DISC DRIVE DEFLECTED DISC CLAMP LAPPING PROCESS

Technical Field

The invention relates generally to disc drives and specifically to disc drives having several disc platters stacked together to form a platter assembly. More specifically, the invention relates to a lapped disc clamp used to secure a disc platter assembly to a drive motor, as well as a process for manufacturing the lapped disc clamp.

Background

Disc drives are data storage devices that store digital data in magnetic form on a rotating storage medium on a disc. Modern disc drives comprise one or more rigid discs that are typically coated with a magnetizable medium and mounted on the hub of a spin motor for rotation at a constant high speed. Information is stored on the discs in a plurality of concentric circular tracks typically by transducers ("heads") mounted to an actuator assembly for movement of the heads relative to the discs. During a write operation, data is written onto the disc track and during a read operation the head senses the data previously written on the disc track and transfers the information to the external environment. Critical to both of these operations is the accurate locating of the head over the center of the desired track.

The heads are each mounted via flexures at the ends of actuator arms that project radially outward from the actuator body or "E" block. The actuator body typically pivots about a shaft mounted to the disc drive housing adjacent the outer extreme of the discs. The pivot shaft is parallel to the axis of rotation of the spin motor and the discs, so that the heads move in a plane parallel to the surfaces of the discs.

Typically, such actuator assemblies employ a voice coil motor to position the heads with respect to the disc surfaces. The voice coil motor typically includes a flat coil mounted horizontally on the side of the actuator body opposite the

actuator arms. The coil is immersed in a vertical magnetic field of a magnetic circuit comprising one or more permanent magnets and vertically spaced apart magnetically permeable pole pieces. When controlled direct current (DC) is passed through the coil, an electromagnetic field is set up which interacts with the magnetic field of the magnetic circuit to cause the coil to move in accordance with the well-known Lorentz relationship. As the coil moves, the actuator body pivots about the pivot shaft and the heads move across the disc surfaces. The actuator thus allows the head to move back and forth in an arcuate fashion between an inner radius and an outer radius of the discs.

Modern disc drives typically include one or more discs mounted to the spin motor. Spacers are used to provide the separation between discs necessary for the actuators arms to movably locate the heads in relation with the disc surfaces. The discs and spacers collectively form a disc stack assembly, or disc pack, that is mounted on the spin motor hub and held together with a leaf spring disc clamp.

Disc clamps can be either stamped or milled. While milled clamps are more rigid and less prone to deflecting the abutting disc surface, they are relatively expensive to produce. Consequently, stamped leaf spring disc clamps, which are substantially less expensive, have become popular. The clamp is typically a circular spring-steel, sheet metal structure having a central portion and a rib portion at or near the OD of the clamp, with an annular rib formed in the rim portion of the clamp. The central portion of the leaf spring disc clamp has a partial aperture that is bent or deflected toward the center of the clamp, forming a leaf spring above the level of the annular rib, and includes a plurality of screw holes spaced symmetrically about the central portion of the clamp. The screws used to mount the disc clamp springingly bend and deflect the central portion of the clamp toward the upper surface of the motor spindle as the screws are tightened, thereby forcing the annular rib into firm contact with the uppermost disc surface and applying a clamping force to the disc stack.

This type of disc clamp is not without problems. The disc clamp is secured with a plurality of screws, typically 3, circumferentially spaced around the center of the clamp. The majority of the clamping force is exerted by the rib

portion adjacent the screw locations, with a somewhat reduced level of clamping force exerted by the rib portion between the screw locations. This variation in clamping force can mechanically distort the discs in a phenomenon sometimes referred to as "potato chipping," meaning that the portions of the disc nearest the clamp screws are displaced further than the portions of the disc between the screws.

One solution to "potato chipping" is to increase the number of mounting screws used to secure the disc clamp to the spin motor hub. As more screws are used and are spaced closer together, the discrepancy in clamping force is reduced but not eliminated. A disadvantage of this approach is that the use of additional screws complicates the manufacturing and assembly process.

Mechanical distortion of the disc surface can, in turn, lead to undesirable variations in the read/write signals detected and written by the heads of the disc drive. Since the heads will fly at varying heights around the circumference of the disc while attempting to follow a distorted disc, the signals used to read and write data on the discs may be inadequate to ensure reliable data storage and recovery.

