Motor Bearings, not just a piece of metal

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Abstract

Ordering new Motors, making maintenance of bearings and even adapt existing motors with frequency converters needs certain precaution. As motor bearings are of a high importance in the availability of drive systems the selection and handling of the bearing should be taken seriously.
Not all bearings are suitable for each type of application. A universal, fitting to all purpose bearing does not exist. In this paper we describe the different types of bearing used in the cement industry and we give also an indication for which application and power what conditions have to be considered.

Furthermore, it gives a variety of tips and hints to avoid problems with the bearings, caused by lubrication, greasing, motor cabling, installation and alignment.
A large portion of the paper is also devoted to the supervision of the bearings in terms of temperature and vibration, both of which are vital parameters for long-term, trouble free operation.
Making good maintenance needs the know-how of expected life time of the bearings in order to program maintenance activities.
A large portion is also spent for the sometimes ignored problematic of bearing currents in adjustable speed drive systems its consequences and the prevention of it.

Taking all the tips and hints given in the paper into consideration, sleepless nights because of bearing problems can be avoided, and, more importantly, the availability of the plant will be kept high.

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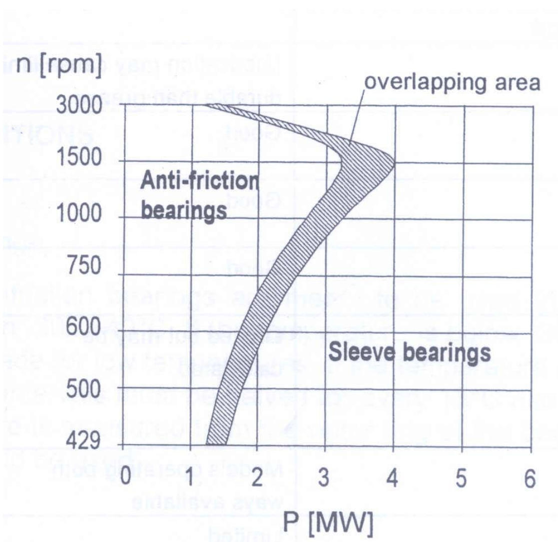
1. Introduction

In spite of different applications related to speed and mounting method, a series of different bearings will cover the requirements. The choice of bearing arrangement is based on the following factors:

- load carrying capacity in the axial and radial direction
- overspeed and duration
- rotating speed
- bearing life

The size of the bearing to be used is initially selected on the basis of its load carrying capacity, in relation to the load to be carried, and the requirements regarding life and reliability.
Also, other qualities have to be taken into consideration like

- operating temperature
- dirty and dusty environmental conditions
- vibration and shocks effecting bearings in running and resting conditions



Picture 1.A shows a graph of the families of bearing selection
Basically, for the motors operating in the cement industry, it can be said that two main family types of bearings are used, the antifriction and the sleeve bearings.
The antifriction bearings cover the area of lower power ratings. The sleeve bearings are to be used for higher power ratings.

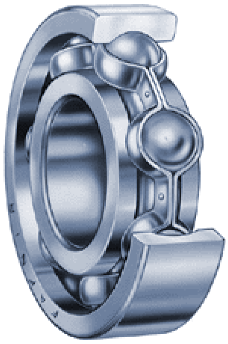
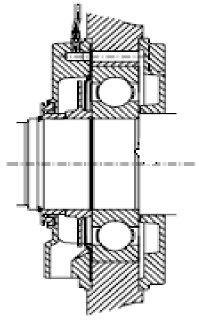
2. Types of Bearings

Many types of bearings are on the market, each of them has different characteristics and is used for different purposes.

2.1 Deep Groove Ball Bearings

These ball bearings are the most common type of bearing. These bearings can handle both radial and thrust loads. Due to their low frictional torque, they are suitable for high speeds.

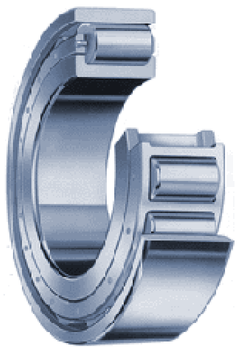
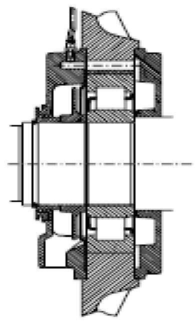
In a ball bearing, the load is transmitted from the outer race to the Ball and from the ball to the inner race. Since the ball is a sphere, it only contacts the inner and outer race at a very small point, which helps it spin very smoothly. But, it also means that there is not very much contact area holding that load, so if the bearing is overloaded, the balls can deform or squish, ruining the bearing.

Picture 2.1.A shows a Deep Groove Ball Bearing

2.2 Cylindrical Roller Bearings

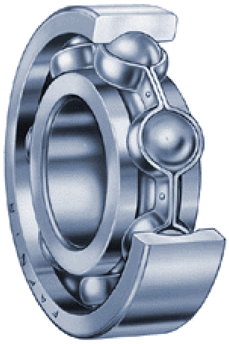
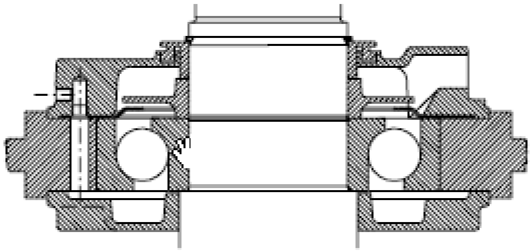
These roller bearings are used in applications where they must hold heavy radial loads.
In the roller bearing, the roller is a cylinder, so the contact between the inner and outer race is not a point but a line. This spreads the load out over a larger area, allowing the bearing to handle much greater radial loads than a ball bearing. However, this type of bearing is not designed to handle much thrust loading.

Picture 2.2.A shows a Cylindrical Roller Bearing

2.3 Angular Contact Ball Bearings

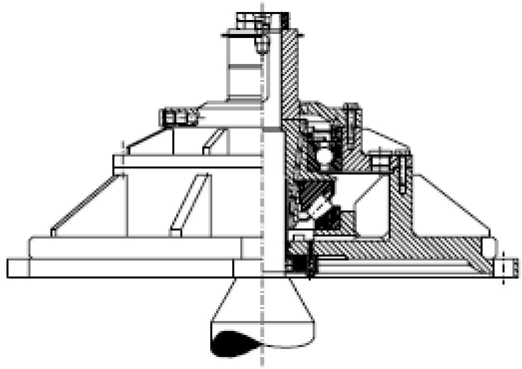
Angular Contact ball bearings have raceways in the inner and outer rings which are displaced with respect to each other in the direction of the bearing axis. This means that they are suitable for the accommodation of combined loads such as simultaneously acting radial and axial loads in vertical machines.

