Laser Structuring Broadens the Application of Silicon Carbide Bearings

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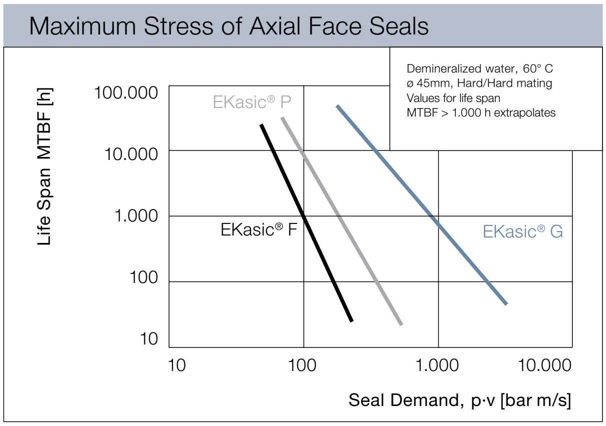
Talk about an optimized sliding surface. Check out how these new sintered silicon carbide materials can solve a wide range of sliding bearing problems.

In high-performance applications, modern sliding bearings make extreme demands on the materials used. For example, process fluid-lubricated bearings, such as those found in high-speed chemical pumps, must employ ceramic materials with a low-wear property profile for pumping corrosive or abrasive liquids.

For use in sliding bearings, standard sintered silicon carbide (SSiC) materials offer advantages over other high-performance ceramics. Furthermore, the SSiC microstructure can be selectively modified to achieve further improvements in the material. Now, a new range of SSiC materials has been introduced to solve an even wider range of sliding bearing problems.

One of these new SSiC materials is characterized by an outstanding load capacity to withstand even extreme pressures and thrust forces. It has graphite particles with sizes of 50-µm to 120-µm homogeneously dispersed in its structure to considerably reduce the coefficient of friction and improve the wear behavior. The self-lubricating effect of the graphite particles even permits temporary dry running. Thus, this material is ideal for tribological applications under poor lubrication conditions, such as in sliding bearings and mechanical seals.

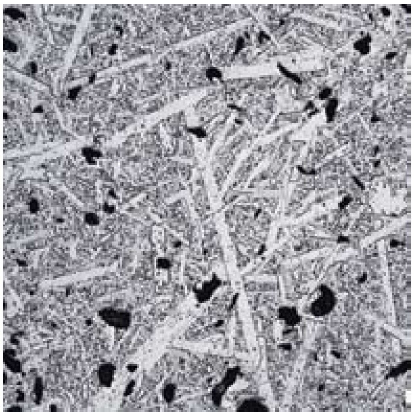
Another new SSiC material is highly corrosion resistant and, like the other, is highly resistant to attack by hot water. Since the water mainly corrodes the boundary layers between adjacent SiC grains (grain boundaries), a coarse-grained structure was developed for this material, with grain sizes up to 1.5-mm. This significantly reduces the grain boundary surface area, providing improved corrosion resistance.



Different load capacities of newly developed SSiC materials.

The long SiC grains have another advantage. They are anchored deep in the ceramic, and hot water or aggressive chemicals, which corrode the material to a depth of 20-µm, therefore have no chance to dissolve out the grains and damage the sliding surfaces.

Furthermore, because of its coarse-grained surface, this second new SSiC material has a higher load capacity. The contact pressure of tribologically loaded systems can therefore be further increased. With its excellent wear behavior, as well, this new SSiC material can considerably expand the application ranges of bearing and seal systems.



Coarse-grained microstructure of a new SSiC material with graphite inclusions to improve the dry-running behavior.

3D-microstructuring by an ND:YAG laser.

Overloaded thrust bearing of standard SSiC.

Reduced Break-Away Torque

As already indicated, besides improving corrosion resistance, the coarse-grained microstructure of these two new SSiC materials also results in a tribological optimization of the sliding surface. Because the extended SiC grains are randomly orientated at the surface of the part, the surface is not homogeneous but, on a microscopic scale, is finely undulating.

