

**SPRING BEAM FOR DISC DRIVES AND METHOD OF MAKING SPRING BEAM
FOR DISC DRIVES**

FIELD OF THE INVENTION

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The present invention relates generally to disk drives and in particular to spring beams for use in disc access systems.

BACKGROUND

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Hard disc drives (HDD) are widely used in computers for storage of electronic data. A hard disc drive has a magnetic disc rotating at high speeds, and the speed of rotation is usually in the order of several thousand revolutions per minute (RPM). The speed of rotation depends on the density of data recording or the number of tracks per inch (TPI) of the magnetic disc.

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A hard disc drive includes a magnetic disc mounted in a dust-free enclosure. An access head for accessing data from the magnetic disc is placed at the tip of an actuator arm assembly, comprising an actuator arm and a spring beam attached to the end of the actuator arm. The movement of some actuator arms is linear, whilst others have rotary movement. In the linear type, the actuator arm and the head move linearly across a radius of the magnetic disc. In the rotary type, the actuator arm and the head move in an arc of a circle across the disc.

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A conventional rotary-type hard disc drive 10 is illustrated in Figure 1. A magnetic disc 3 is supported and driven by a motor spindle 15. The magnetic disc 3 has concentric tracks extending from an outer radius to an inner radius of the disc 3. Data is stored in these tracks as magnetic variations. The data stored in the magnetic disc 3 is accessed by an access head 9 which is mounted below the tip of a spring beam 7. The actuator arm assembly has a solid metal actuator arm 5, which terminates with a spring beam 7. The spring beam 7 is generally a flat plate removably attached to the end of the actuator arm 5. Typically, a single layered spring beam has a thickness of 0.07 mm. One end of the actuator arm assembly is pivotally mounted on an actuator 1 through a hole 13, such that the actuator arm

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assembly is cantilevered. The other end of the actuator arm assembly moves in an arc across the disc 3.

A conventional single layered spring beam 20 of a hard disc drive is illustrated in Figures 2, 2a and 2b. One end of the conventional single layered spring beam 20 has an arm base 17 with a hole 21 at its centre for attaching the spring beam to the actuator arm 5. The other end of the spring beam has a width smaller than the width of the arm base 17. The wider end of the spring beam is attached to the arm base 17 by two narrow webs 18, one by each edge. The narrower end of spring beam is tapered, having an angled region 24 and a tab 26. Between the two ends, the spring beam has tapering edges 23. The spring beam 20 has several apertures 11, 19 through the beam 20, along its length for reducing the weight as well as for positioning the spring beam. An access head 9 is attached below the smallest aperture 19 located proximate to the tab 26.

The memory capacity of a hard disc drive depends on factors such as, physical size of the magnetic disc, type of magnetic coating, number of tracks per inch, speed of rotation of the disc drive, size and type of the access head etc. Improvements have been made to increase the storage capacity of hard disc drives. Increasing the size of the hard disc drive beyond certain limits is impractical. Increasing the number of tracks per inch or the density of data recording of the disc is a preferred way to increase the memory capacity. However, increasing the number of tracks per inch or the density of data recording of the disc leads to several complications.

Firstly, increasing the number of tracks per inch or the density of data recording of the disc requires the access head 9 to be positioned closer to the magnetic disc so as to minimise the air-gap between the access head 9 and the disc 3 during data access. If vibrations such as off-track vibrations (e.g. vibrations at starting and parking instants) arise in the spring beam 7, 20, there is a danger of the rotating disc 3 coming into contact with the access head 9. In such an instance, the access head could damage the disc and hence the data may become irrecoverable. Such vibrations, may even damage the access head 9 which, in turn, could render the hard disc drive unusable.

Secondly, as the spring beam 7, 20 is positioned very close to the disc 3, the rotary movement of the disc 3 at high speeds and the radial movement of the spring beam 7, 20 creates air turbulence around the disc, which hinders data access causing off-track errors.

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Thirdly, the spring beam 7, 20 may be subjected to bending and torsional vibrations if its natural frequencies are exerted. In such occasions, the spring beam 7, 20 may be subjected to bending or twisting along the axis of the spring beam. During such an instance, the access head 9 could be dislocated, which causes off-track errors.

10 Bending and torsional vibrations of the spring beam 7, 20 are dependent on factors such as, in-plane stiffness and out of-plane spring rate.

To overcome some of the above problems, and in particular, tracking errors due to vibrations at off-track modes including bending and torsion modes, the spring beam
15 7, 20 should have increased stiffness. It is known in the art that the in-plane stiffness of the spring beam is proportional to the third root of the thickness of the spring beam. Ideally, a spring beam should have high in-plane stiffness without increasing the out-of-plane spring rate. However, there are limitations on increasing the thickness of the spring beam, bearing in mind the weight of the spring beam. The
20 design of the spring beam should also be a balance between its weight and physical dimensions. Many designs of such spring beams have been proposed.

United States Patent No. 5,731,931 issued on 24 March 1998 to Lloyd C. Goss describes a monocoque spring beam having two layers. A first beam layer is in the
25 form of an elongate shell having two side walls. The side walls have flanges that extend longitudinally. A second planar layer extends between the flanges of the first beam layer to form a monocoque shell.

United States Patents No. 5,734,526 issued on 31 March 1998 to John B. Symons
30 and 5,894,655 issued on 20 April 1999 to John B. Symons describe a monocoque spring beam produced by two overlapping laminae having mutually opposed surfaces and having cavities.