Picture 2.3.A shows an Angular Contact Ball Bearing

2.4 Spherical Roller Thrust Bearing

In Spherical Roller trust bearings, the load is transmitted from one raceway to the other at an angle to the bearing axis. They are suitable for the accommodation of high axial loads in addition to simultaneously acting small radial loads. Spherical roller trust bearings are also self aligning.



Picture 2.4.A shows a Spherical Roller Trust Bearing

2.5 Sleeve Bearings

The bearing life of a Sleeve Bearing is practically infinite, provided that the operation follows the operating condition specified for this type of the bearing.

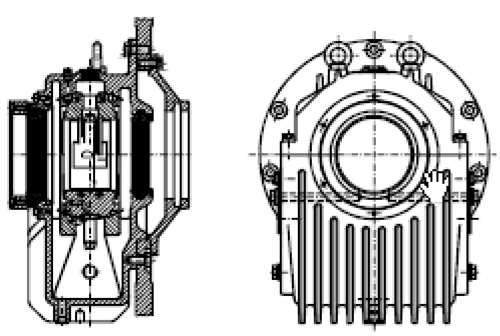
Motors have sleeve bearings at both ends. The bearing on the D end is the guide bearing and means that it can tolerate a limited non axial force. The bearing on the N drive end is isolated.

The bearings are rigidly mounted to the end shield of the machine. The bearing housing is made of cast iron. Tapped holes for thermometer, oil inlet and outlet and oil level are provided on both sides of the housing. The bearings are lubricated by hydrodynamic lubrication, which can be selfubricating or oil circulation type.

The bearing shells are spherically seated in the housing. The oil flow of selflubricated bearings is guaranteed by the central arrangement of the oil ring. The precise shell seating also provides good heat transfer between the bearing shell and the housing. The shell consists of s steel body lined with white metal.

Bearings with a circulating oil system are also equipped with an oil ring, to allow for safe running during a coast stop of the motor, in case of a power failure.

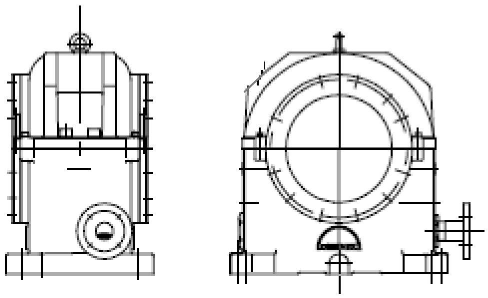
2.5.1 Flange Mounted Sleeve Bearings



Picture 2.5.1.A shows a Flange Mounted Sleeve Bearing

The Flange Mounted Sleeve Bearings are used for machines with a shaft height of up to 1120 mm. Machines with Flange Mounted Sleeve Bearings are easy and fast to align. The air gap between stator and rotor comes already adjusted from the factory, and does not need any further adjustment on site during installation.

2.5.2 Foot Mounted Sleeve Bearings



Picture 2.5.2.A shows a Foot Mounted Sleeve Bearing

Foot Mounted Sleeve Bearings are mounted on a pedestal. The pedestal can be either integrated in the stator frame, or it can be mounted separately. If it is integrated to the stator frame it is easy and fast to align

2.6 Axial Floating and Forces

Sleeve bearings are designed to tolerate only limited continuous axial loads. The axial load is absorbed by the plain, white metallined thrust faces. Precautions must be taken to prevent excessive axial loads. Standard motors are designed for a rotor axial float of +/-8mm from the mechanical centre. The mechanical centre is in the middle of the rotor end float limits.
The magnetic centre does not need to be in the same position as the mechanical centre, but is located in between the end float areas. The magnetic centre is permanently marked on the shaft with a groove. When the motor is running, the rotor will take the position of the magnetic centre.
The sleeve bearing is not designed to withstand any axial forces from the driven machine. All axial forces must be carried by the driven machine. The coupling must be of limited axial float type, and the limit must be smaller than the rotor axial float.

2.7 Radial Forces

Only the radial forces from the coupling are allowed. If there are additional radial forces expected, they will have an influence on the bearing design.

2.8 Balancing

All motors leaving the factory are dynamically balanced.
After manufacturing, the rotor is not balanced because of manufacturing tolerances. Dynamic imbalance is caused by unevenly distributed masses around the rotor. As the centrifugal forces are increasing, with the square root of the speed, any imbalance will lead to strong no symmetrical radial forces. These forces are causing swinging movements to the shaft of the rotor and can lead to harmful vibration to the rotor itself and the bearings. To avoid this effect, the rotor will be dynamically balanced.
Balancing can be made with half key, full key and with the coupling half.
The rotor balancing method is marked on the shaft end.

2.9 Vibration

The vibratory stresses in the motors, connected machine parts and foundation must be reliably kept within the specified limits. Any violation of these limits will have a negative influence on the lifetime of the bearings, beside other negative effects.
Care has to also be taken when the rotor shaft is passing trough a region of resonance.
The allowable vibration is defined in IEC 34 -14.

For motors above 300 kW the following values are valid

Motor running without being coupled

<500 <n < 1800 <	< 1.8 mm/sec
<1800 <n < 3600 <	< 2.8 mm/sec

Support class	Validation	RMS Velocity Mm/sec
Rigid	A / B B / C C / D	2.3 4.5 7.1
Flexible	A / B B / C C / D	3.5 7.1 11.0

Validation A
Newly commissioned motors should be in this range

Validation B
Acceptable for long term operation

Validation C
Motors operating in this area are normal considered as unsatisfactory for long term continuous operation, but operation is permitted for a limited time period

Validation D
Standard Motors operating in this area of vibration are likely to get severe damage

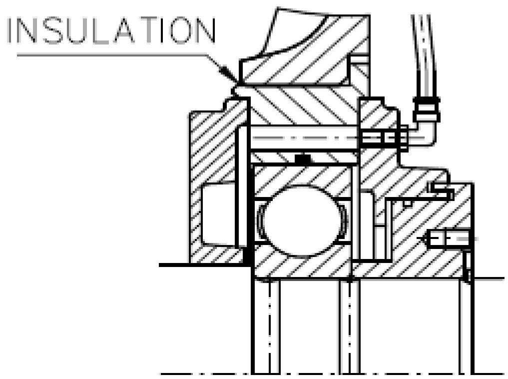
The rule of thumb shows the following values for the protection settings.

