



# A TECHNOLOGICAL — PIONEER —

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THE SCIENCE BEHIND A NEW  
DRIVE SYSTEM FOR VERTICAL  
ROLLER MILLS.

## **Introduction**

By the end of the first decade of the 21<sup>st</sup> Century, two main events had forced gear manufacturers to think about new drive solutions for vertical roller mills. The first was the demand for more power, driven by the increased production rate of single mills. The second was an accumulation of fatal gear failures. Recognising these issues, and seeking to reduce the complexity of

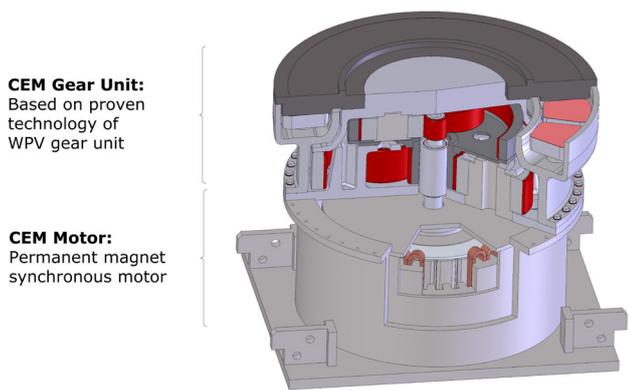


Figure 1. CEM drive concept.

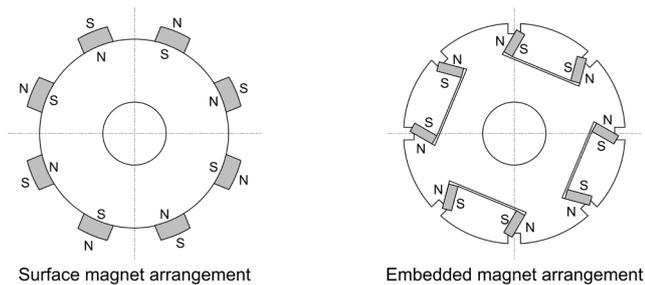


Figure 2. Rotor concept for permanent magnet excited motors.

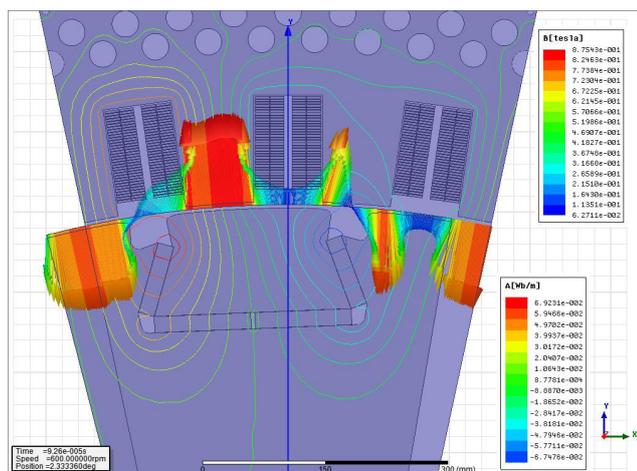


Figure 3. Air gap induction and magnetic flux density.



Figure 4. Distributed vs single coil winding.

the drive system, product development engineers from FLSmidth MAAG Gear began to develop a new solution ten years ago.

An obvious answer was the substitution of the bevel gear by a vertical motor, which not only increases power and reliability, but also reduces the number of rotating parts in the drive train to an absolute minimum.

This is not a new idea: the first patent applications for direct driven vertical mills date back to 1940. So why was it never built on a large scale?

The answer to this question is simple: the vertical orientation of the motor is unusual for such a large model. Vertically-oriented electrical machines of similar design power can be found in hydroelectric power plants, where they are driven by Francis or Pelton turbines, but such generators are far too big to be placed directly under the mill.