This microscopic structuring is the consequence of the anisotropic wear behavior of the SiC monocrystals (grains), which, according to their orientation, are abraded to different extents as the bearing stops and starts under poor lubrication conditions. Therefore, after the bearing surfaces have run in they are not polished to a mirror finish. Instead, a specific surface roughness remains.

Like sharkskin, whose reduced flow resistance is a consequence of it not being ideally smooth, the residual roughness of the bearing surface can also be seen to improve its flow properties. The risk of adhesive sticking between the sliding parts also reduces and therefore lowers the initial break-away torque on start-up of the bearing. This has particular advantages when using these materials in highly loaded mechanical seals.

Improved Load Capacity

Moreover, selective modification of the surface of certain silicon carbide sliding bearings significantly improves the hydrodynamics of the lubricating fluid. If micrometer-sized cavities are introduced into the surface by laser ablation, this provides hydrodynamic support of the liquid film, with increased pressure in the lubricant and therefore improved load capacity of the system.

Thrust bearing of new SSiC material with lubrication groove and hydrodynamic structuring.

Radial bearing of new SSiC material with lubrication groove and hydrodynamic structuring.

The cavities are designed such that they form a wedge-shaped gap between the two sliding surfaces of the bearing. This gap is responsible for the hydrodynamic build-up of the pressure maximum. The two sliding parts then experience a lift, similar to a water skier, even at low sliding velocities. However, the wedge-shape of the cavities can only be achieved with the necessary accuracy by special machining techniques.

In the case of certain ceramic sliding bearings, micromachining is carried out by means of a neodymium laser with a wavelength of 1064-nm. When the laser pulses are in the nanosecond range, the laser energy causes heating up of the surface for the duration of the pulse.

Since thermal conduction only permits slow energy transfer into the volume, the incident energy is concentrated on a very thin layer. The surface therefore reaches very high temperatures and the SiC material is suddenly vaporized. The machining accuracy achieved in both the lateral and vertical direction is of the order of less than 1-µm.

In addition, analysis of the structured surfaces by electron microscopy does not show any damage to the ceramic material beneath the structures. The mechanical strength, and therefore the reliability, of the SiC bearing part are not limited by microcracks or other damage patterns.

From Practice

The new SSiC materials, together with the development of innovative structuring and coating technologies, can significantly improve existing bearing and seal systems.

This improvement is necessary because of the continually increasing demands on sliding bearings in pump systems resulting from strict environmental regulations and increasingly harsh service conditions. A typical example is the exploitation of new gas and oil reserves, where modern extraction technology is penetrating into ever deeper regions where temperatures and pressures are higher.

Pumping out highly abrasive and corrosive oil sludge mixtures from the borehole requires a resistant, high-performance pump with carefully designed bearings and seals. After discovering that harsh stresses were severely reducing the lifetimes of borehole pumps equipped with conventional SSiC systems and consequently increasing the operating costs of the complete boring rig, a new SSiC bearing system was developed.

It was possible to exploit the excellent corrosion resistance of this new material and its resistance to wear by the solid particles in the oil sludge. Even more importantly, its suitability to ceramic design of the parts considerably improved performance, with lifetimes increased by orders of magnitude.

A similar task faced a manufacturer of magnetically coupled cargo pumps. Beside the necessity for rapidly pumping a large number of different fluids with variable viscosities and solids contents, the potential of breakdown resulting from incorrect operation had to be considered.

For example, the pump could be started up without opening the shut-off valves or the system could be shutdown too late after the tanks are empty, leading to an interruption of the fluid flow and dry running of the bearings. Such operating conditions inevitably meant that the critical loading limits of the SSiC thrust bearings being used were regularly exceeded. The new SSiC material has already proven valuable for use in cargo pumps to withstand the extreme loads and ensure reliable pump operation.

A further increase in the load capacity of the axial bearings was produced by the laser-induced application of hydrodynamically active fine structures on the sliding surface of the thrust bearing. Such optimization of the liquid behavior in the sliding gap, besides increasing the hydrodynamic pressure in the liquid film, also improves lubrication when there is insufficient process fluid.

The homogeneous lubrication film that is produced acts as a spring buffer, helping to intercept axial thrust peaks in the bearing system. Overall, the changes introduced, both to the design and the material used, have increased the critical loading limit by more than tenfold.

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