New bearing generation for seal-less pumps

High on the wish lest of every plant owner are an increase in plant safety, a combination of lower maintenance costs and longer maintenance intervals, and the highest possible degree of availability. This is why seal-less canned motor pumps and mag-drive pumps are increasingly taking the place of traditional pumps fitted with mechanical seals. Zero-leakage pump units are normally designed with product-lubricated plain bearings. Because of its dependable sliding properties and a high degree of corrosion resistance, silicon carbide (SiC) is the preferred bearing material. Today, there are a number of SiC based materials whose properties make them all more or less suitable as product lubricated pumps bearing materials. To them all more or less suitable as product lubricated pumps bearing materials. To take full advantage of the strengths of technical ceramics, there is a need for special, ceramic-based designs. At KSB, this has resulted in a patented bearing design.

Mechanisms taking effect under critical operating conditions:

The course of events which eventually cause components to fail typically starts when parts come into contact with solid matter, which invariably results in wear. This situation occurs, for example, during start-up and shut-down, i.e., during the phase referred to as ‘mixed friction or semi fluid lubrication’. Because of their design, the surfaces of bearing elements come into contact with each other in only a few places.

Ceramic material by its nature is largely resistant to plastic deformation and only subject to very little elastic deformation. This means that the contact areas remain small and that the compressive stress acting on these small areas tend to be very large. Under load conditions, all frictional energy is converted in the few places of contact on the rough surface. In these areas, the energy is converted into plastic deformation, heat as well as material loss by abrasion. Up to a certain load level, the energy is eliminated through heat and a process of deformation. As soon as the limit is exceeded, surface cracks develop at the roughness peaks.

This is the starting point of material loss by abrasion. In radial bearings, it causes the hydrodynamic fluid film to build up less easily. Consequently, bushes and rotors remain longer in the semi-fluid lubrication phase, thereby adding to the amount of solid contact taking place. As a result of the high pressure per unit of area, a large amount of energy is converted in a small surface area. This is turn can lead to thermal stress cracking, which may eventually lead to fracture.

Materials examined:

A number of sintered silicon carbides were examined within the scope of a joint project. Technically speaking, the distinguishing features of these materials are the sizes and types of their grains and the way these grains are distributed (Figs. 1-4). From this it follows that the way to influence a material’s properties is by altering its microstructure. One can, for example, add pores to serve as lubricant stores in a period of low lubricant supply, or add a solid lubricant such as graphite. The third alternative is to alter the parameters of the microstructure itself, in particular by changing the grain size distribution. The characteristics that a material will have are determined by the sintering process. The special materials know-how, i.e., the sintering secret, is to know exactly how much heat to apply, which way to apply it and for how long (relation of time and temperature). The different microstructures are all created from more or less the same base materials. In this respect, the characteristics of the materials included in the investigation only differed negligibly, although, according to the data supplied by the manufacturers, the materials featuring the new grain size distribution demonstrated a better corrosion resistance when exposed to hot water. For example, the typical surface damage caused by hot water (Fig. 5) clearly is much less found in the biomodal, coarse-grained microstructure of Ekasic C (Fig. 6).

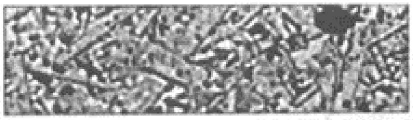

Fig. 1

Micrograph of Ekasic® D

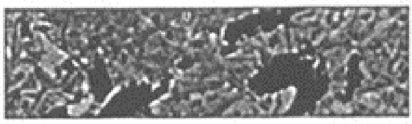

Fig. 2

Micrograph of EKasic® showing pores

Fig. 3

Micrograph of Ekasic® (bimodal grain structure)

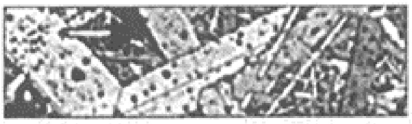

Fig. 4

Micrograph of Ekasic®
(bimodal grain structure + graphite)

Fig. 5

Surface of SiC affected by hot water

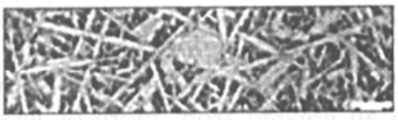

Fig. 6

Micrograph of EKasic® C

The achievement lies in the facts that the grain size by far exceeds the maximum corrosion depth, that the particles are thus prevented from being washed out, and that the point where the material begins to disintegrate, therefore, undergoes a sizeable shift towards a range of higher stress parameters.

