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APPARATUS FOR VIBRATION REDUCTION IN A HARD DISK DRIVE

Field of the Invention

The invention relates to an apparatus for vibration reduction in a hard disk drive and particularly, though not exclusively, relates to an apparatus for suppressing flow induced vibrations on a hard disk drive actuator arm.

Background

Flow induced vibration (FIV) in hard disk drives (HDDs) is one of the major causes of magnetic head positioning error, leading to track mis-registration. This is particularly so for higher rpm types of hard disk drives. As a consequence, FIV constitutes a significant proportion of non-repeatable run-out budget during the design stage of such higher rpm disk drives. Most, if not all, disturbances in higher rpm (> 10K rpm) enterprise class hard drives comes from FIV.

FIV suppressions in production hard disk drives is currently achieved by restricting the volume of high velocity air impinging onto the actuator with an air separator 2 (FIG. 1, FIG. taken from Kirpekar & Bogy (2006)). With the use of the air separator 2 shown in FIG. 1, a major side-effect is accompanying air drag opposing disk rotation. The opposing drag was estimated to increase 20% by Kirpekar & Bogy (2006).

Tests showed that a 15k rpm Cheetah drive fitted with 4 pieces of air separators needs about 2.4 watt of motor power to overcome fluid drag. A typical enterprise drive needs about 10 watts to operate, so 24% or about one quarter of input power to the hard disk

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drive is wasted on overcoming fluid drag. It also leads to a hefty increase in motor power consumption inside the hard disk drive. In addition, the additional motor power would have to be dissipated away as heat, giving rise to further heat reliability problems.

Summary of the Invention

According to an exemplary aspect, a flow mitigating device is provided that comprises at least a pair of triangular shaped protrusions resembling a bird's beak that induce little or no drag. The protrusions may be formed as part of the actuator arm. The flow mitigating device suppresses flow induced vibrations of hard disk drive actuator arms by almost 100% but induces very little air drag. As a consequence, the flow mitigating device is capable of replacing the current air separator, saving energy simultaneously.

Brief Description of the Drawings

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

In the drawings:

FIG. 1 (prior art) is a plan view of a hard disk drive including a hard disk media, an actuator arm and an air separator (taken from Kirpekar & Bogy (2006));

FIGS. 2 (a) to (c) are illustrations and perspective view of an exemplary embodiment of a flow mitigating device on an actuator arm;

FIGS. 3 (a) to (b) are illustrations of an exemplary embodiment of a flow mitigating device on an actuator arm and stream-wise view (air flow direction towards reader) of the flow mitigating device and resultant vortex structures;

FIG. 4 is a perspective view of a dummy 3.5 inch format hard disk with an LDV probe configured to measure in-plane vibrations of a dummy actuator;

FIG. 5 is a graph of in-plane frequency measured on a dummy actuator at 10,000 rpm;

FIG. 6 is a graph of in-plane frequency measured on a dummy actuator at 15,000 rpm; and

Fig. 7 is a table of input power required to spin a dummy hard drive with and without the flow mitigating device of FIG. 2.

Detailed Description of the Exemplary Embodiments

An exemplary apparatus for reducing vibration in a hard disk drive arm is shown in FIGS. 2 (a) to (c). The apparatus is a flow mitigating device 8 comprising at least a pair 10 of protrusions 12 formed on a hard disk drive actuator arm 14 on the trailing edge of the actuator arm 14, so as to be integral with the actuator arm. It will be appreciated that the protrusions may be separate elements mounted on the actuator arm. Alternatively, integral may also allow for the protrusions to be formed as part of the actuator arm, such as cast as a single unit or machined from a larger element. Preferably, each protrusion 12 is triangular-shaped such that a pair 10 of protrusions 12 resembles a bird's beak such that each projection is inclined to a planar face of the actuator arm. Said protrusions may also be placed symmetrically about a plane parallel to the planar face. This parallel plane may be a centrally positioned axial plane of said actuator arm. The number of pairs 10 of protrusions 12 to be formed on the actuator arm 14 is dependent

on the size of vortex shedding region behind the trailing edges 32 of the actuator arm 14, which in turn is dependent on the hard disk drive design.

At least one pair 10 of protrusions 12 per arm 14 is required. In the embodiment shown in FIGS. 2 (a) to (c), two pairs 10 of protrusions 12 are provided on the actuator arm 14. The maximum number of pairs 10 of protrusions 12 is limited only by the dimension of the actuator arm 14. Distance between each pair 10 of protrusions 12 is determined by the size of the vortex shedding region. Each protrusion 12 can take the shape of any type of triangle having a base and a height, e.g. isosceles, scalene, equilateral and all other types of triangles. The aspect ratio of the base to height of the triangle preferably ranges from 2:3 to 3:1. The angle 16 between two protrusions 12 that form a pair 10 resembling a bird's beak may range widely from 5° to 175°, as shown in FIG. 2 (a). The peak 17 to peak 19 distance is preferably not more than 2 times the thickness of the actuator arm 14. Preferably, each protrusion 12 is formed integrally as part of the actuator arm 14.

