

Put a ring on it

Daisy-YueQin Bo, ABB Motion, explains why large slip-ring motors offer advantages for heavy load applications in the cement industry.

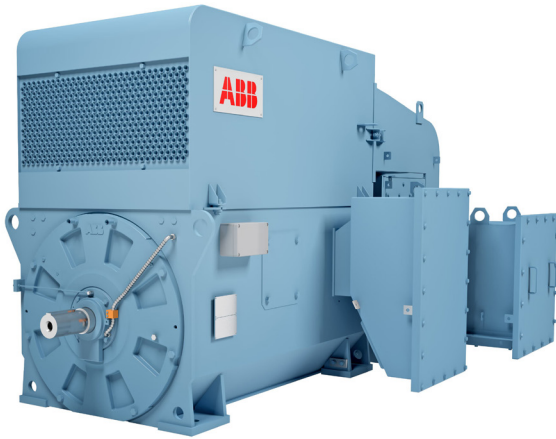
Alternating current (AC) induction motors, otherwise known as asynchronous motors, are the workhorses of the cement industry. These motors are comprised of two main components: a fixed stator with windings that, when energised, function as electromagnets, and the rotor that spins inside the stator. The electric current in the rotor that causes it to rotate is produced by electromagnetic induction from the magnetic field of the stator windings. This design is known as an asynchronous motor because the electrical fields in the rotor and stator are rotating at different speeds – the rotor field lags behind the stator field causing a speed slip.



An AC squirrel-cage induction motor requires no electrical connections to the rotor. This contrasts with a direct current (DC) motor, which requires a current to be fed to the rotor via brushes.

There are two main designs for large induction motors. The key difference is the rotor, which

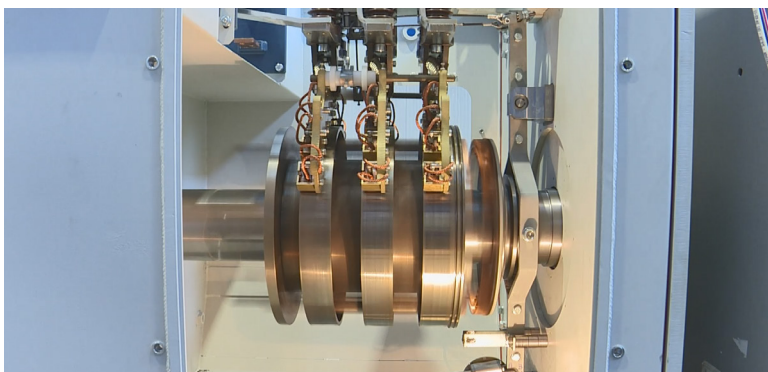
can be either a squirrel-cage or a wound type used with slip-rings. The main advantage of squirrel-cage induction motors is that they are self-starting, reliable and cost-effective. Therefore, squirrel-cage motors are used widely in industrial applications. However, for equipment where a high starting torque is essential to overcome the initial inertia, slip-ring motors can deliver more than double their full-load torque on start-up.



Slip-ring motors can deliver high starting torque while drawing low starting current, and they continue to supply high torque over the entire speed range.



The starting characteristics and torque performance of slip-ring motors make them an optimal match for conveyors, mills, crushers and fans in cement plants.



High starting torque from slip-ring motors also helps minimise mechanical stresses on the driven equipment, increasing the lifetime of the equipment and reducing maintenance needs.

What is a slip-ring?

Slip-rings are devices intended to transmit electrical power, signals or data between rotating parts and fixed parts. They are comprised of one or more rotating rings made of a suitable conducting material such as copper, copper alloy or steel, and a variable number of brushes that are fixed to the non-rotating part of the equipment.

How are slip-rings used in motors?

In a wound-rotor AC induction motor, the slip-rings are not used to carry electrical current. Instead, they are used to connect an external resistance into the rotor windings. In a three-phase motor, three slip-rings are used – one connected to each rotor winding phase. The slip rings are tightly mounted on the shaft by insulated supports so that they rotate at the same speed.

The brushes, commonly made from graphite, are fixed on a support installed on the motor. They slide on the slip-rings as they rotate, maintaining a constant electrical contact. The brushes ensure the connection between the rotor windings and the starter, which is the device that provides the additional resistance and is typically a rheostat.

The purpose of adding resistance to the rotor windings is that this generates a higher starting torque and, at the same time, reduces the inrush current on the network. This also helps to increase the network stability.

Slip-rings are typically used only during start-up. In fact, continuing their use during normal running would result in lower efficiency due to higher mechanical losses. Therefore, as soon as the motor has reached its nominal speed, and the start-up process is completed, the slip-rings are short-circuited, and the brushes are lifted. The motor then operates in the same way as the more common squirrel-cage induction motor.

However, in applications where load sharing is required between multiple motors the slip-rings are left engaged. By regulating the external resistance, the motor speeds are matched precisely, providing equal loading on all motors.

Advantages of slip ring motors

Slip-ring motors are ideal for high inertia applications and are well suited for applications running on weak networks. Their design, the use of high quality materials, and advanced ventilation technology, ensure highly efficient operation, making processes as economical as possible. Reliability in heavy-duty operations is increased by design features such as fully braced and vacuum impregnated windings for both the stator and rotor.

