Plain Bearings Made of Silicon Carbide With Optimized Dry-running Properties for Plastic-lined Magnetic Drive Pumps

Damage to magnetic drive pumps are frequently attributable to running dry; this applies in particular when silicon-carbide plain bearings are used. The frictional heat which is produced in the plain bearings when the pump is activated without medium is so great that the bearings are already damaged after just a few seconds, which results in the complete destruction of the pump if dry running continues.

Dry running

Although every user of centrifugal pumps knows that magnetic drive pumps must not be operated without medium, it repeatedly happens that pumps briefly run dry when the direction of rotation of the prime mover is being checked or when the valves in the suction line are not opened.

Figure 1 shows that the arrangement of the bearing points and the rotating components of the pump are important for the loading of the plain bearings. Large bearing distances and the arrangement of the bearing points near the impeller and pump rotor reduce the load.

Plain bearings made of silicon carbide

Silicon carbide, SiC, has gained wide acceptance over many years as the bearing material for magnetic drive pumps. Its special properties, such as dimensional stability, great hardness, low wear and almost universal chemical resistance, make it an excellent material for bearings.

The high price has fallen substantially in recent years owing to optimized production methods and bearing designs suitable for ceramics.

However, the high coefficient of friction of SiC against SiC of 0.5 to 0.7 means that relatively high frictional energy occurs on the sliding surfaces of plain bearings which are not lubricated or cooled. Table 1 contains frictional energies for various pump sizes in the MNK and MNK-B series.

The contact of the bearing bush and the bearing sleeve takes place in flexible bearings along a line; if the bearings are rigid, contact only occurs at a point. The entire frictional energy is converted into heat in the small contact zone. The result is that very high temperatures occur at this point and they in turn can lead to silicon particles flaking off the plain bearing surface and ultimately destroying the entire plain bearing system in a short time.

In the past a lot of research work was conducted to improve the sliding properties of silicon carbide. For example, attempts were made to reduce the coefficient of friction using SiC grades with embedded carbon particles and to maintain brief emergency lubrication with porous SiC. However, the results were not so successful that magnetic drive pumps could be run dry with these materials. Coatings of SiC plain bearings with a soft carbon layer (e.g. graphite) also permitted only a one-off dry start-up of the pump as the layer wears very quickly.

"SAFEGLIDE" Coating

It consists of an amorphous layer made of diamond-like carbon just a few microns thick which is applied to the silicon carbide bearing by special process. The layer is characterized by the following properties:

- amorphous isotropic, readily adhesive layer
- great hardness (HV0.05 4000-6000)
- good elasticity in spite of great hardness
- high wear resistance
• optimum surface qualities
• good thermal conductivity
• temperature-resistant up to 300°C
• universally resistant to chemicals; cannot be destroyed by wet chemicals

The property which is most important for its use as a friction-reducing layer in plain bearings is the coefficient of friction. It is 0.02 to 0.04 in the non-lubricated, i.e. dry, state ?SAFEGLIDE? against ?SAFEGLIDE.? The frictional energy during dry running falls dramatically with these low co-efficients of friction. Table 2 contains the relevant figures.

This coating made it possible for the first time to let magnetic drive pumps (Figure 2) run bone dry for a period of up to 5 minutes at 2900 rpm.

While it was not possible to measure the development of the temperature in non-coated plain bearings at a speed of 2900 rpm owing to the very rapid destruction of the bearings, the temperature curve illustrated in Figure 3 was measured on coated plain bearings.
Figure 1. Bearing forces during dry running

<table>
<thead>
<tr>
<th>Pump sizes</th>
<th>Impeller frictional energy [J/s]</th>
<th>Rotor frictional energy [J/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 - 125</td>
<td>6.4</td>
<td>98.8</td>
</tr>
<tr>
<td>32 - 160</td>
<td>37.1</td>
<td>198.9</td>
</tr>
<tr>
<td>50 - 200</td>
<td>49.7</td>
<td>345.2</td>
</tr>
<tr>
<td>80 - 200</td>
<td>79.0</td>
<td>575.8</td>
</tr>
</tbody>
</table>