Summary of the Invention

Against this backdrop the present invention has been developed. The performance of a leaf spring disc clamp can be enhanced by increasing the flatness of an annular contact surface in its fully deflected, installed position. Such a disc clamp exhibits a substantially improved flatness in the installed state at a minor expense in applied axial force and thus has a more uniform force distribution applied around the annular contact surface. It has further been determined that a lapping process can be used to achieve a desired level of performance without fully deflecting the clamp prior to installation in a disc pack.

Accordingly, an aspect of the invention is found in a method of manufacturing a leaf spring disc clamp for use in a disc drive to clamp a data storage disc to a spindle hub of a spin motor. The method includes the steps of forming a piece of spring sheet metal into a generally circular leaf spring disc clamp having an annular rim portion and a central bowed leaf spring portion. The clamp is then

placed on a lapping surface, and a force is applied to the central portion of the clamp to partially deflect the central portion of the clamp from an undeflected position toward the lapping surface. The clamp is then moved relative to the lapping surface to abrade and remove a portion of the rim portion to form a flattened annular contact surface on the rim portion.

Another aspect of the invention is found in a leaf spring disc clamp for fastening a data disc to a disc spin motor hub in which an annular rim portion forms an annular rib that has a flat annular contact surface thereon for uniformly distributing clamping force onto the data disc.

These and other features as well as advantages that characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Figures

FIG. 1 is a plan view of a disc drive incorporating a spring disc clamp in accordance with a preferred embodiment of the invention with the disc drive cover partially removed.

FIG. 2 is an exploded view of an exemplary disc pack assembly utilizing three leaf spring disc clamp in accordance with a preferred embodiment of the invention.

FIG. 3 is a cross sectional view taken along the line 3-3 of FIG. 2 of the disc clamp prior to lapping in accordance with a preferred embodiment of the present invention.

FIG. 4 is a view as in FIG. 3 showing the application of clamping force on the central portion of the clamp in the force application step in accordance with a preferred embodiment of the present invention.

FIG. 5 is a view as in FIG. 4 showing the flattening of the annular rib during the lapping step in accordance with a preferred embodiment of the present invention.

FIG. 6 is a cross sectional view of the disc clamp as in FIG. 3 after the lapping step and after reversal of the clamping force.

Detailed Description of Preferred Embodiments

A disc drive **100** constructed in accordance with a preferred embodiment of the present invention is shown in FIG. **1**. The disc drive **100** includes a base **102** to which various components of the disc drive **100** are mounted. A top cover **104**, shown partially cut away, cooperates with the base **102** to form an internal, sealed environment for the disc drive in a conventional manner. This assembly is called a head disc assembly (HDA). The components include a spin motor **106** which rotates one or more discs **108** at a constant high speed. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates about a bearing shaft assembly **112** positioned adjacent the discs **108**.

The actuator assembly **110** includes a plurality of actuator arms **114** which extend over the surfaces of the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118** which includes an air bearing slider enabling the head **118** to fly in close proximity above the corresponding surface of the associated disc **108**.

The spin motor **106** is typically de-energized when the disc drive **100** is not in use for extended periods of time. The heads **118** are moved over park zones **120** near the inner diameter of the discs **108** when the drive motor is de-energized. The heads **118** are secured over the park zones **120** through the use of an actuator latch arrangement **122**, which prevents inadvertent rotation of the actuator arms **114** when the heads are parked.

The radial position of the heads **118** is controlled through the use of a voice coil motor (VCM) **124**, which typically includes a coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets and return plates **128** which are spaced apart and establish a vertical magnetic field between them in which the coil **126** is immersed. The controlled application of current to the coil **126** causes magnetic interaction between the permanent magnets **128** and the coil **126** so that the coil **126** moves in accordance with the well known Lorentz

relationship. As the coil **126** moves, the actuator assembly **110** pivots about the bearing shaft assembly **112** and the heads **118** are caused to move across the surfaces of the discs **108**.

A flex assembly **130** provides the requisite electrical connection paths for the actuator assembly **110** while allowing pivotal movement of the actuator assembly **110** during operation. The flex assembly includes a printed circuit board **132** to which head wires (not shown) are connected; the head wires being routed along the actuator arms **114** and the flexures **116** to the heads **118**. The printed circuit board **132** typically includes circuitry for controlling the write currents applied to the heads **118** during a write operation and for amplifying read signals generated by the heads **118** during a read operation. The flex assembly terminates at a flex bracket **134** for communication through the base deck **102** to a disc drive printed circuit board (not shown) mounted to the bottom side of the disc drive **100**.

