

PARTICLE FREE SHIELD ASSEMBLY FOR SPINDLE MOTOR**Cross Reference to Related Applications**

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This application claims priority from United States Provisional Patent Application Serial Number 60/117,822 filed January 29, 1999.

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Field of the Invention

The present invention relates generally to the field of disc drives, and more particularly for shielding a ferrofluid seal from particles during assembly, as well as a method for putting the shield in place.

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Background of the Invention

Disc drives, including magnetic drives, optical drives and magneto-optical disc drives, are widely used for storing information. A typical disc drive has one or more discs for storing information in a plurality of concentric circular tracks. This information is written to and read from the discs using read/write heads mounted on actuator arms which are moved from track to track across surfaces of the discs by an actuator mechanism. The discs are mounted on a spindle which is turned by a spindle motor to pass the surfaces of the discs under the read/write heads. The spindle motor generally includes a shaft fixed to a baseplate and a hub, to which the spindle is attached, having a sleeve into which the shaft is inserted. Permanent magnets attached to the hub interact with a stator winding on the baseplate to rotate the hub relative to the shaft. One or more bearings between the hub and the shaft facilitate rotation of the hub.

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The spindle motor also typically includes an exclusion seal to seal interfacial spaces between the hub and the shaft. This is necessary, because lubricating fluids or greases used in the bearings tend to give off aerosols or vaporous components that migrate or diffuse out of the spindle motor and into a disc chamber in which the



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discs are maintained. This vapor often transports other particles, such as material abraded from the bearings or other components of the spindle motor, into the disc chamber. These vapors and particles deposit on the read/write heads and the surfaces of the discs, causing damage to the discs and the read/write heads as they pass over the discs. Thus, the migration of these contaminants into the disc chamber must be prevented.

To prevent the migration of these contaminants into the disc chamber, the latest generation of spindle motors utilize a ferrofluidic seal between the shaft and the hub. Ferrofluidic seals are described in, for example, U.S. Pat. No. 5,473,484, which is incorporated herein by reference. A typical ferrofluidic seal consists of a ferrofluid, an axially polarized annular magnet and two magnetically permeable annular pole pieces attached to opposing faces of the magnet. The ferrofluid is conventionally composed of a suspension of magnetically permeable particles suspended in a fluid carrier. Generally, the magnet and the pole pieces are fixed to the hub and extend close to but do not touch the shaft. Magnetic flux generated by the magnet passes through the pole pieces and the shaft, which is also magnetically permeable, to magnetically hold the ferrofluid in magnetic gaps between the pole pieces and the shaft, thereby forming a seal.

However, a problem arises from the existence of particles and the like which may exist or be created during assembly of the motor. For example, the typical fixed shaft has a center hole into which a screw is threaded. When the screw is backed out of the hole, very tiny magnetic particles may be created which could fall into the ferrofluid.

Efforts have been made in the past to press a shield onto the outer surface of the shaft to serve as a cover over the ferrofluid and prevent particles from falling in. However, the very fact of an interference fit between shaft and seal directly above the magnetic fluid, may create burrs and loose particles which could fall into the fluid. Particles 50 microns or greater in size could cause the magnetic fluid to splash out of the field. Further, slivers of metal could be created which, if they protrude into the seal, could cause the ferrofluid to migrate out of the gap. In addition to diminishing the

effectiveness of the seal, during operation of the motor once it is installed into the disc drive, the fluid could either be splashed or migrate out of the motor region to the head disc area and cause disc drive failure. Therefore, a solution is needed to address these problems.

5 Other features and advantages of this invention will be apparent to a person of a skill in the art who studies the exemplary disclosure to be given below in conjunction with the associated figures.

Summary of the Invention

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The present invention provides apparatus for shielding the ferrofluid of a magnetic seal from particles or the like falling into the fluid. The invention further provides apparatus and a method for installing such a shield without creating particles or burrs.

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According to a preferred form of the invention, in a motor having a fixed shaft and a ball bearing with inner and outer races mounted near one end of the shaft, a magnetic seal is provided which is supported from a seal support which is integrated with or adhesively attached to the back iron which rotates with the hub, the seal magnetic pole pieces extending around the shaft and holding ferrofluid between the ends of the pole pieces and the shaft. A vacuum press holds the shield piece and heats the shield to a temperature so that the inner radius of the washer-shaped seal piece is larger than the outer diameter of the shaft. The press then lowers the shield over the outside diameter of the shaft; the shield is positioned by providing a positioning surface on the vacuum press which butts against the end of the shaft, with the vacuum holding portion of the press extending lower than this alignment surface to place the shield on the outside of the shaft. As the shield cools, it presses against the outside surface of the shaft and is fixed in place without any particles being created while the interference fit between shaft and shield is established.