When FLSmidth MAAG Gear decided to develop such a new drive system with an integrated vertical motor, one of the main goals was to maintain the dimensions of the conventional gearboxes, so that the new drive is interchangeable with existing drive units. This also means that mill suppliers do not need to change their mill stand design when using this drive system for new mill installations.

The first design studies soon showed that a mechatronic system – the combination of an electrical motor with a gearbox – would be the most compact arrangement. In addition, the concept of the planetary gear stage, as used in conventional gearboxes, could be implemented one by one in the new drive unit.

Today, the innovative vertical electrical motor is the centrepiece of the CEM drive. Three main features, designed specifically for this application, make it possible to meet the demanding space requirements.

### Permanent magnet rotor

The permanent magnet-excited rotor is used for this motor to eliminate an external excitation device. Such devices take up a lot of space, create additional losses, and require high maintenance efforts.

There are two rotor concepts for permanent magnet-excited rotors: surface magnets and embedded magnets.

Rotors with surface magnets are characterised by a simple design. The magnets are glued directly to the lateral surface of the laminated rotor, and also fixed with fibre-reinforced tape to protect the magnets from high centrifugal forces. However, the magnetic flux density in the air gap between rotor and stator is limited to below the residual magnetism of the surface magnets, which restricts the power density of the motor.

Embedded magnets require a more detailed rotor design. Nevertheless, moving the magnets away from the air gap into the rotor brings two main advantages. On the one hand, this design achieves a very high concentration of the magnetic field; on the other hand, the magnets are protected against demagnetisation by magnetic saturation of the laminated pole shoes.

It was decided to use the embedded design. Furthermore, and contrary to existing machines,

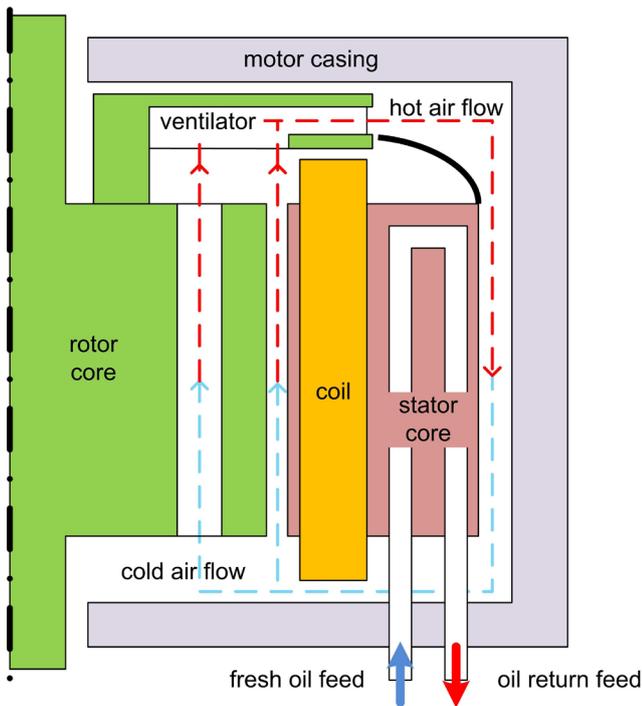


Figure 5. Direct stator cooling.



Figure 6. Easy installation of the CEM drive.

the rotor for the CEM drive would not have a magnetic short-circuit, which creates additional losses through leakage flux. The first version of this type of rotor was put to the test in 2012 and, after some modifications to the fixation system, it was implemented in the first pilot unit.

### Single coil stator

Conventional electrical motors use distributed windings, where the coils are spread over several stator poles. This requires large winding heads and a mostly manual process for the separation, fixation, and insulation of the different motor phases' winding heads.

In the single coil stator, one stator pole is always wound with one coil, meaning the copper wire is only connecting stator slots next to each other. The winding heads are very small, and the use of copper can be reduced by at least a third compared to the distributed winding. The reduction of copper goes hand in hand with a decrease of ohmic losses and provides a very high overall efficiency of 98.5% for this type of motor.

