Bearing head:
New bearing head generation at DE to relieve the axial thrust bearing

All these improvements are incorporated into our new generation of slip ring induction motors, which thus implement the acknowledged state of the art. Thanks to our modular concept, we were able to implement most of these innovations also for older motor generations. The replacement of individual components allows our longstanding customers to participate in the benefits of the latest technical advances.

What is our target?

Based on feedback indicating that customers have faced difficulties with slip rings, bearings, vibration and sometimes connector failures, the VEM management decided to proactively share information on technical improvements, update possibilities and the latest developments. To avoid any loss of information when communicating via intermediate partners, VEM is interested in direct contact with its customers and end users.
Most of the updates and/or improvements can be realised through cost-saving on-site retrofit solutions – avoiding costly workshop time.

All presented solutions are the consequence of intensive and proofed technical investigations by VEM experts, using numerical calculation methods, such as finite element simulations as well as practical tests. All presented topics are successfully implemented in our new products already.

We herewith invite you to learn more about a selection of ongoing developments and retrofit possibilities for your existing VEM products!

Technical information Part 1: Slip rings

Reported issues:

Slip ring and brush problems are manifested in different ways. Typical indicators are:
- Cracked brushes and cables
- Brush vibration, sparks during operation
- High wear rate
- Poor run-out of slip ring surface
- Slip ring and brush surfaces with craters

If any one of the problems arises, all other indicators will similarly accelerate, leading to improper motor operation with costly consequences.

Possible root causes

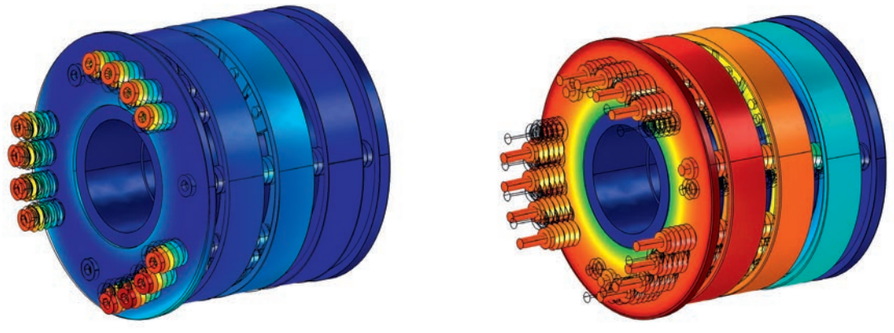
There is no single root cause for slip ring or brush problems. Typically, there is a combination of several unfavourable influences, such as:
- Correct number of brushes for the application → electrical
- Correct type of brushes → electrical
- Replacement sequence of brushes → electrical
- Correct starter procedure → electrical, mechanical
- Correct salt concentration of liquid starter → electrical, mechanical
- Number of motor starts → electrical, mechanical

Mechanical loads

The mechanical stability of the slip ring is related to the ratio of internal forces to external forces. As long as the internal forces are higher than the external forces, the slip ring is mechanically stable.
- **External forces:** The slip ring is designed to withstand typical external mechanical loads such as centrifugal forces or the starting torque for a normal start procedure.

Radial deformation at 1 200 rpm

Torsion with 84 rad/s²



FE-Simulation of loads on slip ring: centrifugal forces (left) and torque (right)

Technical information Part 1: Slip rings

- **Internal forces:** The mechanical structure of the slip ring consists of more than 200 individual parts which are held together by bolts and nuts. The mechanical stability of the slip ring is related to the continuous presence of internal bolt forces which clamp all parts together.

Increased external forces, e.g. from a faulty starter procedure, can cause internal movement between slip ring parts, leading to increasing looseness of the assembly. Once the mechanical looseness is initiated, the mechanical slip ring assembly will be subject to an accelerated destruction process.

