Fluid Dynamic Bearings (FDB)

New Technology to Replace Ball Bearings in Western Digital Hard Drives

Hard drive designs must constantly evolve to meet the increasing demands of computer applications and configurations. One component of hard drive designs that has had to evolve is the spindle motor bearing.

The spindle is the rod-like axle inside the hard drive. The disks inside a hard drive are center-mounted on the spindle, and the spindle motor rotates the spindle and the disks.

The majority of hard drives on the market implement ball bearing (BB) spindle motors. However, the industry is moving toward a different type of bearing design known as fluid dynamic bearings (FDB).

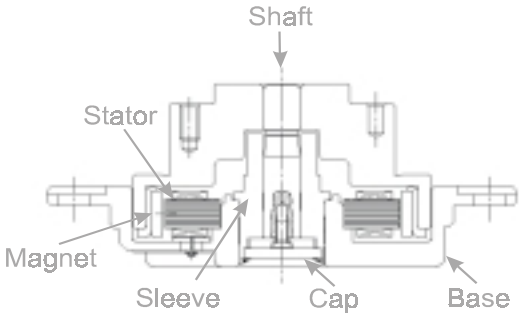
Bearing Technology

For 50 years, fluid dynamic bearings have seen usage in gyroscopes and precision machine tools. However, because of the tight tolerances required to manufacture FDB components, they were not used in high-volume applications until recently. FDB motors were first introduced in hard drives in 1997 and over several generations of volume production have proven reliable. Though most hard drives today use BB spindle motors, this technology has limitations. Ball bearings exhibit imperfections in roundness that can cause irregular track writing to disk. Because future increases in hard drive capacity will likely come from expanding track density, ball bearing motors may soon reach the limit of their effectiveness.

Spindle Motor Technology

In a BB motor, the spindle is built with two conventional ball bearings with contacting bearing raceways and balls. The metal-to-metal contact between the raceways and balls provides a high-stiffness system. Mechanical contact in the ball-race interface is facilitated by a boundary lubricant film. The disks inside the hard drive are mounted on the spindle motor with spacer rings resident between the disks.

The FDB motor differs significantly in spindle design compared to a BB motor. In an FDB motor, the spindle is supported by two hydrodynamic journal bearings and two hydrodynamic thrust bearings. The hydrodynamic journal and thrust bearings are formed between a shaft and thrust-plate and a sleeve with the controlled clearance filled with lubricant. The lubricant is typically a few microns in thickness. The bearings are made with a specially designed herringbone or other type of groove pattern to provide stable operation of the spindle.



Western Digital Fluid Dynamic Bearing Motor

Western® Digital

The Advantages of FDB versus BB

The physics of ball bearings in spindle motors cause them to lag behind the effectiveness of fluid dynamic bearing designs in the following areas:

- Storage capacity
- Acoustics
- Shipping and handling robustness
- Non-operational shock
- Rotational speed

Constant advancement in each of these areas is essential to the development of hard drive technology.

Storage Capacity/Minimized NRRO

The BB spindle exhibits a high level of random departure from the precise circular motion of the spindle hub due to surface imperfections in the BB design. This limiting factor is known as non-repeatable runout (NRRO).

The elimination of metal-to-metal contact in FDB designs due to geometric defects enables the attenuation of NRRO. NRRO limits how tightly information can be packed together on a hard drive. Thus, it is possible to achieve higher track densities and areal densities in FDB-equipped hard drives since BB-equipped drives have a typically higher rate of NRRO.

Acoustics

Lower acoustics has become an important feature in hard drives due to their increasing use in consumer electronics products.

FDB dramatically reduces noise levels over BB since there is no mechanical contact between the drive housing and the turning part of the spindle motor. The fluid in FDB hard drives also acts as a damping agent, further limiting noise levels.

Shipping and Handling Robustness

FDB drives exhibit none of the fretting corrosion issues found in some ball bearing drives during shipping (fretting refers to micro-movement within the drive that leads to corrosion, accelerated wear, and potential failure). Furthermore, FDB drives are insensitive to acoustics aging, or degradation of acoustics due to long term running, shipping, and handling.

Non-Operational Shock

FDB spindle motors show much better non-operating shock resistance compared to BB motors. The small contact areas between the balls and raceways in a BB motor may suffer bearing damage resulting in high acoustics and NRRO degradation after experiencing non-operating shocks. The conformance between the shaft and sleeve in FDB motors greatly reduces contact stress. The lubricant film in FDB drives also provides additional damping to shock.

Rotational Speed

BB hard drives begin to have lubrication and overheating problems if pushed to high rotational speeds, and as a result can have a reduced lifespan. The lack of metal-to-metal friction in FDB drives means they can withstand higher rotational speeds and last longer than BB drives.

Cost

The ball bearings used in BB spindle motors can be produced for less than a dollar each at this time. However, recent major reductions in FDB manufacturing costs allow FDB to be a competitive alternative to BB technology moving forward. Since they use fewer components than ball bearings, fluid dynamic bearings have the potential to achieve increasingly lower production costs.

Summary

The hard drive industry is beginning to move away from ball bearing spindle motors and use fluid dynamic bearings in more and more products. The FDB bearing design incorporates a layer of lubricant instead of ball bearings in the hard drive spindle motor. As an alternative to conventional ball bearing technology, FDB designs provide increased storage capacity, non-operational shock resistance, speed control, shipping and handling robustness, and improved acoustics.

FDB designs will continue to be used more frequently, especially as production costs are reduced. FDB hard drives will help manufacturers maintain the competitive, rapid increases in storage capacity and access that spur the industry.

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