Friction, wear and lubricating characteristics:

The available materials were systematically tested for friction and wear characteristics and hence their suitability for use in pump components using different laboratory tribometers.

The so-called critical load, in particular, is an indication of a material's success as a bearing material, and is therefore very much worth determining. To do this, test set-up equipment with a giving pre-load and subjected to continuous load increases was quickly accelerated from the starting condition to rated speed, the load was further increased until a given friction moment had been attained. This was taken as the criterion for switching off. The maximum axial forces in evidence at this point were then used as a means of evaluating the loading capacity of two mating specimens. Fig. 7 shows a comparison of the various materials in respect of their maximum normal force.

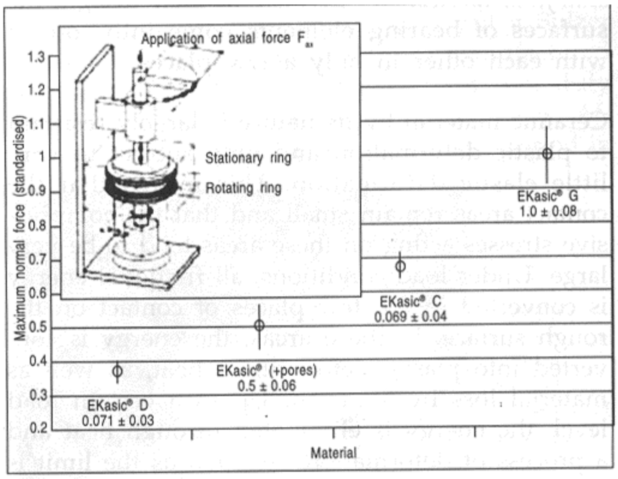

Fig. 7

Maximum normal force reached in critical load test.

Ekasic® is a registered trademark of Wacker AG	Ekasic® D	Ekasic® C	Ekasic® G
Density (g / cm^3)	> 3.10	>3.10	>3.02
Porosity [% by vol.]	<3.0	<3.0	<3.0
Grain size spectrum (um)	5-250	10-1500	10-1000
Phase composition	SiC	SiC	SiC, graphite
Vickers hardness (RT) (HV 10)	2600	2600	2500
Modulus of elasticity (RT) (Gpa)	410	410	410
Bending strength (Mpa m$^{1/2}$) (4 point RT)	350	300	300
Fracture toughness (Mpa M$^{1/2}$) (sharp incipient fracture, RT)	3.2	3.2	3.2
Coefficient of thermal expansion 20°C-500°C [10^{-6} / K]	4.0	4.0	4.1
Thermal conductivity (RT) [W / (mK)]	110	110	110

The materials with a coarser grained microstructure were found to perform better than those with a finer microstructure. The normal force of the newly developed material Ekasic C was twice that of a conventional material such as as Ekasic D, the normal force Ekasic G (Fig. 8) was as much as 2.8 times that of Ekasic D.

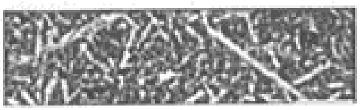

Fig. 8

Micrograph of Ekasic® G
(bimodal grain structure + graphite)

Testing of compressive stress levels in pumps:

The results obtained in the laboratory were verified in a series of tests conducted on a hot water test bay on the plain bearings of a mag-drive chemical pump type Magnochem 50-200. All test specimens were tested under identical conditions and using hog water of 200°C as the pumping fluid. Whereas Ekasic D developed up to 100um deep cracks generated by surface corrosion, Ekasic C remained completely clear of corrosion and cracking (Figs. 9 and 10). The more robust anchoring of the bar shaped, bimodal grain structure within the overall microstructure also takes some of the credit for this positive effect. The reason why these microstructures have not been used for traditional ceramic bearings earlier is that the positive effect of the bar shaped structure had thus far only been demonstrated on a laboratory scale and that it had not been systematically tested before.