Improved mechanical stability

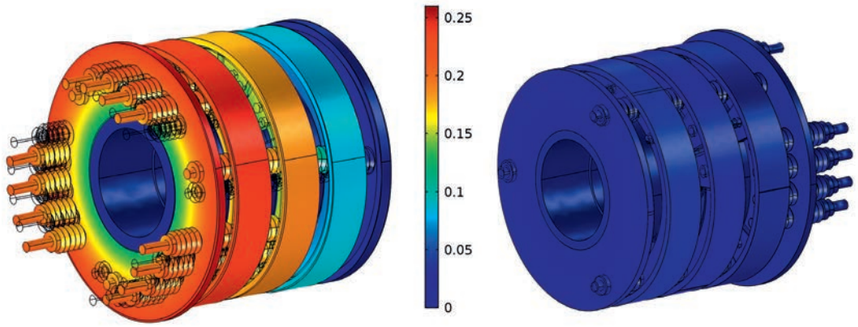
VEM's goal is to increase the robustness to withstand any external force impact. Intensive investigations (experimental and finite element simulations) were performed to understand and improve the situation. Over the past years, the following measures have been introduced in the design and manufacturing of slip rings:

- Old: Only "mechanical stability bolts" clamp the slip rings parts together
- New: Increased bolt forces for the "mechanical stability bolts" enhance the internal forces
- Old: "Electrical current bolts" made from copper were used for electrical purposes only
- New: "Electrical current bolts" now contribute significantly to mechanical clamping forces
- New: Special "temperature procedure" during slip ring manufacturing simulates the thermal aging of isolating discs – extended mechanical lifetime
- Change of force transmission path from the slip ring hub to the slip rings and bolts (switching of floating and fixed disc on hub). Forces from torque shocks (e.g. faulty start procedure) are now transferred directly to accelerate the heavy current bolts. Less internal movement!

All slip rings manufactured in 2016 or later feature this increased mechanical stability.

Torsion of 84 rad/s² on old slip ring design

Torsion of 84 rad/s² on new slip ring design



Reduced tangential movement on torque load (old on left, new on right) due to switching of the fixed and floating disc (finite element simulation)

Upgrade for existing motors

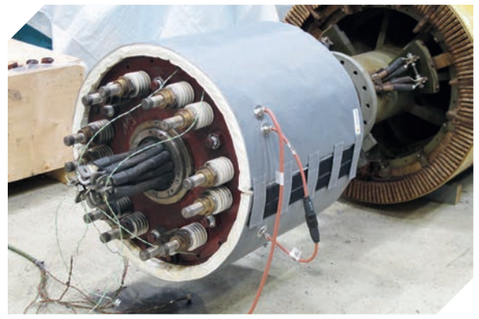
There are several options to improve slip rings of the old design:

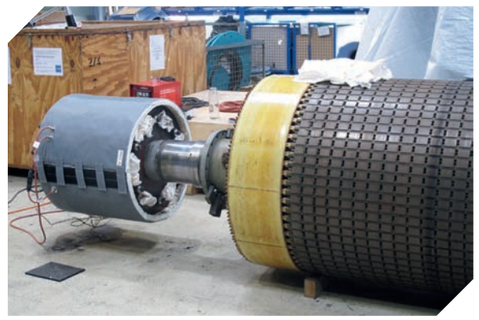
1. Replace old slip rings with new slip rings which can be ordered via VEM Customer Service.
2. Refurbish old slip rings on site

Old slip rings can be refurbished on site if the rotor is outside the stator. Refurbishing instructions lead the engineer through all individual steps. They are available at VEM and cover the following steps:

- Disassembly of connectors
- Application of a heating blanket to perform the temperature procedure
- Tightening of stability and electric current bolts in hot condition
- Cool-down of slip ring
- Adding pins for additional torque transmission between hub and floating disc
- Re-assembly of connectors
- Machining of slip ring surface

If an oven is available, the rotor can be heated as a whole for the temperature procedure. A detailed description of this process is available in a separate manual from VEM.