Table 1. Frictional energy of dry-running SIC plain bearings
(n = 2900 rpm, \( \mu = 0.6 \))

<table>
<thead>
<tr>
<th>Pump sizes</th>
<th>Impeller frictional energy [J/s]</th>
<th>Rotor frictional energy [J/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 - 125</td>
<td>0.43</td>
<td>6.59</td>
</tr>
<tr>
<td>32 - 160</td>
<td>2.47</td>
<td>13.26</td>
</tr>
<tr>
<td>50 - 200</td>
<td>3.31</td>
<td>23.01</td>
</tr>
<tr>
<td>80 - 200</td>
<td>5.27</td>
<td>38.38</td>
</tr>
</tbody>
</table>

Table 2. Frictional energy of dry-running “SAFEGLIDE” SIC plain bearings
(n = 2900 rpm, \( \mu = 0.04 \))
Experience with ?SAFEGLIDE?

After the introduction of ?SAFEGLIDE?-coated plain bearings for the magnetic drive pumps of the MNK and MNK-B series, the statistics of the users showed that pump damage caused by improper operation, which resulted in dry running, fell dramatically within a very short time.

After the initial excellent results with coated plain bearings, the range of operating conditions was increasingly extended. The pumps were now also used for media with a permanently high solids content and for low-boiling products near the evaporation point. Modes of operation, e.g. pumping containers completely empty, monitored by the dry-run signal, became possible with the new plain bearings. Expensive monitoring facilities, such as filling level display, could be dispensed with. Instead, low-cost motor load monitors were and still are frequently used in conjunction with ?SAFEGLIDE.?

Studies on the plain bearings used demonstrated that the coating is still fully functional even after prolonged service in highly corrosive media.

One example of this excellent result is the plain bearing system of an MNK 32-160 shown in Figure 4 which was in operation for roughly 40,000 hours. Moreover, one problematic aspect was that the product crystallized out and the sliding surfaces of the bearings were thus contaminated with crystalline solids.
The examination of the sliding surfaces showed that the coating was intact even after this lengthy period of operation.

**Refinement of ??SAFEGLIDE?? to ??SAFEGLIDE PLUS??**

The design and production process of the plain bearings have been further optimized in recent years. The parameters of the coating process were also improved, which means that today a very uniform, defect-free ??SAFEGLIDE?? coating can be manufactured in large series. Dry-running tests were continuously conducted with these plain bearings, which are optimal for magnetic drive pumps.

It is very difficult to reliably observe the temperature which is produced on the sliding surfaces during dry running. The temperature must remain so low that the surrounding plastic-lined components are not damaged.

Moreover, the pump user must bear in mind that high temperatures occur with prolonged dry running. If the suction valve is suddenly opened after dry running, the product which is to be conveyed and which also flows through the plain bearings is heated. This can cause undesirable reactions with sensitive products.

The situation becomes even more critical when an explosive mixture is in the pump during dry running or the medium to be conveyed has a low ignition temperature. In this case it is very important to limit the dry running time to a few minutes, e.g. by using appropriate monitoring facilities like a motor load monitor.

![Figure 4. Photo of an MNK "SAFEGLIDE" bearing after 40,000 hours of operation](image)

"SAFEGLIDE PLUS"

The entire tribosystem was examined and optimized in a 2-year research project. Different layer variations based on the ??SAFEGLIDE?? were manufactured and tested. The latest coating processes, e.g. the so-called ??multi-layer coating process?? were also included in the studies. However, the use of soft graphite layers was intentionally omitted in order to guarantee a long-life coating and thus the capability to repeatedly run dry.

In addition, various details of the bearing mount were changed in order to eliminate the negative effects of the temperature rise during dry running.