Motor coupled to the load	warning	> 7 mm/sec
Motor coupled to the load	trip	> 9 mm/sec

Usually, the customer is responsible for the motor foundation; however, the responsibility for it has to be defined. The foundation should not only be rigid enough to withstand short circuit forces, but also the natural frequencies of the system motor and foundation shall not coincide with the rotational frequency of the machine, or with any of its harmonics. The foundation construction shall not cause any substantial decrease in critical speed for the operation of a motor.

2.10 Insulated Bearings

In general the non drive end bearing is insulated. If the motor is operating on a frequency converter the insulation of the non drive end bearing is a must, because of the existing bearing currents.



Picture 2.10.A shows the bearing insulation system.
The insulation is made by a shrink fitting insulation layer in the shield

The bearing insulation has to be checked after replacement of bearings

3. Common Bearing Problems

The antifriction bearings have a usual life of more of 100,000 hours, which means an active lifetime of about 12 to 15 years. The sleeve bearings should have an infinite lifetime. This requires that the bearings be correctly sized and dimensioned, using the right type of bearing, and also well maintained. If not, the lifetime can and will be significantly shorter. Below is a summary of the most common bearing problems.

3.1 Vibration

Roller bearings are damaged easily from vibration when the motor is not running. Therefore the rotor is locked during transportation.

Ball bearings can sustain more vibration than Roller bearings when not running.
Both Roller and Ball bearings can only sustain single and infrequent shocks of 2 to 3 g without damage, therefore, shocks of bigger magnitude should be avoided.

Sleeve bearings can sustain a formidable amount of vibration without damage. They can withstand single and infrequent shocks of 3 to 5 g Shocks of bigger magnitude should be avoided. In order to fix the rotor axially during transportation, the rotor will be locked. Don’t forget to unlock the rotor before energizing the motor.

Vibration in motors are normally caused by

- Unbalanced loads, like fans mounted on base frames that are not rigid, can provoke heavy vibration, resulting in bearing problems
- Operating equipment in the areas of resonance points, especially when adjustable speed drives are used, can provoke heavy vibration, resulting in bearing problems
- Lack of uniformity in the magnetic field
- Partial short circuit in the windings
- Damaged bearing
- Exceeded axial forces

- Misalignment radial or axially between the motor and the load machine
- Coupling half is not balanced correctly

3.2. Lubrication and greasing

The purpose of the bearing lubrication is to prevent direct metallic contact between the various rolling and sliding elements. This will be achieved by the formation of a thin oil film between the two surfaces
Only lubricants which are recommended by the supplier of the motor, or which has very similar characteristics as the one recommended by the supplier, should be used. The use of other lubricants will lead to bearing problems, sooner or later.
But, bearing problems because of grease or lubrication can also shorten the lifetime of the bearings in the following situations. The greasing interval recommended by the bearings supplier has to be strictly followed.

3.3. Causes of High Bearing Temperature

- Over - greasing the bearing, forcing bearing balls to push through excess grease as they rotate, leading to a sharp temperature rise
- Too little grease in the antifriction bearing or too little oil in the sleeve bearing
- Not enough, or too high temperature, of the oil cooling water for the sleeve bearing
- Too high radial forces on the bearings
- Tension of v belt drives is too high
- Ambient temperature is too high, for instance, the Kiln drive motor below the kiln has insufficient heat protection
- Friction of the bearing sealing. Bad shaft seals leading to loss of grease or oil.
- Use a low-temperature grease which does not provide adequate viscosity at the normal operating temperature.
- Mixing incompatible greases, which can reduce the consistency of the grease and possibly the overall viscosity

3.4. Installation

Too high radial forces will lead to shortened lifetime of the bearing:

- Too high a tension on the v belt drives t leads to higher bearing temperature and shorter lifetime of the bearing
- Coupling half is not balanced correctly
- Misalignment radial or axially between the motor and the load machine

3.5. Motor Specification

- Radial bearing load is not correctly specified
- Axial load is not correctly specified, especially in the Kiln drive, were the motor is mounted with a slope between 2 and 5 degrees. The result will be higher bearing temperature and also shorter lifetime of the bearing
- Existence of bearing currents not specified
- In motors in the Megawatt range, specify a grounding ring with grounding brush to avoid for sure bearing currents

3.6. Motor noise

Basically, sleeve bearings don’t make noise at all, and Ball bearings are more noisy than Roller bearings

- Damaged bearings create higher motor noise as well
- Antifriction bearings, without adequate grease, also create higher motor noise

3.7. Motor Storage

General
If motors have to be stored before installation it has to be done appropriately in order to avoid damages. After long time storage, it is recommended in general that the bearings have to be inspected carefully. Any corrosion must be removed. If the shaft shows imprints, on the lower half, it must be replaced.
The storage place has to at least be vibration and shock free, and free of corrosive gases. In cases were the storage is done in the vicinity of the sea, the entire motor has to be protected for salt water and humidity, not just the bearings.

Antifriction bearings
Antifriction bearing have to be well lubricated during the complete storage period. In longer storage periods, the lubrication condition of the bearings has to be checked from time to time. Depending on the ambient storage temperature of the motor, a fully penetrating grease lubricant with capability over a wide temperature range, for instance -30 to + 100 degree Celsius, has to be used.
To maintain the antifriction bearings of the motor in good condition, the rotor should be turned about 10 revolutions every 2 months. Before turning the rotor the transportation lock has to be removed, and after turning, the transportation lock has to be fixed again. But remember not fix the lock too tight, because this could harm the bearings. It is advisable to tighten the screw only with the torque of about 10 Nm.

Sleeve bearings
The motor with sleeve bearings are, in most cases, delivered without oil. During the storage of a motor, it is important to make sure the surface of the bearing is always covered with Tectyl. The Tectyl should be sprayed into the bearing through the filling hole, if the storage time is longer than one month. But, if the storage time is much longer than one month, the treatment with Tectyl has to be repeated every 6 months.
If the storage is longer than 2 years, the bearings has to be dismantled and threatened with corrosion protection separately
Before the use of the stored motor, the bearings have to be filled with oil of a high quality. The supplier of the motors will recommend the oil which is suitable for trouble-free, long-term operation of the bearings.