The flow mitigating device 8 should be placed close to where the trailing edge vortex structures 30 would likely to appear. As a consequence, placement of the flow mitigating device 8 should avoid any part of the actuator arm 14 that extends out of the air space enveloped by the walls of the rotating disks 35, where vortex shedding is unlikely to happen.

Preliminary studies into hard disk drive flow fields have revealed complex vortex shedding phenomenon behind the trailing edges 32 of the actuator arms and FIV were

attributed to these vortical structures. The leading edges 33 and trailing edges 32 are defined by the stream-wise direction 34 – the air stream flows past leading edges 33 first before flowing over the body of the actuator arm 14 and then past the trailing edges 32. Flow structures also change with increasing disk rpm. Referring to FIGS. 3(a) and 3(b), the flow mitigating device 8 functions to generate streamwise-vorticities 31 that interact with the trailing edge vortex structures 30. The trailing edge flow structures consequently weaken significantly in the streamwise direction 34. Therefore, fluid forces imposed on the solid actuator arm 14 are correspondingly weakened for streamwise vorticity weakened flow structures.

To determine the efficacy of the flow mitigating device 8, in-plane vibrations of a dummy actuator 24 on a dummy 3.5 inch format hard drive 26 was evaluated from Laser Doppler vibrometer (LDV) measurements as shown in FIG. 4. LDV tests were run when the actuator 24 was positioned at middle diameter (MD) where the FIV effects are the largest. The LDV measured in-plane frequency spectra shown in FIG. 5 at 10,000 rpm and in FIG. 6 at 15,000 rpm demonstrate that the flow mitigating device 8 is able to completely suppress disturbances at around 17 kHz, which is the swaying mode of the dummy actuator 24.

It is observed that energies from the turbulent fluid were transferred through the swaying mode to the solid dummy actuator 24 causing FIV. When the flow mitigating device 8 was incorporated onto the dummy actuator 24, fluid energies transferred through the swaying mode was prohibited and therefore FIV on the hard disk drive actuator arm 24 was attenuated. The flow mitigating device 8 had altered and weakened

the flow structures significantly so much so that fluid energy had not been able to seep through the sway mode.

The flow drag generated by the flow mitigating device 8 was also evaluated using the same dummy 3.5 inch format hard drive 26 shown in FIG. 4. The input power required to spin the circular disks 28 at 15K rpm having a dummy actuator 24 with and without the flow mitigating device 8 was compared, as shown in the table of FIG. 7. It can be concluded that there is no additional flow drag caused by the flow mitigating device 8.

The saving in electricity costs due to the reduction in fluid drag can be enormous. As a guide, one million units of new enterprise class hard disk drives are assumed to be deployed annually and each drive requires 10 watts to operate. For 24/7 operation, the data centre would require 300 billion MW-hour to power the hard disk drives. If each kW-hour costs S$0.23, it would be a 75 billion dollar electricity bill annually. The incorporation of the flow mitigating device 8 onto hard disk drive actuator arms would therefore take twenty five billion dollars off the annual electricity bill.

Whilst there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention. For example, the protrusions may have other shapes than triangles. The angle of each pair of protrusions with respect to the actuator arm may vary along the actuator arm for different pairs of protrusions.

The Claims

1. An apparatus for vibration reduction in a hard disk drive having at least one actuator arm, the apparatus comprising:

a flow mitigating device comprising a first pair of protrusions on the actuator arm.

2. The apparatus of claim 1, wherein each protrusion has a triangular shape having a base and a height.

3. The apparatus of claim 2, wherein aspect ratio of the base to the height ranges from 2:3 to 3:1

4. The apparatus of any one of claims 1 to 3, wherein the pair of protrusions define an angle therebetween ranging from 5° to 175°.

5. The apparatus of any one of the preceding claims, wherein peak to peak distance between the pair of protrusions is less than or equal to two times a thickness of the actuator arm.

6. The apparatus of any one of the preceding claims, wherein each protrusion is integral with the actuator arm.

7. The apparatus of any one of the preceding claims, wherein the pair of protrusions are located on the actuator arm where trailing edge vortex structures are likely to appear during rotation of the hard disk.

8. The apparatus of any one of the preceding claims, wherein a total number of pairs of protrusions on the actuator arm is dependent on a size of a vortex shedding region behind trailing edges of the actuator arm.

9. The apparatus of claim 8, further comprising a second pair of protrusions on the actuator arm, wherein a distance between the first pair of protrusions and the second pair of protrusions is determined by the size of a vortex shedding region.

10. An actuator arm for a hard disk drive comprising

a planar face;

a pair of flow mitigating protrusions projecting from a trailing edge of said planar face;

wherein the protrusions are inclined to said planar face.

11. The actuator arm according to claim 10, wherein the protrusions are arranged symmetrically about a plane parallel to the planar face.