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In a further feature of the invention, the seal support which supports the radially outer edge of the magnetic seal, may include a catcher recess which faces the

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shaft and is in a position to catch any additional stray metal particles which may exist in the air gap between the shield piece and the magnetic seal.

In a preferred embodiment of the invention, the assembly press, in addition to including the vacuum for holding the shield in place, is modified to include a closed looped heating system to preheat the shield.

The features and advantages which characterize the present invention will be apparent upon reading the following detailed description and review of the associated drawings.

Brief Description of the Drawings

Figure 1 is a plan view of a disc drive in which a spindle motor incorporating a ferrofluid seal and shield according to an embodiment of the present invention is especially useful.

Figure 2 is a sectional side view of an embodiment of a spindle motor incorporating a ferrofluid seal as supported in the prior art.

Figure 3 is a partial sectional view of the spindle motor of Fig. 2 as modified to show the seal support and the shield of the present invention.

Figure 4 is a partial sectional view of the motor of Fig. 3 in schematic form showing the press shield and shaft as they are used to position the shield.

Detailed Description

FIG. 1 is a plan view of a magnetic disc drive for which a spindle motor having a ferrofluidic seal according to the present invention is particularly useful. Referring to FIG. 1, a disc drive 100 typically includes a housing 105 having a base 110 joined to a cover 115. A number of discs 130 having surfaces 135 covered with a magnetic media (not shown) for magnetically storing information are attached to a spindle 140. A spindle motor (not shown in this figure) turns the spindle 140 to rotate the discs 130 past read/write heads 145 which are suspended above surfaces 135 of the

discs by a suspension arm assembly 150. In operation, the discs 130 are rotated at high speed past the read/write heads 145 while the suspension arm assembly 150 moves the read/write heads in an arc over a number of radially spaced tracks (not shown) on the surfaces 135 of the discs 130. Thus, enabling the read/write heads 145 to read and write magnetically encoded information to the magnetic media on the surfaces 135 of the discs 130 at selected locations.

FIG. 2 is a sectional side view of a spindle motor 155 of a type which is especially useful in disc drives 100. Typically the spindle motor 155 includes a rotatable hub 160 having an inner surface 165 disposed about an outer surface 170 of a shaft 175. A ferrofluidic seal 185 according to the present invention seals and electrically connects the outer surface 170 of the shaft 175 to the inner surface 165 of the hub 160. One or more magnets 190 attached to a periphery 195 of the hub 160 interact with a stator winding 205 attached to the base 110 to cause the hub 160 to rotate. The hub 160 is supported on the shaft 175 by one or more bearings 215. The bearings 215 can be either a ball-bearing (as shown) or a fluid-dynamic bearing (not shown). A ball-bearing generally includes one or more balls 220 loosely held by a retainer 225 between an inner race 230 and an outer race 235. Interfacial spaces 245 between the balls 220, the retainer 225 and the inner and outer races 230,235, are filled with a lubricating fluid or grease to facilitate movement of the balls 220. In a fluid-dynamic bearing, a lubricating fluid, such as gas or a liquid, provides a bearing surface between the hub 160 and the shaft 175. Dynamic pressure-generating grooves (not shown) formed in races on the inner surface 165 of the hub 160 or the outer surface 170 of the shaft 175 generate a localized area of high pressure which radially supports the hub. Preferably, regardless of the type of bearings 215 used, the outer race 235 forms a raised annular shoulder 250 or ledge around the inner surface 165 of the hub 160 against which the ferrofluidic seal 185 is held.

Referring specifically to the enhanced shield design of FIG. 3, this figure shows a shaft 300 which in this example is a fixed shaft surrounded by a rotating hub 302 supported from a rotating back iron 304 which supports a magnet 306 which rotates outside a stator 308. Activation of the stator causes high speed, constant speed rotation

of the hub and any disc or discs it may support. In this example, a ball bearing generally indicated at 310 includes inner race 312 and outer race 314. The outer race 314 supports a seal support element 316 which supports both a positioning ring 328 and a magnetic seal 318 which includes pole pieces 320, 322 and magnet 324. The magnetic seal provides the necessary magnetic attraction to retain the ferrofluid 326 in the region between the ends of hole pieces 320, 322 and the outer surface of the shaft 300. However, in order to maintain the fluid in its location, especially under high speed long-term operating conditions, measures must be taken to prevent any particles, however small, from falling into the ferrofluid 326. It has therefore become important to put a shield 330 in place adjacent the end of the shaft 300 and spaced across a small gap 332 from the upper pole of the magnetic seal.