3.8. Summary of reasons for bearing failures

Impending bearing problems are preceded by a change in the behaviour of the bearing. Early indications for potential bearing problems are an increased temperature, higher vibration levels or higher noise levels of the motor.
In a correct installation, and under adequate supervision, the temperature and the vibration can be visualized easy by trend logs. The noise level however can only be detected by the maintenance staff during routine checks.
If the potential problems are not recognized and analyzed promptly, or if wrong assumptions of the problems are made, it will lead sooner or later to a bearing problem. A substantial bearing problem will not only damage the bearing in a short period of time, but will also reduce the expected life of over 100 000 hours.

The failure analysis, the interpretation of the failure, and also resolving the causes for bearing failures, are areas of activities for future Maintenance strategies, which will become more and more important to ensure the expected results of the equipment in operation.

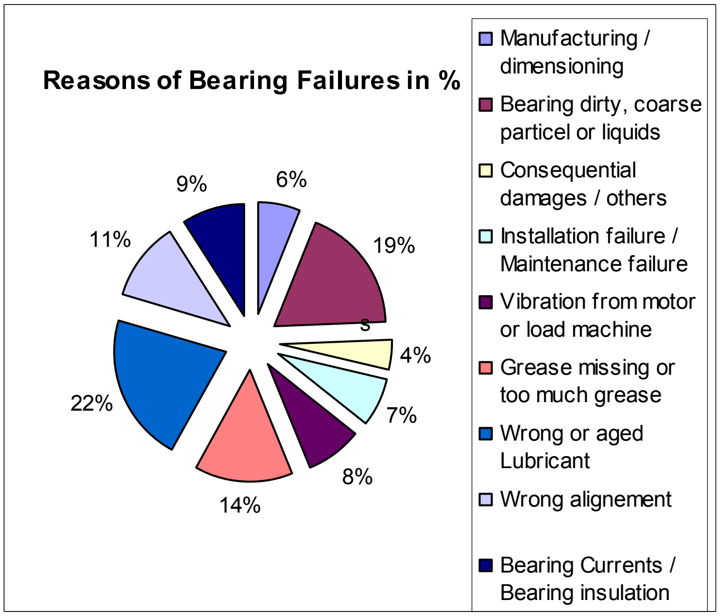


Chart 3.8.A summarizes the most common reasons for bearing failures in % of its occurrence.

Mostly of the known Bearing failures are failures which can be avoided by the maintenance staff, or when a proper bearing diagnostic and supervision system would be installed.

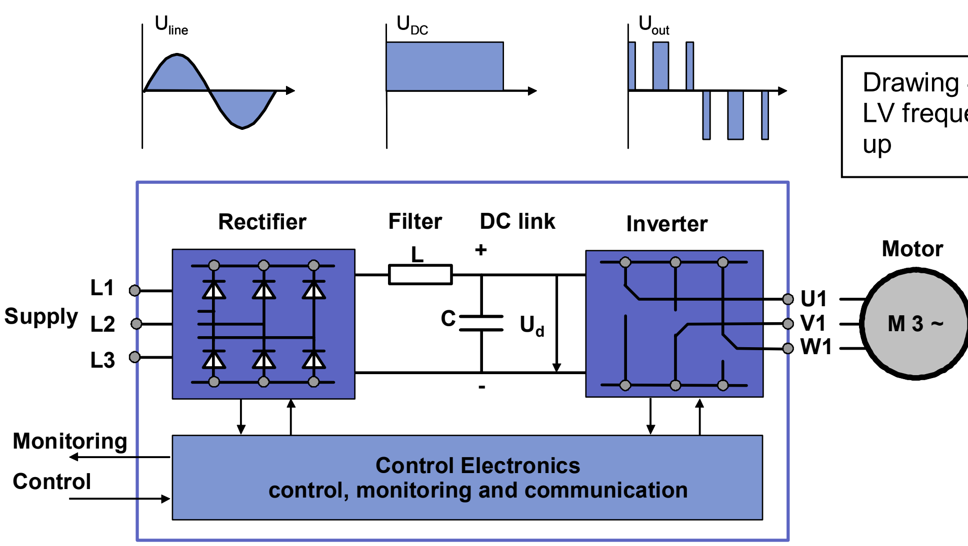
The installation of a proper system however is able to supervise the bearing behavior, but it is even important to be capable to interpret the measurements which such a system provides

It is worth mentioning after analyzing the chart, that a significant amount of problems were caused by too little or too much grease in the bearings , meaning that over greasing is as bad as under greasing

4. Bearing Currents

Bearing currents have been recognised for a long time. Around the 20's, the bearing currents where a consequence of unsymmetrical stator windings.
As the fabrication of the windings and motors become better and more symmetrical, these currents, today, are no longer important.

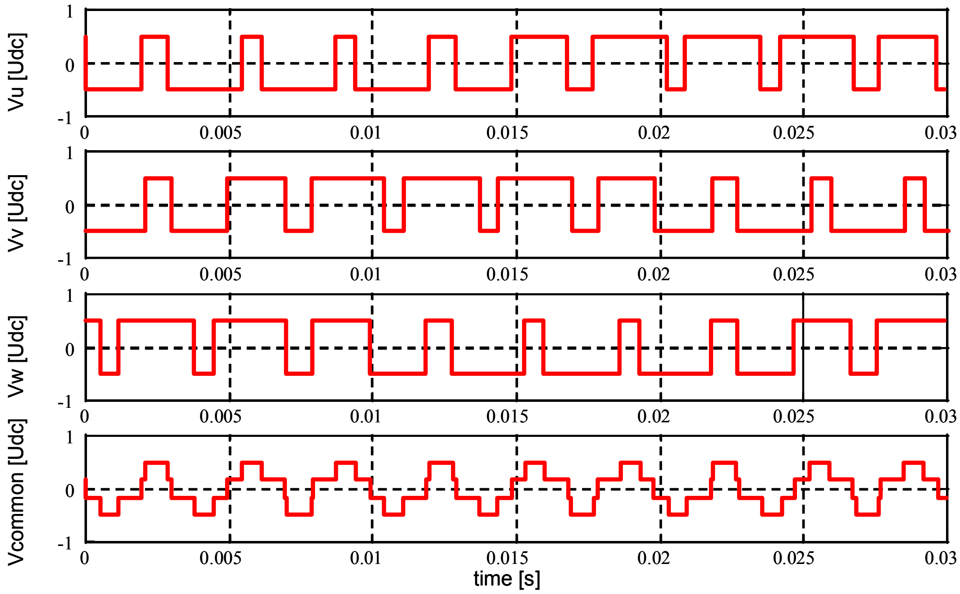
But on the other hand, in recent times, the growing use of frequency converters with PWM technology has brought back the bearing current discussion again.