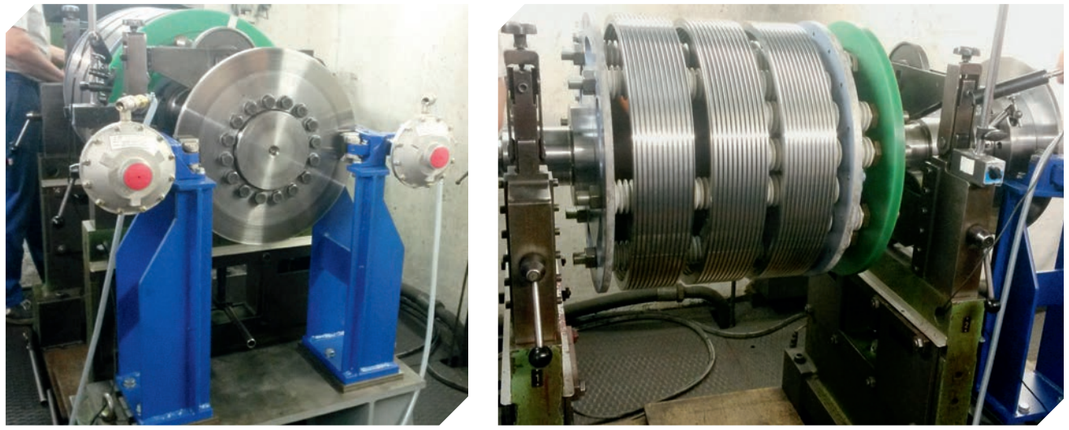


Mobile heating blanket for temperature procedure during slip ring refurbishment

Technical information Part 1: Slip rings

Proof of measures

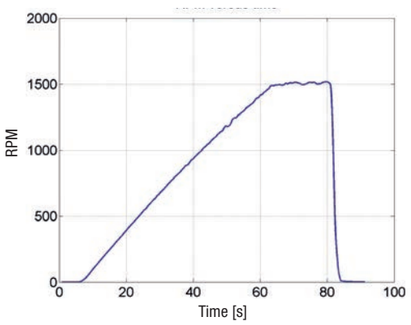
To prove the success of increased mechanical stability, hardware tests were performed wherein old and new slip rings were exposed to severe mechanical loads. VEM used a disc brake in a test facility for extreme torsional loading. Slip rings were decelerated from 1 800 rpm to 0 rpm within 1 second!



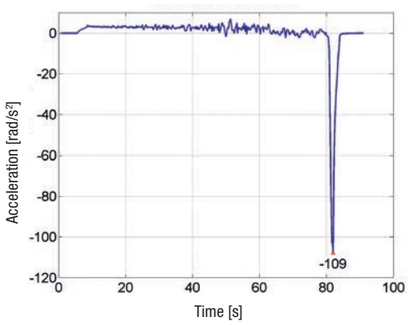
Disc brake in test facility for extreme torsional loading of slip rings

The run-out of the slip ring surfaces was recorded as a quality criterion for mechanical stability.

RPM versus time



Acceleration versus time



Rotational speed (left) and acceleration over time (right) during slip ring tests

All slip rings delivered from 2016 incorporate the aforementioned modifications. So far, no customer complaints are known. All possible tests, as well as initial customer feedback, have been able to prove the improved mechanical behaviour of the new slip rings.

Important remark

The mechanical stability will increase the robustness of the slip ring against external mechanical influences. Even so, it remains imperative to ensure a correct starter procedure and the correct brush setup in order to minimise the external mechanical impact.

End users who face the described slip ring problems are invited to upgrade the slip ring and thus to improve the overall mechanical situation. Please contact the VEM Customer Service for more information. VEM Customer Service will make an individual check to determine the update possibilities for your specific motors.

Technical information Part 2: Bearing lubrication

Reported Issues:

Customer feedback has mentioned the following issues relating to grease and bearing lubrication:

- Generally high bearing temperatures
- Bearing temperature very sensitive during re-greasing
- Unexpected bearing temperature changes during normal operation
- Empty old-grease containers even after long operation
- Grease leakage inside the main machine and slip ring chamber
- Hardened old-grease inside the bearing

Such scenarios were reported by several end users. The complaints triggered intensive investigations inside VEM to optimize the configuration.

