Bearsings

PTFE submersible bearings: part 2

Drs Fumitaka Kikkawa, Ryutaro Ogawa and Hiroshi Satoh of Mikasa Corp discuss the characteristics and advantages of submersible bearings made from PTFE. Here, the importance of the bearing material and the grooved structure is further elucidated with reference to ‘dry-start’ capability, abrasion resistance and vibration behaviour.

We continue where we left off at the end of the first article in this two-part series, with discussion of the grooves on the sliding surface of submersible bearings. In fact, there remains plenty of room for debate concerning the need for such grooves, especially for rubber bearings. However, for PTFE bearings intended for dry-start applications, we would go so far as to insist that they are essential. We draw this conclusion from a test using a real pump. The test compared two types of PTFE bearings. One features strips of PTFE that have been glued on to the surface of nitrile butadiene rubber (NBR), so as to create spaces between each of the PTFE pieces, namely, to form channels or grooves (Figure 1a); the other uses a PTFE cylinder instead (Figure 1b). This test was performed to clarify which type of PTFE configuration is suitable for use in a ‘dry-start’ bearing.

Peeling test

First, we need to digress slightly to address the issues concerning the strength of the adhesion between the PTFE and NBR in these bearings, because it was known that almost all the customers who were the initial adopters of these multilayer bearings were anxious about this aspect. However, the results of tests (Figure 2) suggested that peeling never takes place at the adhesive interface between the PTFE and NBR, and that instead the flaking occurs within the NBR itself. Needless to say, the cleaning process including de-oiling and the choice of adhesive agents for the interface of both materials are very important. In fact, it can be said that the only possible adhesion-related problem would be the crevice corrosion that is sometimes generated at the interface between the metal shell and the NBR at both ends of a bearing when used in sea water. The utilization of resin as the shell material is one of the possible solutions for that problem.

‘Dry-start’ ability

During the initial stage of development, both cylindrical- and strip-type PTFE bearings were set in a real pump together simultaneously, as shown in Figure 3, and the starting test in the absence of water (as described in Ref. 2) was repeated at the laboratory of the pump manufacturer, DMW Corp. After more than 100 continuous starting cycles at regular intervals, a screeching sound was heard and the test pump was dismantled. The sound...
indicated that seizure of the bearings with the shaft sleeves was occurring at arbitrary locations. The amounts of wear for both bearings presented a characteristic phenomenon. The amount of wear for the bearings made of strips of PTFE was far less than the wear shown by the cylindrical PTFE bearings, as shown in the right-hand part of Figure 3. The reason for this difference was attributed to the elasticity of the bearing itself. That is, bearings made with PTFE strips have much more free surface of rubber between the strips compared to those that utilize cylindrical PTFE. The gradual rise in the temperature of the bearing as the result of the repeated dry-starts causes expansion of the rubber layer. In the strip type there is plenty of free rubber surface to ‘absorb’ this expansion but in the cylindrical type the same expansion pushes against the PTFE layer, causing a reduction in the bearing’s inner diameter such that it seizes against the shaft more and is therefore subject to greater wear.

A further role for grooves

The presence of the grooves fulfills an additional role. No one can see the actual mechanism of shaft (sleeve) wear in slurry. However, the fact that the amount of wear of the sleeve is sometimes larger than that of the bearing tells us that the passage of particles such as sand might be accompanied by deformation of the softer (bearing) surface and induce the wear of the harder (sleeve) surface. In other words, the grooves have the effect of allowing the hard foreign material that enters the gap between the slide surface and the shaft to pass out along the shortest passage to a neighboring groove, as shown schematically in Figure 4.

Spring coefficients

Vibration engineering teaches that abnormal vibration of the shaft is likely to be caused by a strong spring nonlinearity in the bearings. From this point of view, the spring constants of the water film of the submersible bearings are too small, and are under boundary lubrication conditions. Consequently, the spring constants of the bearing’s raw materials also influence the total spring constant. When we consider this aspect, the grooves in the split-type bearings are very valuable because the existence of free rubber surfaces softens the hard spring characteristic. From tests 1
performed in our laboratory using test pieces, it has been determined that the spring coefficient of the PTFE bearing with the composite structure is weak and close to that of the NBR bearing, as seen in Figure 5. From this graph, it is also possible to infer that a silicon carbide (SiC) bearing made of three layers (metal, rubber and SiC), and of the cylindrical (flat-faced) type, would cause abnormal vibration of the shaft, because of the strong nonlinearity in the spring constant of the SiC bearing. However, SiC bearings are one of the favoured types for sewage applications, so careful consideration of the location and sizing of these bearings is needed in such cases to avoid abnormal vibration of the pump.

Vibration behaviour

When the destabilizing force that acts tangentially to the bearing reaction force (supporting force) is large, there is a possibility that precession of the shaft may occur. In actual fact, as would be expected from Figure 5, only the SiC bearing showed this tendency during an experiment that compared the three bearing materials (NBR, PTFE and SiC). The experiment was performed using a pseudo pump (Figure 6) where the diameter of the column pipe is 200 mm; the set-up uses a flywheel instead of an impeller to avoid the effect of flow inside the column. The abnormal vibration shown in Figure 7 was observed. It is understood from the wave form analysis (Figure 8) that this vibration, accompanied by the jumps in amplitude, is a self-excited vibration. We had also previously experienced a similar vibration to this with a pump in real-life operation using phenolic resin bearings (these were as-supplied components of solid resin with no layered structure). As for the NBR and PTFE bearings, very quiet operation was possible without generating such vibration phenomena.

Abrasion characteristics

The effect of abrasive slurry on wear was investigated for test bearings made from PTFE, NBR and phenolic resin using the horizontal test rig shown in Figure 1 of the first article. The slurries prepared for the investigation contained large sand particles of approximately 0.1 mm in size rather than the size distribution found in actual seawater. Concerning slurry concentration, it was known from our sampling of sand concentration at a real power station that uses sea water to cool the equipment that a concentration of 3 ppm corresponds to seawater when it is calm and 300 ppm to the conditions during a typhoon. Figure 9 is a comparison of the amount of wear obtained in slurries with different sand concentrations under the same test conditions (bearing pressure, velocity and duration). The results showed the amount of wear for the phenolic resin bearing was greater than that of the other two in all the concentrations of sand studied. In particular, it increases rapidly at high concentrations. The amount of wear for the PTFE bearing is lower than that of the NBR bearing at low concentrations and greater at the higher concentrations, with the two curves intersecting at about 200 ppm. It is clear that this difference originates in the amount of sand that lies between the bearing slide surface and the shaft, and the PTFE bearing is thought to be advantageous over the predominant adhesive wear region with little sand, because it has the lower frictional coefficients. In contrast, the NBR bearing, which possesses the full deformability of the rubber material, is comparatively advantageous in the abrasive wear region where there is a lot of sand. The fact that the amount of wear of the phenolic resin bearing is lower at 30 ppm than at 3 ppm suggests that, in this case, the presence of a moderate concentration of sand particles lying between the sliding surfaces acts to control the adhesive wear.

Concluding remarks

We have confirmed, as explained in the above discussion, that PTFE bearings lined with rubber are, at present, the best for
vertical pumps that need ‘dry-start’ capabilities. However, there is still room for improvement. One such area is the resistance of the bearings to water containing abrasives, and we have already started the development of a new design, again utilizing the properties of the rubber. We hope to make these new bearings public in the near future. Look out for details in a future edition of World Pumps.

References


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