Drawing 4.A shows a typical LV frequency converter set-up

Modern AC Converters have, as their motor output, a high du/dt combined with a high switching frequency. This results in the sum of the 3 phase voltages not being zero anymore, as it is in a 3-phase network.

The so-called Common voltage is depending on the Intermediate circuit DC voltage and the switching frequency.



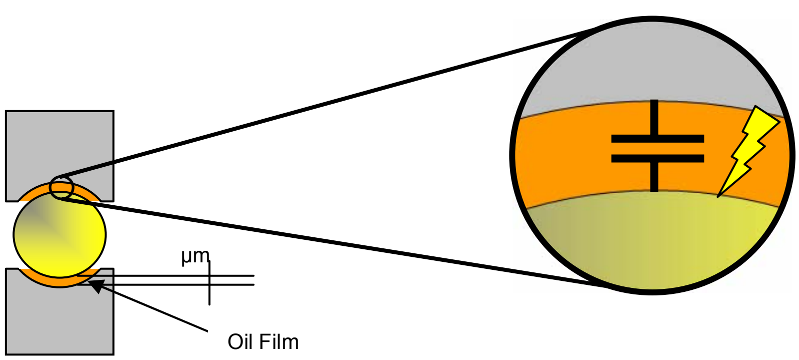
Graph 4.B shows that the total sum of the 3 motor phase voltages is not zero.

Without taking into consideration counter measures on these effects, a motor bearing can be destroyed within few month of operation.

If such a common mode voltage is present there might be different dominant root causes of problems. This voltage always tries to generate a current flow.

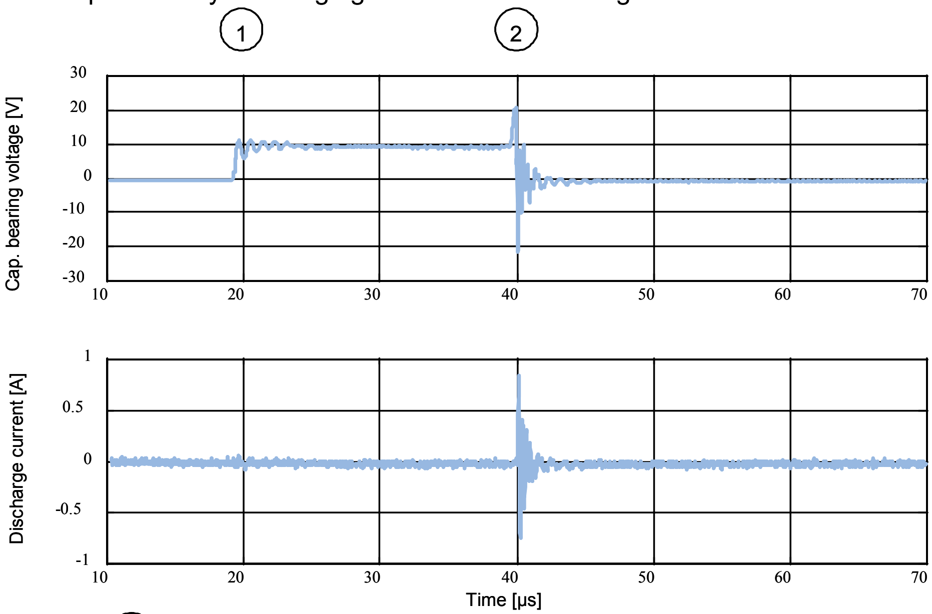
4.1 How are the bearing damaged

Basically the damage is always caused by partial discharge.
The so called **E**lectrical **D**ischarge **M**achining (EDM).



Sketch 4.1.A shows the created capacitor within a bearing between inner / outer race and the ball

The oil film between the race and the ball acts as a di-electricum. This so-called capacitor will be charged by the bearing currents. As soon as the voltage level is high enough it will be discharged by short circuit. Such periodically discharging will lead to an eroding of the metal.



Oszillogram 4.1.B shows the growing common mode voltage (above) and the resulting discharge current (below)

(1) Common mode voltage change

(2) Common mode voltage change and oil film breakdown in the bearing.

The speed of the rotor influences the eroding. Higher revolutions create a thicker oil film and therefore more capacity. Because of this, the voltage, until a flash over occurs, is higher and the damage bigger. Whereas, lower speeds have a thinner oil film, but at the same time, the ‘contact’ area is bigger and the risk of damage is much lower.

To conclude: the higher the speed, the higher the nominal power, and the higher the DC Voltage, the more risk of a damage appears.

Picture 4.1.C shows a typical pattern of a damaged bearing outer ring

4.2 What are the dominant figures:

There are different ways of damaging a motor and/or a load bearing. Depending on the motor power, other dominant features are determined.
For motors with a nominal power larger than 100kW mainly