The discs **108** are secured to the hub **230** of a spin motor **106** in spaced-apart fashion. As illustrated in FIG. **2**, three discs **108** are alternatively stacked together with spacers **220** that provide the vertical spacing necessary for actuator assembly function (described hereinafter). Any combination of discs **108** and spacers **220** can be assembled together to form a disc pack. The stacked set of discs **108** and spacers **220** are mounted to the spin motor **106** via the disc clamp **210**. This combination of discs **108** and spacers **220**, along with disc clamp **210** can be referred to as a disc assembly or disc pack. Preferably, three mounting screws (not shown) are used to secure disc clamp the **210** to the spin motor hub **230** using threaded bores **222** in the hub 230.

FIG. **2** shows the leaf spring disc clamp **210** according to a preferred embodiment of the present invention. The leaf spring disc clamp **210** has a bowed central leaf spring portion **218** that has a central aperture **216**. The clamp **210** also has an annular rim portion **240** that forms an annular rib **330** (better seen in the sectional views of FIGS. **3-6**). As described hereinafter, annular rib **330** preferably provides the contact surface between the disc clamp **210** and the upper surface of the uppermost disc **108**. In the embodiment illustrated, the leaf spring

disc clamp 210 has a total of three screw mounting holes 212 and three spanner slots 214. The spanner slots 214 are used for alignment during the assembly process. Without these spanner slots 214, the disc clamp 210 would simply rotate as one attempts to tighten the first mounting screw (not shown). If desired, the spanner slots 214 may be replaced with holes for receiving guide pins.

It should be noted that the deflection and lapping process in accordance with a preferred embodiment of the present invention can be used just as easily with a spring clamp having any number of screw holes and can also be applied to a solid or milled clamp. The invention is described herein with particular reference to a stamped leaf spring disc clamp utilizing three screws, as exemplary, for description purposes only. The deflection and lapping process used to manufacture these clamps is illustrated in FIGS. 3-6.

A downward deflective force is applied around each screw hole location during the lapping process of the present invention. FIG. 4 illustrates the positioning of the downward or deflective force applied near each screw hole location 340. The effect of the deflective force can be seen in this figure by the position of central leaf spring portion 320 relative to lapping plane 420. Lapping plane 420 represents the working surface of a lapping station and represents a flat surface from which relative positions can be described.

Lapping can begin once the leaf spring disc clamp 210 has been partially deflected as seen in FIG. 4. FIG. 5 illustrates disc clamp 210 after lapping has been completed. The annular rib 330 now has an annular flat contact surface 335 that approximately corresponds to the portion of the disc clamp 210 that contacted the lapping surface. Because stamped materials can present variations in configuration, it is possible, indeed probable, that dissimilar amounts of material may be removed from the annular rib 330 in creating the annular flat contact surface 335. This is illustrated in FIG. 5, in which annular flat contact surface 335 is represented as having an uneven width. The annular flat contact surface 335 is wider, for example, at location 530 in comparison with location 535.

FIG. 6 shows the leaf spring disc clamp 210 after lapping and after the deflection force applied in the previous lapping step has been removed. Central

leaf spring portion 320 can be seen in its undeflected position in which it is relatively further away from an imaginary line drawn across the bottom of the disc clamp 210. In comparison with FIG. 5, it can be seen that annular flat contact surface 335 appears narrower at location 635 than at location 535, since portions of annular flat contact surface 335 can twist or deflect from a planar position once the deflective force has been removed. It is intended that the annular flat contact surface 335 be as flat as possible when the disc 210 is installed. It may not be as flat when in an undeflected position.

When installed, the disc clamp 210 may not have a flat annular contact surface 335 that is entirely planar. The lapping process is preferably carried out while the disc clamp 210 is only partially deflected. Thus, while the resulting annular contact surface 335 would be even flatter if lapping took place while the clamp 210 was fully deflected, full deflection may structurally damage the clamp 210. When the clamp 210 is fully deflected (as installed), it undergoes plastic deformation. It is important that plastic deformation of the disc clamp 210 not occur until final installation. As a result, it is preferred that the disc clamp 210 be deflected to a position approximately halfway between an undeflected position and a fully deflected, installed position during lapping. This corresponds to a deflective force during lapping that is about 70 percent that of the force applied to the fully installed clamp 210.

