

A Disk Drive

The present invention relates to a disk drive of the type in which data is read/written to a rotating magnetic disk. In particular, the invention relates to
5 improving the stability of the disk during rotation.

In many known magnetic disk drives, such as hard disk drives, floppy disk drives, the disk rotates with a frequency of several hundred Hertz. It is known that at these speeds air-flow induces vibrations of the disk (so-called "flutter") may occur, giving rise to potential errors in reading the disk and to head track
10 position errors. The problem is particularly acute for magnetic disks which comprise a plastic substrate, since its inherent elastic parameter is lower than that of aluminium disks.

Flutter places a limit of the maximum track density which can be achieved on the disk drive. In particular, it generates "non-repeatable run-out" (that is noise
15 with no periodicity) which cannot be solved by servo-control.

Disks such as floppy disks which are removable from the disk drive, are conventionally encased in a cartridge which is inserted into the disk drive, e.g. when data is to be read from or written to the disk. The cartridge has the functions of preventing contamination of the disk, and stabilising the disk
20 when it is in the drive. Access to the disk within the cartridge is provided by an access window. When this window is opened, a head gimbal assembly (HGA) mounted on a movable arm can be inserted into the window. The head gimbal assembly generally comprises a load beam (or suspension) mounted on the arm, a gimbal (or flexure) mounted on the end of the load
25 beam and a slider mounted on the gimbal, the slider carrying an electromagnetic transducer. When the head gimbal assembly is inserted into the open window, the slider can be placed in contact with or in close proximity

to the surface of the disk. The head gimbal assembly and arm are moved by a linear actuator (such that the slider is carried radially across the disk) or by a rotary actuator which rotates the arm about a pivot axis parallel to the axis to the disk rotation so as to move the slider in an arcuate path towards and away
5 from the centre of the disk.

As shown in Fig. 1, the access window to the disk 1 in cartridge 3 may be in the form of a generally rectangular radially extending head access slot 5, as in Fig 1(a), or in the form of a head access sector window 7, as shown in Fig. 1(b). A slider slot is particularly important if the actuator is a linear one; a head
10 access sector window is particularly appropriate if the actuator is a rotary actuator. A head access slot is shown in cross section in Fig. 2, which is a view towards the axis of the cartridge. The slot is formed by a pair of recesses 9 formed respectively in the upper and lower portions 11, 13 of the cartridge which sandwich the magnetic disk 15. It is known that access windows are
15 important causes of flutter.

Known methods for reducing flutter include using a magnetic disk having a higher specific stiffness (see for example US Patent No. 6055140). Alternatively, air flow regulators may be located within the cartridge or the disk enclosure to stabilizing the air flow (see for example US Patent No. 5189574).
20 Alternatively, the cartridge may be modified by placing stationary squeeze air bearing plates near the rotating disk (see for example Ono K. and Maeda E., "Suppression of disk flutter by a squeeze air bearing plate", J. Information Storage and Processing Systems, 2000, Vol. 2).

Apart from flutter, another cause for instability in flexible disks is due to their
25 low critical speed. The spinning flexible disk is a gyroscopic system, which could lose stability if its rotating speed exceeds its critical speed. This instability leads to the failure of the head-disk interface and the malfunction of tracking follow. To achieve a higher performance, floppy disk drives will use a

higher RPM (revolutions per minute), and accordingly their critical speed should if possible be improved by increasing their stability.

The present invention seeks to address the above problems, and in particular to provide a disk drive having improved stability.

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In general terms the present invention proposes that a stabiliser is provided on the arm(s) which carry the HGA(s). The stabiliser projects towards the disk surface, and comes into close contact with it, so as to develop a squeeze air film which urges the disk towards a desired position. Since part of the arm is
10 located within the access window, the stabiliser is ideally located to combat the causes of instability which arise there.

Specifically, the present invention proposes a disk drive for transferring data to or from a magnetic disk positioned within the disk drive, the disk drive including:

15 a rotator mechanism for rotating the disk;

at least one movable arm for extending over a corresponding surface of the disk as the disk is rotated by the rotator, the or each arm carrying a slider comprising an electromagnetic transducer which is movable over the corresponding surface of the disk by movements of the arm;

20 a stabiliser provided on the or each arm, the stabiliser comprising a portion spaced from the slider and extending towards the corresponding surface of the disk for developing a pressure on the corresponding surface of the disk as the disk is rotated by the rotator.

The disk drive may be a floppy disk drive, a hard disk drive or any future
25 magnetic disk drive system. The disk drive may include the disk as a permanent component, or alternatively the disk may be removable from the disk drive. For example, it may be a disk which is provided in a cartridge as

described above. The arm may be moved by a linear actuator or by a rotary actuator.