The problem presented by this shield is the requirement for an interference fit between the outer surface of the shaft 300 and the inner surface of the shield in order to prevent undue expense in mounting the shield on the shaft. However, these two parts, when pressed together, may create burrs and loose particles due to gauling. These particles may fall into the magnetic fluid. Burrs touching the fluid, or particles greater than 50 μm will cause the magnetic fluid to splash out of the ferrofluid seal 318. Burrs or other long pieces stretching into the magnetic fluid can easily cause the fluid to wick out of the region. The magnetic fluid can then migrate out to the head disc area and cause disc drive failure. Any ferrofluid splash or migration will also lower the pressure capacity of this seal and result in leakage through the motor, over the long-term resulting in drive failure.

Therefore, the approach utilizing press 400 shown in Fig. 4 has been adopted. In this approach, the press incorporates or cooperates with a heater to heat the shield; preferably a closed loop heating system is incorporated in the press to preheat the shield 330. The material of the shield was chosen to be aluminum, in contrast to the stainless steel which is typical of shaft 300. The material was chosen for its ease in heating and its response to the heating in expanding its inner diameter generally indicated at 350. As the diameter expands to be greater than the outer diameter of the shaft, with the shield held in place preferably by a vacuum against the lower surface of

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the press, then the press lowers the shield 330 over the outer diameter of the shaft. The position of the shield relative to the shaft is established by having a reference, preferably surface 410 defined on a region of the press which will bump up against the upper surface 420 of the shaft 300. After the shield 330 is properly in place, it quickly
5 loses its heat because of the high conductivity of the aluminum, and heat is carried away through the shaft. The shield shrinks to fit tightly against the outer surface of the shaft without any creation of burrs or any other metal particles. After the shield has cooled sufficiently, the vacuum, which is imposed through the source 420, is withdrawn and the press is drawn away in the direction of the arrow 415 leaving the shield in place.

10 In summary, with the shield material preferably changed to aluminum, and the assembly press modified to include a closed loop heating system to heat the shield to the desired target temperature and achieve the necessary expansion to slip smoothly over the outer surface of the shaft, the inner diameter of the shield is expanded so that interference between the parts during the assembly process is eliminated. As a result,
15 the particle generation due to gauling is eliminated while the interference fit is ultimately achieved.

In a further feature of the invention, it should be noted that a particle catcher region 332 is also supplied or defined in the shield support piece 328. Due to the high speed rotation of the hub 302 around the shaft, any particles which may be
20 captured between the shield 330 and the seal 318, tend to exist in the gap 360. The centrifugal force created by the high speed rotation of the hub and the seal which rotates with the shaft, will cause any loose particles to be thrown outward towards the catcher region 332 and be held in this recess so that they cannot escape through the gap between the shield 330 and the protruding edge 362 of the seal support 316.

25 Other features and advantages of the present invention will be apparent to a person of skill in the art who studies the present invention disclosure. Therefore, the scope of this invention is to be limited only by the following claims.

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Claims

What is claimed is:

1. In a spindle motor comprising
5 a shaft with one or more ball bearings each having an inner and outer race supported on said shaft and supporting a hub from the outer race for rotation against the shaft, and
a magnetic seal adjacent the ball bearing and nearer the ball bearing to an end of the shaft, and
10 a shield supported by an interference fit near an end of said shaft between the magnetic seal and the end of the shaft,
a method of placing the shield around the shaft near the magnetic seal comprising heating the shield to cause the inner over diameter of the shield to be greater than an outer diameter of the shaft,
15 holding said shield on a press and actuating said press to place said shield over said outer diameter of said shaft, and
holding said shield in place until it cools sufficiently to create an interference fit between the inner diameter of the shield and the outer diameter of the shaft.
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2. A method as claimed in claim 1 wherein the press includes a heating system for heating said shield so that the inner diameter of the shield is greater than the outer diameter of the shaft.
- 25 3. A method as claimed in claim 2 wherein said shield is aluminum and said shaft is steel so that the shield may be easily heated to have the inner diameter be greater than the outer diameter of the shaft.
4. A method as claimed in claim 3 wherein said shield is heated to about 400
30 degrees fahrenheit.

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5. A method as claimed in claim 4 wherein said press includes a reference surface which butts against a reference on said shaft so that said shield is located consistently in the same location relative to the end of the shaft.