- High Frequency Circulating current
- High Frequency Shaft Grounding Currents

are the damaging elements, whereas, for smaller motors,

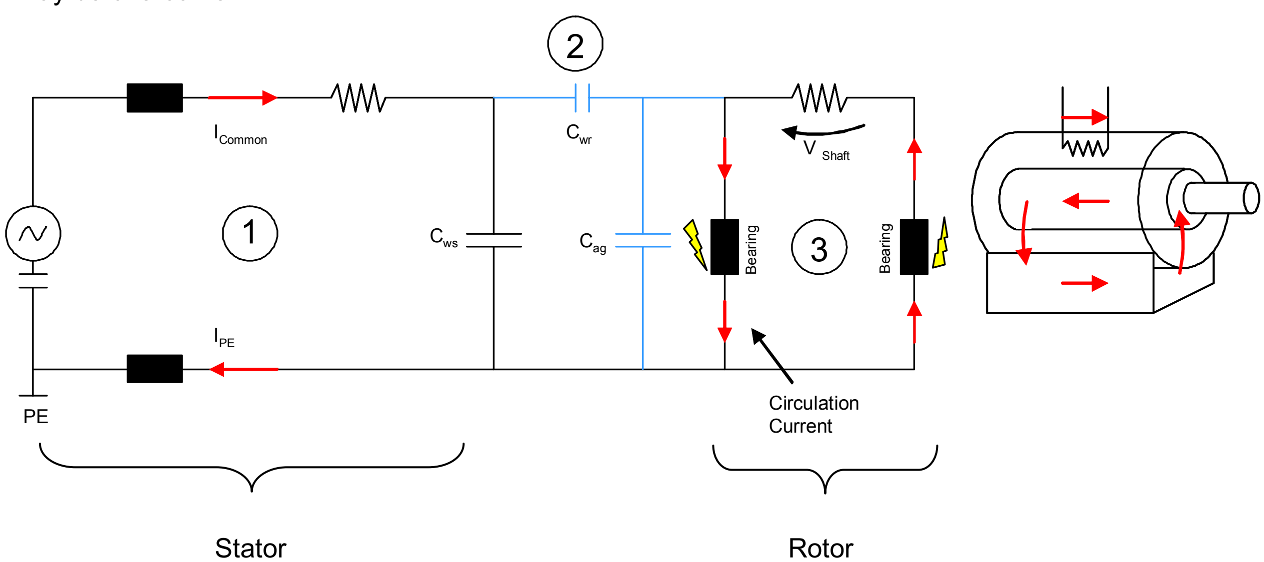
- Capacitive discharge currents

may lead to damages.

The following section explains roughly the different kind of currents.

4.2.1 High Frequency Circulation Currents:

The high frequency common mode current ① induces via the air gap ② a transient voltage between the shaft ends ③.
This voltage develops a compensating current. The bearings and the motor frame provide a path, and the current starts to flow.If the voltage is high enough, the dielectric strength of the bearing lubrication film may be overcome.

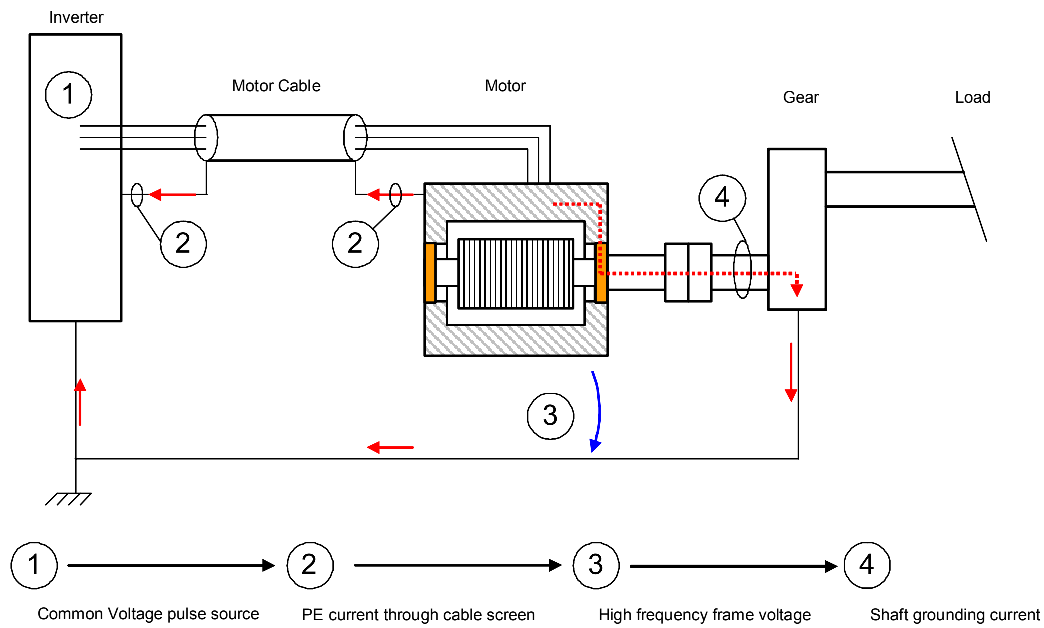


① Common Mode current loop: AC Drive, Cabling Motor and PE

② Mutual inductance coupling between stator and rotor circuits

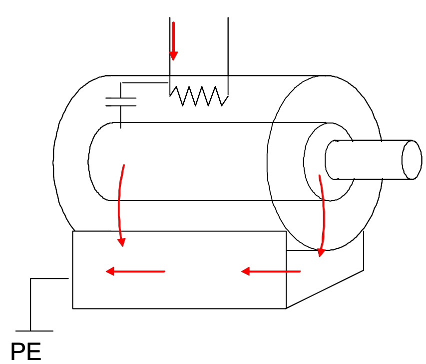
③ Circulating current through shaft, bearings and motor frame

4.2.2 High Frequency Shaft Grounding Currents



Due to asymmetrical unshielded motor cable and poor stator grounding, a high frequency PE current can flow through the motor frame to ground (3), or through the motor bearing and shaft towards the load machine, and then to ground (4). This current flowing through the shaft can, depending on drive power and installation setup, damage the load bearing.
Therefore by using a frequency converter without sinus filter at the output the motor cables has to be 3phase and shielded type. The shield has to be connected on both sides motor and converter. This enables the common mode current to flow back on a defined path to its source.

4.2.3 Capacitive discharge currents

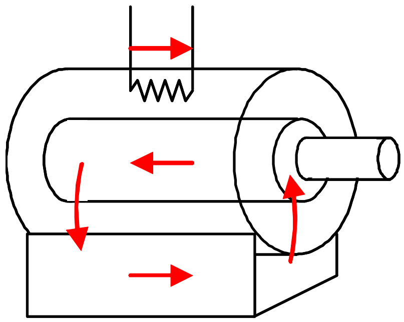


The airgap capacity acts as a voltage divider of the common mode voltage. This result in a voltage coupled between the shaft and motor frame. The so-called ‘airgap’ capacitor discharges through the motor bearing to ground. Due to mechanical design, this phenomena is mainly present in small motors below 100kW, and typically below 30kW.