Preferably, each stabiliser develops the pressure proximate the radially outermost portion of the disk. In the case that the arm is moved by a rotary
5 actuator, so as to pivot about an axis, the stabiliser is preferably provided at a location on the arm closer than the slider to the axis.

In the case of a disk in which both sides of the disk are readable, it is known to provide an arm to each side (face) of the disk. In this case, the invention proposes that a stabiliser is preferably provided on each of the two arms.

10 In the case of a disk drive for a disk which is an assembly of stacked disk portions ("head stack assembly"), it is known to provide at least one arm for each disk portion (normally, two are provided per disk portion so that there is one on each face of each disk portion, for reading data off that face). In this case, the present invention proposes that a stabiliser is preferably provided on
15 each of the arms.

Many variations are possible in the shape of the stabiliser. For example, the stabiliser could have a substantially flat stabiliser surface facing away from the arm, and this surface may be generally rectangular, square, oval or indeed of any other shape. The stabiliser may have tapered edges, squared-off corners
20 or rounded corners. Its stabiliser surface may be provided with one or more cavities or recesses, or with texture. Precisely which configuration is selected depends upon the configuration of other elements of the disk drive, but a skilled person can select a suitable configuration for the stabiliser.

For example, the stabiliser(s) may be selected according to known squeeze
25 film design techniques to develop a positive pressure on the corresponding surface of the disk when the disk is rotated. Alternatively, the stabiliser(s) may be selected according to known squeeze film design techniques to

develop a negative pressure on the corresponding surface of the disk when the disk is rotated.

The stabiliser(s) may be integral to the corresponding arm, or affixed thereto (for example adhered thereto).

- 5 Preferably, the weight of the stabiliser is low. Preferably, this is due to the stabiliser being formed of a low density material (e.g. of lower density than the arm and/or the magnetic disk). Alternatively or additionally, the stabiliser may include a cavity, or indeed be a hollow body.

- 10 Preferably, the stabiliser is selected to have a hardness less than that of the disk which is to be stabilised by it, so that it is not liable to damage the surface of the disk in the case that, for example due to an external shock, the stabiliser contacts the disk. Thus, the shock resistance of the disk drive is improved. Preferably the upper limit of hardness of the stabilizer is no more than 5 GPa.

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Embodiments of the invention will now be described for the sake of example only with reference to the following figures, in which:

Fig. 1, which is composed of Fig. 1(a) and 1(b) shows a view of a known disk cassette;

- 20 Fig. 2 is a cross section of the known disk cassette of Fig. 1(a);

Fig. 3 is a cross section of part of a first embodiment of the invention;

Fig. 4 is a cross section of part of a second embodiment of the invention;

Fig. 5 is a cross section of part of a third embodiment of the invention;

Fig. 6 is a sketch helpful for understanding a principle underlying the invention;

Fig. 7 is a perspective view of an arm suitable for use in an embodiment of the invention;

5 Fig. 8 is a perspective view of the arm of Fig. 7 with a stabiliser attached to it;

Fig. 9, which is composed of Figs 9(a), 9(b), 9(c) and 9(d), shows four stabilisers suitable for use in an embodiment of the invention;

10 Fig. 10, which is composed of Figs. 10(a) and 10(b), shows a further stabiliser suitable for use in an embodiment of the invention;

Fig. 11, which is composed of Figs 11(a) and 11(b), shows a further stabiliser suitable for use in an embodiment of the invention; and

Fig. 12 is a perspective view of a further arm suitable for use in an embodiment of the invention.

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Fig. 3 shows a portion of a disk drive which is an embodiment of the present invention. A disk 15 is carried by a hub 17 which is rotated by a known rotator device (not shown). Sliders 19, 21 including respective electromagnetic heads (not shown) are provided for reading data from the faces 23, 25 of the disk 15. The sliders 19, 21 are supported by load beams 27, 29, constituting a head gimbal assembly. The load beams 27, 29 are respectively supported by arms 31, 33. The lower surface of the arm 31 and the upper surface of the arm 33 are provided with respective stabilisers 35, 37.