Lapping can be accomplished in a variety of manners. A combination of lathe and mandrel can be used, although a lapping station is preferred. A lapping station includes a flat plane bearing an abrasive material suitable to remove small amounts of material from the spring disc clamp. The clamp can be made from a variety of materials, although stainless steel is preferred. The flat plane of the lapping station moves relative to the disc clamp 210. The flat plane can be square, circular or some other shape and can either vibrate, oscillate or rotate at a speed sufficient to remove material at a desirable rate. Alternatively, especially for low volume production, the lapping station could be stationary and the disc clamp 210 could be moved about on the abrasive surface. Preferably, only a small amount of material is removed from the annular contact surface. In a preferred embodiment,

less than about 0.004 inches is removed. More preferably, the amount of material thickness removed is between about 0.001 inches and about 0.003 inches.

The following non-limiting example is intended only to illustrate one preferred embodiment of the invention.

Working Example

Standard production stamped clamps were processed according to the following procedure:

- Deflect clamp to a position approximately halfway between an undeflected position and a fully deflected (installed) position.
- Remove a small amount of material (approximately 0.004 inches) from annular contact ring of clamp using a mandrel on a lathe.
- Subsequent inspection under a microscope indicated that more material was removed from the annular contact ring in areas in radial alignment with the screw holes.

Five disc packs were assembled using the processed clamps, and five were assembled using unprocessed clamps. The average axial force was reduced by 15 to 20 percent in the disc packs using the processed disc clamps. Average flatness, which was measured at peak acceleration at an ID radius) was improved by about 70 percent. This roughly corresponds to the flatness of an unclamped disc.

In summary, the invention involves a method of manufacturing a leaf spring disc clamp (such as **210**) for use in a disc drive (such as **100**) to clamp a data storage disc (such as **108**) to a spindle hub (such as **230**) of a spin motor (such as **106**). The method includes forming a piece of spring sheet metal into a generally circular leaf spring disc clamp (such as **210**) having an annular rim portion (such as **240**) and a central bowed leaf spring portion (such as **218**). The clamp (such as **210**) is placed on a lapping surface, and a force is applied to the central leaf spring portion (such as **218**) of the clamp (such as **210**) to partially deflect the central portion (such as **218**) of the clamp (such as **210**) from an undeflected position toward the lapping surface. The clamp (such as **210**) is moved relative to the lapping surface to remove a portion of the rim portion (such as **240**) to form a flattened annular contact surface (such as **335**) on the rim portion (such as **240**).

Preferably, the force applied is effective in deflecting the central leaf spring portion (such as **218**) of the clamp (such as **210**) about half way between the undeflected position and an installed position. The lapping step preferably removes less than about 0.004 inches of material from the annular rim portion (such as **240**). In a preferred embodiment, the annular rim portion (such as **240**) includes an annular rib (such as **330**) that has a curved cross sectional shape bearing the annular contact surface thereon.

Preferably, the central leaf spring portion (such as **218**) of the clamp (such as **210**) has a plurality of screw holes (such as **340**) therethrough for fastening the disc clamp (such as **210**) to the spindle hub (such as **230**). Preferably, the force applied to deflect the clamp (such as **210**) is applied substantially equally to the central portion (such as **218**) around each of the screw holes (such as **340**).

A preferred embodiment of the invention is found in a leaf spring disc clamp (such as **210**) for fastening a data disc (such as **108**) to a disc spin motor hub (such as **230**). The leaf spring disc clamp (such as **210**) has a generally circular disc shaped body having a bowed central leaf spring portion (such as **218**) and an annular rim portion (such as **240**). The central spring portion (such as **218**) defines a central aperture (such as **216**) therethrough and has spaced apertures (such as **212**) around the central aperture (such as **216**) for mounting the disc clamp (such as **210**) to a spin motor hub (such as **230**). The rim portion (such as **240**) forms an annular rib (such as **330**) that has a flat annular contact surface (such as **335**) thereon for distributing clamping force onto the data disc (such as **108**).