All the optimization aspects relating to the bearing situation of the magnetic drive pumps of this manufacturer are being launched onto the market as the ??SAFEGLIDE PLUS.??
This optimized bearing system repeatedly produced the temperature curves shown in Figure 4 for the impeller and rotor plain bearings during dry-running tests. The result shows that it is possible to let magnetic drive pumps with ?SAFEGLIDE PLUS? plain bearings run dry for over 75 minutes. This outstanding result was repeatedly confirmed in many tests and on pumps of various sizes.

Further test series were conducted in order to check whether the layer properties are changed after such a long dry-running period. In these tests the plain bearings which had previously been subjected to a dry run of 75 minutes were used. Then the same bearings were operated 19 times with a dry run of 10 minutes and the temperature rise was measured on the plain bearings (table 3).

<table>
<thead>
<tr>
<th>Pump sizes</th>
<th>Temperature rise $\Delta T$</th>
<th>Rotor side</th>
<th>Impeller side</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 - 160</td>
<td>65</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>50 - 200</td>
<td>87</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>80 - 200</td>
<td>98</td>
<td>56</td>
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Table 3. Average temperature rise on the rotor and impeller plain bearings in a 10-minute dry run at 2900 rpm.

This test provides much more information as the objective of the development of plain bearings suitable for dry running cannot be a centrifugal pump which runs dry once over several hours but rather the proof that plain bearings provided with ?SAFEGLIDE PLUS? also survive frequent dry runs without suffering any damage. 10 minutes are normally enough for the operator to detect a functional error and to take appropriate action.

As a final test, a dry run over 75 minutes was conducted again. A subsequent evaluation of the plain bearings showed that no damage to the components had occurred.

It is understandably very important for industrial practice that the dry-running properties are also retained after a long period of operation and that this dry-running safety feature is still present when the pump is repeatedly switched off and started up again. To this extent other coating systems which have an additional soft carbon layer on a hard support material to achieve as long a dry running time as possible are not viewed as being favorable. The reason for this is that the soft layer wears down during pump operation and then after de-activation and renewed start-up of the pump it might possibly no longer satisfy the requirement. This aspect would be even more important for solids-containing media.

Finally, another test was conducted to determine whether, after a dry run followed by a sudden supply of cold medium, the silicon carbide bearings with ?SAFEGLIDE PLUS? are damaged by the temperature shock. In this test an MNK 50-200 was allowed to run dry until the temperature had risen to about 110?C (230°F) on the impeller plain bearings and to 150?C (302°F) on the rotor plain bearings. Then the suction valve was opened while the pump was running so that 20?C (68°F) cold water could flow directly into the pump. The temperature at the bearing points fell within 3 seconds to about 20?C (68°F). A subsequent examination of the plain bearing components showed that all the parts had survived the test without suffering any damage.

**Summary**

The problem of dry running has virtually been eliminated by the plain bearings made of silicon carbide with a ?SAFEGLIDE PLUS? coating which are now available to magnetic drive pumps of the MNK and MNK-B series. Dry-running times of half an hour up to several hours, depending on the pump size, are
now possible. Bone dry running of half an hour is possible even with the pump size with a transmitted magnetic drive rating off 65 kW at 2900 rpm without reaching the temperature limit of the pump and in particular that of the PFA lining. A dry run of several minutes up to one hour is also possible with pumps with less temperature-stable plastic linings made of PVDF (temperature limit 90°C/194°F).

The "SAFEGLIDE PLUS" coating has been proving its universal applicability for many years in a very large number of pumps of the MNK and MNK-B series with their very different and sometimes extreme operating conditions. The coating is still fully functional even after years in operation in highly corrosive media. The plain bearing "SAFEGLIDE PLUS" offer the user even greater safety reserves, which means that damage to these magnetic drive pumps through dry running can virtually be excluded.

Figure 5. Typical temperature curve of "SAFEGLIDE PLUS" bearings during dry running.