25 Each stabiliser 35, 37 has a stabiliser surface which faces away from the corresponding arm and towards a respective one of the faces 23, 25 of the

disk 15. In use, the stabiliser face of the stabilisers 35, 37 is preferably within a range of 50 to 500 μ m of the faces 23, 25. When the disk 15 spins, a squeeze air bearing film is created between the stabilisers 35, 37 and the disk 15. This squeeze air bearing serves as a spring and as a damper, urging the disk towards a correct positioning and thus suppressing vibrations and enhancing its stability. The stabilisers 35, 37 can be designed to create a positive pressure (i.e. one atmosphere or more) or a negative pressure (i.e. less than one atmosphere), depending on the surface profile of the stabilisers 35, 37.

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As illustrated in Fig. 3, the stabilisers 35, 37 are solid as solid bodies, however Figs. 4 and 5 show cross-sections of two further disk drives which are embodiments of the invention. In these embodiments the stabilisers 35, 37 are replaced (in the case of Fig. 4) with stabilisers 39, 41 which are hollow in cross section (e.g. they may be actually hollow, totally enclosing an internal space, or they may be tube-shaped) and (in the case of Fig. 5) with stabilisers 43, 45 having a cavity. All other features of Figs. 4 and 5 correspond to respective features of Fig. 3.

At least the stabiliser surfaces of the stabilisers 35, 37, 39, 41, 43, 45 are formed of comparatively low hardness materials, and in particular from materials of lower hardness than the surface of the disk, so that if the disk 15 contacts any of the stabilisers damage to the disk 15 is not likely. Thus, the stabilisers may also act as limiters, which constrain the position of the disk under an applied load.

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The general formulation of the dynamic pressure caused by a gas squeeze film can be derived from the isothermal and compressible Reynolds equation as:

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$$p(x, y, t) = (ap_a \eta / h_0) \{ \text{Re}[E(i)] \sin(\omega t) + \text{Im}[E(i)] \cos(\omega t) \} \quad (1)$$

in which p_a is the ambient pressure, h_0 is the mean spacing between stabilizer surface and disk surface, a and ω are respectively the amplitude and frequency of the stabilizer-disk spacing modulation, η is a coefficient reflecting the effect of stabilizer surface profile, $i = \sqrt{-1}$ and

$$E(i) = \sum_{m,n=1,3,5,\dots} \frac{-16\sigma \sin(\pi m x / l_x) \sin(\pi n y / l_y)}{\pi^2 m n [\pi^2 (m + \delta^2 n^2) i - \sigma]} \quad (2)$$

in which $\delta = l_x / l_y$, $\sigma = 12 \mu \omega (l_x / h_0)^2 / p_a$, where l_x, l_y are the characteristic lengths of the stabilizer in two orthogonal directions x and y , and μ is the air viscosity.

The real part of equation (1) corresponds to the storage modulus and the imaginary part corresponds to the loss modulus. The storage modulus correlates directly to the gas film stiffness, whereas the loss modulus is the damping multiplied by the frequency, so the real and imaginary parts of the pressure have stiffness and damping functions respectively. Thus, the effect of the stabilisers can be understood functionally as a spring k and a damper c as shown in Fig. 6.

In the above equation, the real and imaginary parts of the pressure can be derived respectively as functions of the stabiliser parameters. These parameters include stabiliser-disk spacing, the dimensions and shape of the stabiliser surface, any recess on the stabiliser surface, the surface texture, the inlet/outlet profile (the tapered edge or rounded corner). Thus, a stabiliser with specific properties can be selected by tuning these parameters.

For floppy/flexible disks which possess quite low stiffness, this extra spring and damper can substantially enhance the stiffness of the entire coupling

system, thus accordingly increasing the critical speed and stability. Note that, in contrast to known systems, in the present invention the stabilisation is achieved using the arms, rather than by a selected design of the cartridge or the sliders. The structure proposed by the present invention may permit a
5 squeeze air bearing which can damp remarkably the disk or vibration caused by unsteadiness in the air flow, particularly in the region around the stabiliser.

One of the major concerns in using the present invention is whether the arm causes vibrations of the coupled system. Since the stabiliser works as a spring/damper supporting the disk 15, the arms 31, 33 should be rigid enough
10 to avoid causing a vibration problem. We have carried out FEM modelling to show that a typical known arm has sufficient rigidity. In particular, we have established that the lowest natural frequency of a typical known arm support is 1700 Hz. This is much higher than the lowest natural frequency of the head gimbal assembly (which may be about 227 Hz). Furthermore, we have
15 established that for known plastic hard disks the two lowest vibration frequencies (in the lowest mode the outer edge of the disk 15 remains a circle but it moves oscillates perpendicular to the plane of the disk relative to the centre of the disk; in the next lowest vibration mode the disk 15 flexes about a diameter line) are typically about 300 Hz. Thus, the resident frequencies
20 already present in the system are well separated from likely frequencies produced by the embodiments, and thus coupling vibration is unlikely. Note that the stiffness of a typical arm support is up to 15500 N/m which is much higher than the typical stiffness of the HGA of 16 N/m.