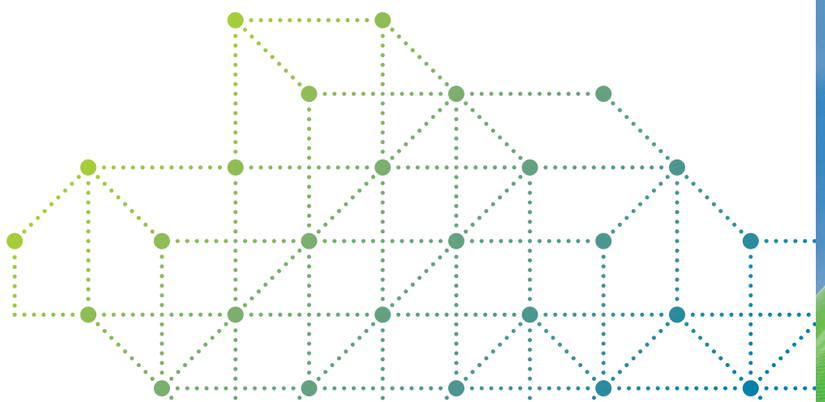
Grease – essential for bearings!

The presence of grease inside the bearing is essential for its functionality. The correct type of grease, its amount and temperature, as well as the service life, must be ensured for safe operation. Viscous grease losses inside the bearings are mainly responsible for thermal heat build-up. When new grease enters the bearing during re-greasing, the old-grease must be transported out of the cap freely to avoid old grease accumulation, overflow or increased grease pressure. Malfunctioning of the old grease removal may lead to drastic temperatures and reduce bearing life time.

Old grease removal concept

Up to 2017 the grease transportation concept inside VEM large drive bearing heads referred to original data from a well-known manufacturer of bearings and bearing heads. Design, grease path, gaps, dimensions and assembly (even complete bearing heads) were directly purchased from one of the world leading bearing manufacturer.

Based on intensive investigations in 2015 and 2016, VEM decided to modify the concept of old grease removal for the large drives from 2017 to improve the overall bearing situation.



Benefits of new concept

VEM engineers worked to optimise the old grease removal to

- reduce bearing temperatures
- ensure constant bearing temperatures in operation
- reduce temperature sensitivity during re-greasing
- allow new grease to fill spaces more easily by actively removing old grease from the bearing
- avoid retention of hardened old grease inside the bearing head
- avoid grease pressure and accumulation inside the bearing head
- extend bearing life time

Details of the modification are explained in the following paragraphs and diagrams.

Technical information
Part 2: Bearing lubrication

New concept for old grease removal

The old grease removal is realized by the harmonized arrangement of baffle plate and rotating grease slinger inside the bearing head. The components have the following tasks:

- The baffle plate controls the amount of grease which remains inside the bearing in operation.
- The rotating grease slinger throws out the used old grease into the old grease container.

Core of the new concept is the radially extended rotating grease slinger disc to actively transport the old grease from bearing head into the old grease container. The baffle plate is separated into two parts to allow radial overlap with the rotating grease slinger. The radial extension of the rotating grease slinger provides radial acceleration of old grease which contacts the slinger disc. Any old grease accumulation or pressure will be avoided by this simple modification.

This concept is applied to drive-end and non-drive-end bearing heads. All new motors implement this concept. Old motors are retrofittable!

Verification of improvement

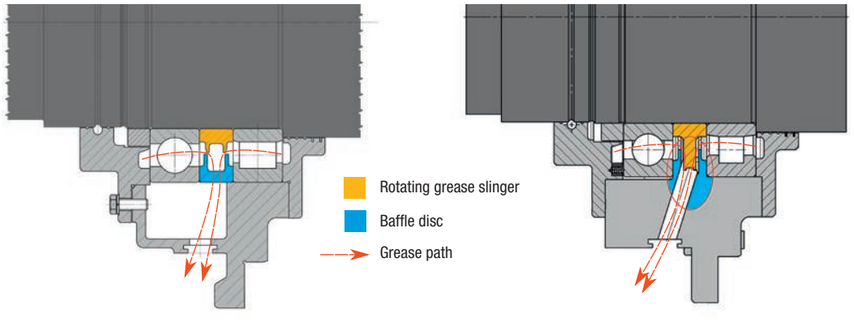
A dummy test rig was built to enable different configurations of old grease transportation settings to be tested and compared. Long-term runs were performed with simulated concentrated re-greasing processes. According to VEM experts, the average bearing temperatures in operation were significantly reduced. The re-greasing procedure became more robust against temporary temperature increase. Recorded quantities to verify the improvement were:

- temperature trends
- mass flows records of grease

All measured quantities confirm a significant improvement which we would like to share with our customers.