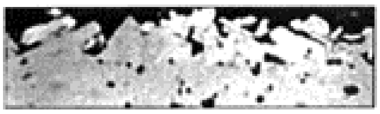

Fig. 9

Corrosion on Ekasic® D, 200°C, 20h

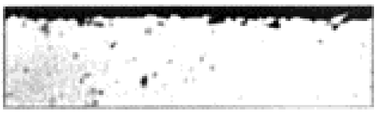

Fig. 10

Surface of Ekasic® C, 200°C, 20h

New ceramic materials require new bearing designs:

As far as using technical ceramics for the manufacture of pump components is concerned, it takes more than a simple exchange of the old materials for new ones. The technological advantages of ceramics cannot be utilised to the full unless the design of plain bearings is matched to the new material's characteristics. For example, it has to allow for reliable operation at both low and high temperatures, be capable of sustaining sudden temperature changes, and be strong enough to cope with the different types of mechanical stress. In addition, a means for the frictional heat generated in operation to adequately dissipate must be provided for. And, to complete the list of demands, the bearing must be easy to handle. Fig. 11 shows the new bearing design, a KSB patent, developed for a seal less pump. Its spring loaded elements and cones serve two purposes;

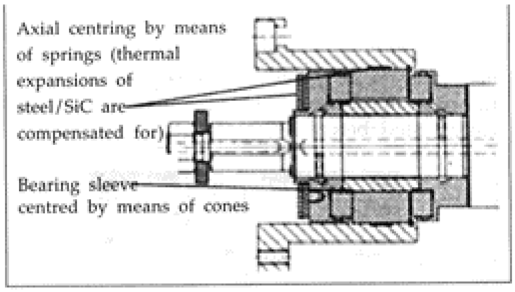

Fig. 11

Bearing design matched to the characteristics of ceramic material (KSB patent).

they centre the contact faces axially and radially, compensate for the different degrees of thermal expansion. With this design, the two opposite frictional elements always have the largest possible contact surface, irrespective of the temperature. It does away with edge contact areas and high compressive loads per unit area. In addition, the new design allows the frictional heat to build up evenly and to dissipate, and at the same time, prevents the bearings from being mounted wrong during assembly. The properties of the new material in connection with a design suitable for ceramic

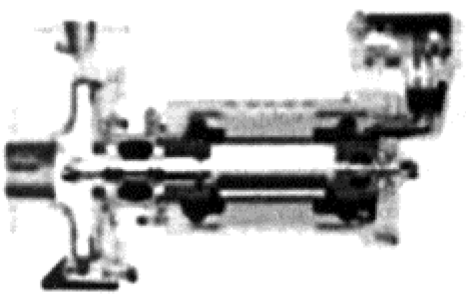

Fig. 12

Bearings of a SECOCHEM Ex pump

material have thus been able to broaden the application range of product lubricated bearings. The bearings of the SECOCHEM Ex pump are a case in point (Fig. 12) SiC materials continue to be modified and developed further, however, and the new developments are now in use.

Summary:

Compared with the tested materials described above, the specific properties of the materials available on the market today have meanwhile undergone further improvement. The technical implications made possible by the different material microstructures can be put into practice based on the nearly identical mechano-technologies characteristics. However, as explained before, the vital criterion for any application is the difference in a material's microstructure. In the autumn of 2001, KSB started manufacturing the patented bearing design from the new material. Bearings of the said design are produced as modular units suitable for installation in a number of pump series. This has allowed the manufacturer to place, what must be regarded from a technological viewpoint as the higher quality solution, also on a sound foundation economically.

Reference book:

Indian Pumps
Vol. XXXVII, March 200