The high starting torque produced by slip-ring motors helps ensure that equipment is started on the first attempt and multiple, stress inducing attempts, are avoided. The low starting current of slip-ring motors also reduces the electrical stress when starting heavy equipment and increases the working lifetime of the electrical system. A further benefit of slip-ring motors is their high-power density. This means that they can deliver the required power in a smaller frame size. Less space is needed to install the motors and it is easier to lift and handle the motor on site, lowering installation costs as well as transportation costs.

A choice of two slip-ring unit designs

Slip-ring motors are available with either permanent contact brushes or brush-lifting gear. In both cases, the slip-rings are enclosed in a dedicated housing, located at the non-driven end (N-end) of the motor, separate from the main motor housing. This arrangement provides easy access and maintenance. It keeps carbon dust from the brushes out of the motor and offers the possibility of having different enclosures and cooling methods for the slip-ring housing.

In ABB slip-ring motors, the slip-ring units with permanent contact brushes are manufactured from highly corrosion-resistant copper-tin-nickel alloy. They feature helical grooves as standard, enabling a uniform brush wear leading to a more even distribution of the current to help prevent local spot heating, thus ensuring cooler operation and contributing to a longer service life.

These slip-ring units with brush-lifting gear are manufactured from stainless steel and have a smooth non-grooved surface. After the motor has reached its full speed, the brush-lifting and slip-ring short-circuiting gear (BLG) first short-circuits the rotor winding and then raises the brushes from the slip-rings.

The choice between permanent contact brushes or using brush-lifting gear will depend

on the specific application and the planned maintenance regime.

Permanent contact brushes have a lower initial cost, but as they remain in continuous contact with the slip-rings throughout the normal operation of the motor, both the brushes and slip-rings will exhibit wear over time. This then requires plant operations to be interrupted for maintenance and replacement.

For the majority of applications there is no need for the brushes to remain in contact with the slip-rings once the motor is up to speed. Therefore, while brush-lifting gear is more expensive on initial purchase, it will reduce the wear on brushes and slip-rings, helping to increase maintenance intervals, reduce service costs, and boost reliability.

Other design considerations

There are a number of key design considerations in slip-ring motors, involving the rotor, the stator, bearings, and cooling.

Rotor

Because large AC motors are installed in extremely demanding environments, all parts, but especially the rotor, are subjected to vibrations that can reduce their useful life. This requires the use of materials that can withstand these conditions, as well as ensuring low vibration levels through a solid structure and the perfect balance of each component. In ABB motors, the rotor shaft is constructed to meet the various needs of specific work cycles and their related operating conditions. The rotor itself is dynamically balanced at the maximum operating speed.

Windings are manufactured following several design criteria that minimise vibrations. For example, a reinforced rigid wrapping minimises the effects of distorting centrifugal forces on the rotor windings.

Stator

ABB stators are designed and built to obtain a compact, stiff and uniform system for long operating life, even in harsh conditions. Special radial ducts are used for appropriate and optimal ventilation. The stator core lamination plates are in accordance with EN10106, which defines the general requirements and the magnetic properties of electrical steel sheet intended for the construction of magnetic circuits.

Once the winding is complete, the whole stator undergoes a special VPI (vacuum pressure impregnation) process, forming a single block that keeps its rigidity over a long service life. Wiring is simplified by the terminal boxes designed to make wire connection easier and reduce installation time.

Bearings

Bearings are an essential element for motor operation. ABB's bearing design helps to ensure long operating life and easy maintenance.

According to the type of motor, operating conditions and customer requirements, bearings are available as antifriction or sleeve designs. The antifriction bearings are typically designed for a 60 000 hour life and their structure minimises noise levels and prevents dust penetration.

Cooling

The internal air circulation is provided by a standard shaft mounted fan or by an optional externally mounted blower. In air-to-air cooled motors, the external cooling air is circulated by a shaft mounted fan or a separate blower. The standard versions are self-ventilated. In weather-protected motors, the cooling air is drawn through the motor by a shaft mounted fan. Protection is provided by a weatherproof cover which also serves as a silencer. While air-to-water and air-to-air cooled motors come with IP55 protection as standard, higher protection degrees are available as standard options.

The stator frame construction is designed to facilitate efficient cooling air flow. Slip-ring units with permanent contact slip-ring brushes are

equipped with a heat exchanger or protective cover matching the motor. A shaft mounted fan circulates the cooling air through the slip-ring unit, filter and upper cover. This cooling system is isolated from that of the motor for easy maintenance and inspection and to prevent the carbon dust from contaminating the stator and rotor windings.

Summary

When it comes to buying a slip-ring motor it is important to ensure that the motor not only meets all applicable IEC or NEMA standards, but it is also designed according to the customer needs for each application. All ABB motors are given a routine test at the factory and an optional heat run test can also be conducted. ■

About the author

Daisy-YueQin Bo is the ABB Motion Product Manager for large motors and generators, responsible for squirrel-cage rotor and slip-ring rotor MV modular induction motors. Daisy has more than 30 years of experience in the design and manufacturing of industrial electric motors, including research and development, order engineering, and product marketing management.