Old situation

New situation



Radially extended rotating grease slinger is core of the new bearing lubrication concept

Upgrade for existing motors

The new old grease concept can easily be retrofitted into existing motors with minimum effort. For most machines, new bearing heads could be delivered at the customer's request. In addition to the old grease removal concept, new bearing heads would automatically introduce other positive modification made to VEM large-drive bearing heads since 2011.
With this concept, VEM is confident that it can offer a significant upgrade for your motor reliability in respect to one of the most sensitive topics.

Technical information Part 3: Connector bars

Reported issues:

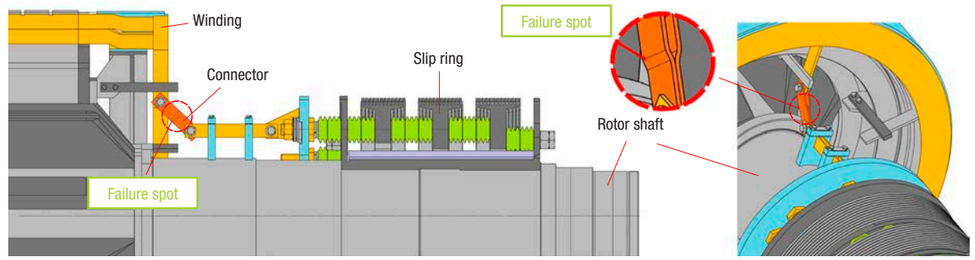
Connector bars provide the electrical connection between slip ring and rotor winding (see Figure below).

- Broken connector bars
- Operation with electrical flashes
- Electric motor failure
- Winding head movement in radial direction caused by centrifugal forces pulling on connector
- Rigid connection of connector bar on rotor shaft
- Large number of motor starts amplifies possible fatigue issue
- Elbowed connector design in 45° part with notches which concentrate mechanical stress at indicated failure point

Possible root causes

There is no single root cause, but rather several circumstances which may arise simultaneously and lead to this type of failure:

Coincidence of the aforementioned factors leads to mechanical fatigue at the indicated failure spot.



Position of elbowed connector bar between slip ring and rotor winding

Implemented improvements

Over the past years, VEM has implemented several improvements in new products in order to drastically reduce the risk of fatigue problems in connector bars. The following adaptations were made:

- Modifications to winding head protection tape (fibre glass layer covering the rotor winding heads). Design and manufacturing were optimised to minimise radial winding head movement under centrifugal forces.
- Stronger winding head support structure to mechanically resist the higher pre-tension forces of the fibre glass tape
- The elbowed 45° connector bar was replaced with a straight bar to avoid notch stress at the indicated failure spot.
- The attachment point of the connector holder was moved to achieve greater flexibility

Upgrade for existing motors

Some of the measures can be retrofitted as improvements to existing motors.

- The elbowed 45° connector bars can be replaced with straight bars to avoid notch stress.
- If the rotor is in a qualified workshop, the winding head tape can be replaced with a new tape as specified by VEM. Specified parameters for the new winding head tape refer to:
  - the tape material,
  - the number of windings,
  - the tension forces on fibre glass tape during re-winding,
  - the definition of intermediate curing processes.

This reduces the winding head movement which otherwise causes the mechanical stress in the connectors.

- It is **not** possible to supply a new winding head support structure for existing motors without removing the rotor winding.
- Relax the clamping rigidity in the rotor-side connector holder to allow more radial movement of connector bars.

Because of the limited options for a winding head support structure replacement, a full upgrade equivalent to the latest production design is not possible. Even so, the aforementioned measures can greatly extend the mechanical lifetime of the connector bars.
Workshops or end users who are planning to upgrade the connector bars are welcome to contact the VEM Customer Service for detailed instructions.

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VEM-HS-NS-2018-03
Printed in Germany. Subject to change.