Fig. 7 illustrates an arm 33 and a load beam 29. The load beam supports a
25 slider 21. The arm 33 includes an aperture 47 that is aligned with the aperture of the load beam 29, for receiving a portion of a stabiliser 37 having a stabiliser surface 50 as shown in Fig. 8. Thus, the assembly shown in Fig. 8 is suitable for use as the lower part of the embodiment of Fig. 3.

Whereas in Fig. 8 the stabiliser surface 50 of stabiliser 37 is circular, Fig. 9(a) shows an alternative stabiliser which would be suitable in an embodiment of the present invention, having an oval stabiliser surface 51. Fig. 9(b) shows a stabiliser with a substantially square upper surface 53.

- 5 Fig. 9(c) shows that the oval stabiliser of Fig. 9(a) can be provided with recesses 55 in its oval stabiliser surface 57. Fig. 9 (d) shows that recesses 59 may also be provided in a stabiliser having a square stabiliser surface 61.

The stabiliser shown in Fig. 10, corresponds to that of Fig. 5. As shown in perspective in Fig. 10(a) it has a floor 65, and a roof 63 joined by a single wall
10 67. The upper surface 69 of the roof 63 constitutes the stabiliser surface.

As shown in Fig. 11, the stabiliser may be formed having two walls 76, 77, spacing apart a floor 73 and a roof 71. The upper (outer) surface 75 of roof 71 provides the stabilisation surface.

- Whereas Figs. 7 and 8 illustrate an arm 33 to which a separate stabiliser 37 is
15 attached, Fig. 12 shows an alternative arm 83 in which a stabiliser 81 having a trapezoidal stabiliser surface is integrally formed on the arm 83.

Although individual embodiments of the invention have been described above, the invention is not limited to these embodiments and many variations are possible within the scope of the invention as will be clear to a skilled reader.



CLAIMS

1. A disk drive for a magnetic disk positioned within the disk drive, the disk drive including:
 - a rotator mechanism for rotating the disk;
 - 5 at least one movable arm for extending over a corresponding surface of the disk as the disk is rotated by the hub means, the or each arm carrying a head gimbal assembly comprising an electromagnetic transducer which is movable over the corresponding surface of the disk by movements of the arm;
 - a stabiliser provided on the or each arm, the stabiliser comprising a
10 portion spaced from the head gimbal assembly and extending towards the corresponding surface of the disk for developing a pressure on the corresponding surface of the disk as the disk is rotated by the hub means.
2. A disk drive according to claim 1 in which the or each stabiliser develops the pressure proximate the radially outermost portion of the disk.
- 15 3. A disk drive according to claim 1 or claim 2 in which the or each arm pivots about an axis, the stabiliser being closer than the slider to the axis.
4. A disk drive according to any of claims 1 to 3 in which each stabiliser develops a positive pressure on the corresponding surface of the disk.
5. A disk drive according to any of claims 1 to 3 in which the stabiliser
20 develops a negative pressure on the corresponding surface of the disk.
6. A disk drive according to any preceding claim in which each stabiliser is integral to the corresponding arm.
7. A disk drive according to any of claims 1 to 6 in which each stabiliser is affixed to the corresponding arm.



8. A disk drive according to any preceding claim in which the stabiliser includes a cavity.
9. A disk drive according to any preceding claim in which there are two said arms, corresponding to opposite sides of the disk.
- 5 10. A disk drive according to any preceding claim which is adapted to receive a disk having a plurality of stacked disk portions, each disk portion having two surfaces, the disk drive including a said arm for at least one surface of each of the disk portions.
- 10 11. A disk drive according to any preceding claim which is adapted to receive a magnetic disk provided within a cartridge having an access window, the head and stabiliser being arranged to access the disk through the access window.
12. A disk drive in which the stabiliser is of lower average density than the corresponding arm.
- 15 13. A disk drive according to any preceding claim in combination with a magnetic data disk, the stabiliser having a hardness lower than the surface of the disk.
14. An arm assembly for a disk drive for a magnetic disk, the arm assembly including:
- 20 an arm;
- a head gimbal assembly attached to the arm comprising an electromagnetic transducer for movement over a surface of the disk by movements of the arm; and a stabilizer attached to the arm spaced from the head gimbal assembly, the stabiliser comprising a portion for extending towards the surface of the
- 25 disk for developing pressure on the surface of the disk.