The first feasibility studies indicated that the necessary power density could only be achieved using the single coil design. However, the use of a single coil stator, in combination with permanent magnet rotors, provokes a very characteristic torque ripple, which affects the operating behaviour of the motor. The counter measurements introduced in the pilot machine are as simple as they are effective. By dividing the rotor into two halves and twisting the upper part by one-half of an electrical cycle, the torque ripple of the two rotor halves compensate for each other.

### Direct stator cooling

Finally, an integrated motor needs a capsuled cooling system to reduce the risk of dust and dirt getting inside the motor and gears. Classic water jacket cooling requires a relatively large shell surface to work efficiently. This is contrary to the requirement of high power density.

Direct stator cooling is the solution. A well-defined number of cooling tubes per stator pole are inserted directly into the back of the laminated stator. Gear lubrication oil is used as cooling media and reduces the number of auxiliary systems. In the same way, it simplifies the setup of the entire installation.

Heat losses of the stator are directly dissipated into the cooling media, while the rotor itself is cooled by an internal airflow, thanks to the installation of a rotor-mounted fan. The hot air from the rotor is guided to the back of the stator, where it is cooled again. The rotor cooling in this enclosed arrangement is especially important, because high temperatures can affect the lifetime of the magnets.

## Testing the motor

The first motor was successfully tested in 2012, while a gear part for the first pilot installation was being built. The pilot unit was installed in an existing raw mill in South America, in place of the conventional gearbox. The assembly and the factory acceptance test of the drive unit were performed at the beginning of 2013, and the customer was impressed by the smooth running of the equipment.

At the same time, the erection in the cement plant began with the setup of the new power supply and the preparation for a no-load test in front of the raw mill. All these tasks were carried out while the raw mill was still in operation with the conventional drive unit, so as not to interrupt cement production. The temporary setup and no-load testing was also used to train the operators to run the new drive system, and to check all interfaces between the local drive control and the overall plant control system.

Finally, at the beginning of 2014, the exchange of the conventional drive unit with the CEM drive system was performed; production was interrupted for only three days. Immediately after installation and final system checks, the mill was put back into operation and was at full production after a short commissioning phase. Nevertheless, a winding short-circuit forced the cement plant to change back to the conventional drive unit three months later. Valuable experience was gained during this first operating period. This enabled FLSmidth MAAG Gear to further improve the drive unit, while repairing the winding short-circuit and providing a new and improved drive unit back to the client. This pilot drive unit has been in operation since the end of 2016 and is operating smoothly. In particular, the vibration level during start-up has been dramatically reduced, enhancing the lifetime of the entire grinding system.

## Simple integration into the mill system

The latest development from FLSmidth is the OK™ raw mill. It is based on the proven OK cement mill technology and shares many common parts for cement and raw grinding. The new raw mill offers the inherent stability of the cement mill, as well as its proven ability to grind wet components. It also enables cement producers to benefit from parts commonality, reduced inventory requirements, and consistent maintenance procedures.

The CEM drive fits perfectly into this concept of interchangeability. With the integrated motor design, the size of the drive unit depends only on the mill table size. The graduated range of products consists of nine different motor sizes and 10 gearbox sizes. It allows both the individual combination of motor power and gear size when supplying the drive system for one mill, and interchangeable drive systems for mills of the same size, no matter if these are raw, cement, or slag mills. Adjustments of the gear ratio are not required; the grinding process solely defines table speed and, thanks to the flexibility of the variable frequency converter, the required speed will be matched exactly.

## Summary

CEM drive, the integrated drive system from FLSmidth MAAG Gear, manages to balance the newest technology and proven design, as well as standardisation, without losing the flexibility to adapt to the individual grinding process. Whether it is used in combination with the OK mill, or if it replaces a conventional gearbox under any kind of vertical roller mill, it operates at the optimum point according to the process requirements.

The first CEM drive unit has been in operation for more than six months and is testimony to the success of this new development. 