4.3 Bearing Current Summary

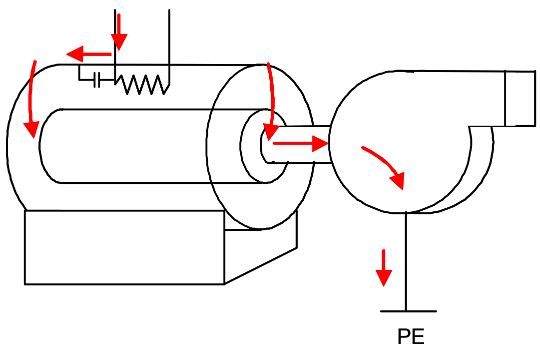
The above mentioned 3 types of currents can be classified as follows

High frequency circulation current



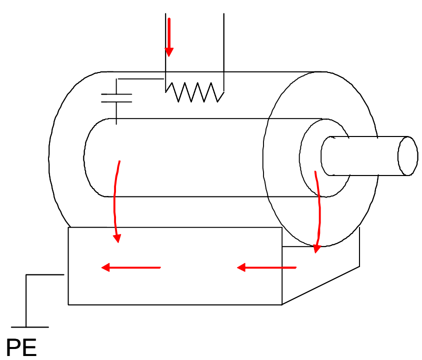
- Risk in medium and high power motors. Frame sizes IEC 315 and up, PN >100 kW
- High du/dt and high switching frequency increase the risk
- > 95 % of cases

High Frequency shaft grounding currents



- Asymmetric, unshielded motor cabling
- Poor stator grounding
- Incidental grounding of the motor shaft through the gearbox or driven machinery

Capacitive discharge current



- Special cases with small motors
- Motor frame grounded
- Shaft is not grounded via machinery

Conclusion

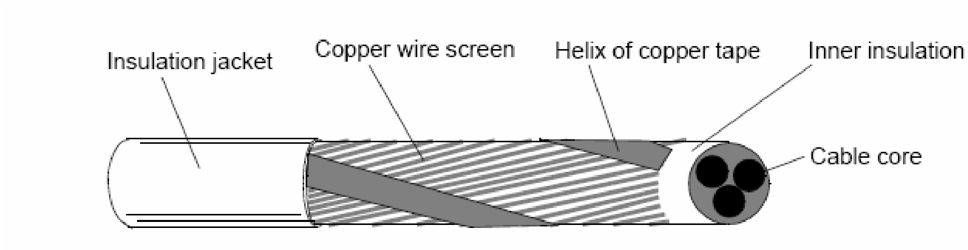
- The majority of damages has been caused by the circulating currents
- The shaft grounding current is usually related to improper cabling or grounding arrangements
- The selection of correct cable type is important
- Cable shield, PE-conductor connections are an important part of preventing damages
- Motor, driven machinery installation can influence the location of damages
- Capacitive discharge currents may be a problem in specific conditions with small motors

4.4 How can high frequency bearing currents be prevented?

Most mistakes that are done are simple installation issues.

Cable

For motor cables always use shielded 3 phase cable. Never install single phase or un-shielded cables. The shield gives possible common mode currents a defined way back to the source (converter) without passing its way through the bearings.



Du/dt

As the modern Frequency converters generate a high du/dt, its is recommended that the converter be equipped with a du/dt filter at the output to prevent high frequency circulation currents. As this is mainly the key issue in motor power above 100kW, frequency converters for motors below this power normally don’t need to be equipped with a du/dt filter.

Picture 4.4.A
du/dt filter for external mounting in IP00 and IP22 design

Breaking the current path

By insulating a bearing, the current path can be interrupted. It has to made certain, that the current does not then take another way, via the load bearing, to ground. As mentioned above, a shielded motor cable is essential in providing defined current paths.

For drives basically equipped with a sinus filter, there are no special actions to be considered in terms of high frequency circulation currents. .

5. Diagnosis and protections on Bearings

For the correct functioning of the bearing, two conditions are important; to supervise the vibration and the temperature of the bearing. If both of these parameters are within the specified ranges, the chances of being confronted with bearing problems are small.

5.1 Vibration

Vibration of different magnitudes can be detected on all rotating equipment. Vibration can be measured in 3 ways.
Displacement, means the actual distance amplitude the object moves usually measured in mm.
Acceleration, means a part that is moving from rest, speeding up, slowing down and stopping twice per cycle, is accelerating and decelerating continuously. Acceleration is measured in m/sec2
Velocity, means the speed in which the object moves. Velocity is measured in mm/sec.
Acceleration and velocity are constantly changing. One can measure a peak value of either, but a mean value often gives a better indication of the forces involved in the movement. Most measuring instruments give the RMS value of the movement.

In the Vibration aspect, one of the aims is to protect the drive from a too high or destructive a vibration, and the other is to know how big the level of vibration is, and the frequency spectrum of which the vibration is composed. When both vibration supervision and protection are required, the less expensive version of the vibration detection is sometimes used for smaller motors.. It is mounted on the bearing housing and produces a trip or a warning when the vibration exceeds it limit. This equipment does not show any frequency spectrum. For bigger motors, a vibration measuring and protection system is made out of a vibration sensor which shows all the spectrum of the vibration and its magnitude. With this sophisticated system, the bearing condition can be detected long before the bearing becomes a problem. The data retrieving can be done by hand held portable equipment, or by a permanently installed system. The data collection is done on certain predefined points on the bearing.

Shock Pulse measuring (SPM)
The motors above a certain size, and using antifriction bearings, are equipped with SPM (Shock Pulse Measuring) nipples on both sides of the motor, at the drive end and the non drive end. The condition of the bearing can be measured and checked using the shock pulse method.
A shock pulse transducer, produces a large amplitude oscillation to the weak shock pulses, because it is excited at its resonance frequency of 32 kHz. Motor bearing frequency of a much lower frequency is filtered out.