Preferably, the flat annular contact surface (such as **335**) lies in a common plane when the central portion (such as **218**) of the clamp (such as **210**) is deflected to an installed position. In a preferred embodiment, the annular contact surface (such as **335**) lies in a common plane when the central portion (such as **218**) of the clamp (such as **210**) is deflected to a position between an undeflected position and an installed position.

The invention also involves a disc drive (such as **100**) having a data storage disc (such as **108**) carried on a spin motor (such as **106**) for rotating the disc (such as **108**) and an actuator assembly (such as **110**) for moving a read/write head (such as **118**) over a surface of the disc (such as **108**). The disc drive (such as **100**) includes a leaf spring disc clamp (such as **210**) attaching the disc (such as **108**) to a hub (such

as 230) of the spin motor (such as 106). The clamp (such as 210) has an annular rim (such as 240) portion having a flat annular contact surface (such as 335) thereon contacting the disc (such as 108) to distribute clamping force to the disc (such as 108) to minimize disc distortion.

The invention also involves a disc drive (such as 100) having a data storage disc (such as 108) carried on a spin motor (such as 106) for rotating the disc (such as 108) and a disc clamp (such as 210) fastening the disc (such as 108) to the spin motor (such as 106). The disc drive (such as 100) includes means on the disc clamp (such as 210) for substantially evenly distributing a clamping force between the disc clamp (such as 210) and the disc (such as 108) to minimize surface distortion of the disc (such as 108).

It will be clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been described for purposes of this disclosure, numerous changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.

Claims

What is claimed is:

1. A method of manufacturing a leaf spring disc clamp for use in a disc drive to clamp a data storage disc to a spindle hub of a spin motor, the method comprising the steps of:

(a) forming a piece of spring sheet metal into a generally circular leaf spring disc clamp having an annular rim portion and a central bowed leaf spring portion;

(b) placing the clamp on a lapping surface;

(c) applying a force to the central portion to partially deflect the central portion of the clamp from an undeflected position toward the lapping surface; and

(d) moving the clamp relative to the lapping surface to remove a portion of the rim portion to form a flattened annular contact surface on the rim portion.

2. The method according to claim 1 wherein the force applied in step (c) further comprises applying a force effective to deflect the central portion of the clamp about half way between the undeflected position and an installed position.

3. The method of claim 1 wherein the lapping step (d) comprises removing less than a thickness of about 0.004 inches of material from the annular rim portion.

4. The method of claim 1 wherein step (a) includes forming an annular rib around the rim portion having a curved cross sectional shape, having the annular contact surface thereon.

5. The method of claim 4 wherein the step (d) includes removing material from the annular contact surface.

6. The method of claim 4 wherein step (a) further comprises forming a plurality of screw holes through the central portion for fastening the disc clamp to the spindle hub and step (c) includes applying the force substantially equally to the central

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portion around each of the screw holes to partially deflect the central portion of the clamp.

7. A leaf spring disc clamp for fastening a data disc to a disc spin motor hub comprising:

a generally circular disc shaped body having a bowed central leaf spring portion and an annular rim portion, the central spring portion defining a central aperture therethrough and having spaced apertures around the central aperture for mounting the disc clamp to a spin motor hub, wherein the rim portion forms an annular rib having a flat annular contact surface thereon for distributing clamping force onto the data disc.

8. The leaf spring disc clamp according to claim 7 wherein the flat annular contact surface lies in a common plane when the central portion of the clamp is deflected to an installed position.

9. The leaf spring disc clamp according to claim 7 wherein the annular contact surface lies in a common plane when the central portion of the clamp is deflected to a position between an undeflected position and an installed position.

10. A disc drive having a data storage disc carried on a spin motor for rotating the disc and an actuator assembly for moving a read/write head over a surface of the disc, the disc drive comprising:

a leaf spring disc clamp attaching the disc to a hub of the spin motor, the clamp having an annular rim portion having a flat annular contact surface thereon contacting the disc to distribute clamping force to the disc to minimize disc distortion.

11. A disc drive having a data storage disc carried on a spin motor for rotating the disc and a disc clamp fastening the disc to the spin motor, the drive comprising:

means on the disc clamp for substantially evenly distributing a clamping force between the disc clamp and the disc to minimize surface distortion of the disc.

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