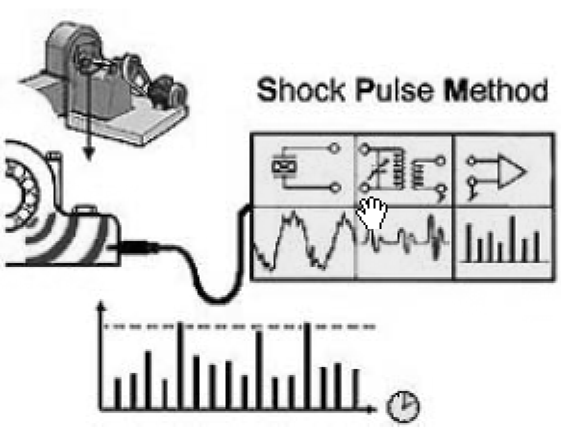


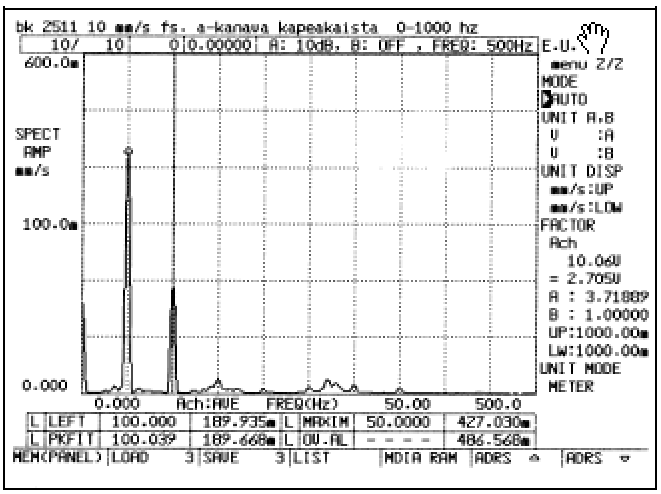
Figure 5.1.A shows the shock pulse method.
- The first vertical line of boxes shows the transducer and the vibration signal from the motor bearing.
- The second box shows the electric filter which passes a train of transients. The amplitude depend on the energy of the shock pulses
- The last box shows the converted shock pulses signal from the bearing, consisting of a rapid sequence of stronger and weaker electric pulses

The filtered transducer signal reflects the pressure variation in the rolling interface of the bearing. When the oil film in the bearing is thick, the shock pulse level is low, that means without distinctive peaks. The level increases when the oil film is reduced. Bearing damage causes strong pulses at irregular intervals.

Spectrum analysis

A more exact and detailed vibration signal analysis provides the method of the spectrum analysis. In the spectrum analysis, speed spectrums and acceleration spectrums are usually followed. The alarm limits can also be specified based on the spectrum, in which case the question is in the spectrum supervision. The calculation of the spectrum is based on the utilization of the mathematical Fourier series.
Any measured complex waveform can be separated into simple sinusoidal waveform components. As the sine waves are separated from the combined waveform, they are converted to vertical peaks which have an amplitude determined by their magnitude and are given a position along the frequency axis.

Usually the analyzer forms the spectrum by calculating them mathematically with the help of FFT. (Fast Fourier Transformation) FFT is a microprocessor algorithm applied to the incoming sampled data, from the signal captured in the analog world, which is a time domain. This must be transformed into the frequency domain using series of mathematical operations.



Picture 5.1.B shows a vibration measurement on a 2 pole motor
One possibility to detect bearing failure by vibration monitoring is to determine the typical bearing defect frequencies. Every time a defect is over rolled, it causes a peak in the vibration signal. The repetition of these peaks depends on the position of the defect on the bearing and the bearing geometry and speed.

5.2 Bearing temperature

One of the key points for an free of bearing problems, is the bearing temperature. If the bearing temperature exceeds its predefined limits, whether caused by ambient conditions or generated within the bearing itself, it has the potential to harm to the bearing. Overheating in electric motor bearings is many times lubricant related.

To prevent harm to the bearings, the bearing temperature is continuously monitored and, depending on the plant information and visualization configuration, also displayed.
The data collection is made with RTD probes. The probes are fitted near the outer ring of the antifriction bearings and have to be of a 4 wire design. Only one probe for each bearing is needed.

6. Future of Bearings … the magnetic bearing?

Drastic changes are expected in bearing technology. In some applications. the actual changes are moving in the direction of magnetic bearing systems. The magnetic bearing system is a different way to the support of the rotating element the rotor.
Magnetic bearings belong to the family of the non contacting technology. This technology has negligible friction losses, no wear and, another big step forward, is the possible high surface speed achieved. Besides this, it does not need any lubrication. This opens up possible applications in areas such as vacuum operation, or those sensitive to contamination.

Picture 6.A shows a radial magnetic bearing.
Magnetic bearings provide attractive electromagnetic suspension by application of electric current to ferromagnetic materials used in both the stationary and rotating parts (the stator and rotor, respectively) of the magnetic bearing. This creates a flux path that includes both parts, and the air gap separating them, through which non-contact operation is made possible.

As the air gap between these two parts decreases, the attractive forces increase, therefore, electromagnets are inherently unstable. A control system is needed to regulate the current and provide stability of the forces, and therefore, position of the rotor. With magnetic bearings, vibration due to unbalance of the rotating part can be virtually eliminated and the shaft centre can be located within a micron sized orbit.
The lifetime of the magnetic bearings is expected to be much more than 25 years, since there is no wear in the non-contacting system, and deterioration is very limited. It is important to note that magnetic bearings provide consistent performance throughout their life.
Magnetic bearings do not wear. Mechanical maintenance on the bearings themselves is eliminated, however, preventative maintenance of auxiliary components, electrical connections etc. has to be done.
In order to form the magnetic field, electric power is needed. The power consumption is mainly due to the resistive losses in the coils. The amount of power varies for each size of bearing and its current rating.
Everything looks fine and fantastic, except when it comes to the question of what happens when the electric power is gone. If power is interrupted to the magnetic bearings, the rotor will de-levitate.
Consequently, magnetic bearings are fitted with auxiliary bearings (roller or sleeve bearings), which are designed to withstand a number of full speed de-levitations as required by each specific application. For enhanced reliability, the system can be backed-up with an uninterruptible power supply (UPS), which will provide the power necessary to support the shaft during coast down.
In the present applications in the cement industry it is not to be expected that in the very near future this type of bearing will be applied. But, in medium and long terms, the magnetic bearings will also play a certain role here.

7. Conclusions

No bearing problems at all in a plant, are as rare as "Chicken with teeth". In all plants, for very different reasons, bearing problems can and will occur.
The aim of this paper was to describe the most common reasons for bearing problems, but it also discusses how to minimize the avoidable bearing problems, and the related sleepless nights, because of unplanned shut downs of the plant.
A part of the reasons which lead to bearing problems can certainly be avoided by not making the mistakes mentioned in the paper. But, another class of bearing problems, also causing shut downs because of the bearings, can be easily avoided by recognizing and interpreting abnormalities in the bearings in an early stage, when bearing problems are developing.
It is utmost important to move away from reaction-based maintenance and repair, and toward to a preventive approach, not waiting until a bearing problem occurs.
Bearing problems don't just occur, bearing problems are allowed to develop.

8. Bibliography

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