United States Patent No. 5,381,289 issued on 10 January 1995 to Richard G. Fiedler
35 describes two layers of the spring beam that are mounted interleavingly on a single

rigid actuator arm such that a first access head mounted to a first beam layer projects through an aperture of the second beam layer whilst a second access head of a second beam layer projects through an aperture of the first layer. Thus, the first access head mounted on a top side of the actuator arm accesses a disk below,
5 while the second access head mounted on a bottom side of the actuator arm accesses a disk above.

United States Patent No. 5,920,444 issued on 6 July 1999 to Thomas F. Heeran *et al* describes a spring beam having an alignment structure for minimising
10 misalignments between a flexure for mounting head and a spring beam.

The spring beams of the above prior art documents have high in-plane stiffness, disadvantageously leading to high out-of-plane spring rate. Accordingly, there is a need for a spring beam with high in-plane stiffness without increasing the out-of-
15 plane spring rate.

SUMMARY

In accordance with a first aspect of the invention, there is provided an elongate
20 spring beam for an actuator arm of a disc access system, comprising: a first elongate beam member; a second elongate beam member, said first beam member being disposed opposite said second beam member, said beam members being longitudinally aligned in a spaced-apart relation; and means for supporting said first and second beam members extending between opposing faces of said first and
25 second beam members and across the width of the spring beam.

In accordance with a second aspect of the invention, there is provided a method of making an elongate spring beam for an actuator arm of a disc access system, comprising the steps of: providing a first elongate beam member; providing a
30 second elongate beam member, said first beam member being disposed opposite said second beam member, said beam members being longitudinally aligned in a spaced-apart relation; and connecting a means for supporting said first and second beam members extending between opposing faces of said first and second beam members and across the width of the spring beam.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting embodiments of the invention are described hereinafter with reference to the accompanying drawings, in which:

- 5 Figure 1 is an exemplary view of a conventional hard disc system;
 Figure 2a is a plan view of a conventional single layered spring beam;
 Figure 2b is a side view of the conventional spring beam of Figure 2a;
 Figure 2c is a perspective view of the conventional spring beam of Figure 2a;
 Figure 3a is a plan view of a spring beam in accordance with a first
10 embodiment of the present invention;
 Figure 3b is a side view of the spring beam of Figure 3a;
 Figure 3c is a perspective view of the spring beam of Figure 3a;
 Figure 4a is a plan view of a spring beam in accordance with a second
 embodiment of the present invention;
15 Figure 4b is a side view of the spring beam of Figure 4a;
 Figure 4c is a perspective view of the spring beam of Figure 4a;
 Figure 5a is a plan view of a spring beam in accordance with a third
 embodiment of the present invention;
 Figure 5b is a side view of the spring beam of Figure 5a;
20 Figure 5c is a perspective view of the spring beam of Figure 5a;
 Figure 6a is a plan view of a spring beam in accordance with a fourth
 embodiment of the present invention;
 Figure 6b is a side view of the spring beam of Figure 6a;
 Figure 6c is a perspective view of the spring beam of Figure 6a;
25 Figure 7a is a plan view of a spring beam in accordance with a fifth
 embodiment of the present invention;
 Figure 7b is a side view of the spring beam of Figure 7a;
 Figure 7c is a perspective view of spring beam of Figure 7a;
 Figure 8a is a top view of a spring beam in accordance with a sixth
30 embodiment of the present invention;
 Figure 8b is a side view of a spring beam of Figure 8a;
 Figure 8c is a perspective view of a spring beam of Figure 8a;
 Figure 9a is a top view of a spring beam in accordance with a seventh
 embodiment of the present invention;
35 Figure 9b is a side view of a spring beam of Figure 9a;

Figure 9c is a perspective view of a spring beam of Figure 9a;

Figure 10a is an exemplary view of an actuator arm including a spring beam in accordance with the sixth embodiment;

Figure 10b is an enlarged view of the spring beam of Figure 10a.

5 Figure 11 is a graph showing the results of experiments, of amplitude and phase response of a conventional single layered spring beam; and

Figure 12 is a graph showing the results of experiments, of amplitude and phase response of a double layered spring beam.

10 DETAILED DESCRIPTION

Figures 3a, 3b and 3c illustrate an elongate spring beam 30 of a first embodiment having two generally flat and parallel elongate beam members, a top beam member 25 and a bottom beam member 27. The two beam members 25, 27 are identical and
 15 each has a first end 2 and a second end 4. The width of each beam member at the first end 2 of the two beam members 25, 27 is greater than the width of each beam member at the second end 4, with a tapered region 37 between the ends. The tapered region 37 has a first linear taper and a second linear taper. The first taper is steeper than the second taper and extends from the first end 2 to about midway
 20 between the ends of the two beam members, whilst the second taper extends from this midway to near the second end 4 of the two beam members.

The second ends 4 of both beam members 25, 27 are tapered, having an angled region 36 and a tab 38. An access head 35 is attached below the tab 38 of the
 25 second beam member 27.

The two beam members 25, 27 are spaced apart, with a support member 29, in the form of a flat plate extending between the inner, opposing surfaces. The support member 29 is near the second ends 4 of the two beam members and extends
 30 across the width of the spring beam, from one side to another side of the two beam members 25, 27. The support member 29 extends orthogonally from the two beam members.

The first ends 2 of the two beam members 25, 27 are mounted to opposite sides of
 35 a mounting block 31. The first end 2 of the top beam member 25 extends from a top

surface of the mounting block 31, whilst the first end 2 of the bottom beam member 27 extends from a bottom surface of the mounting block 31, with the top and bottom surfaces of the two beam members flush with the top and bottom surfaces of the mounting block 31. Each first end 2 is attached to the mounting block 31 by two narrow webs 34, one by each edge of each beam member. The widths of the beam members 25, 27 at the first ends 2 are less than the width of the mounting block 31.

The mounting block 31 (here being 1 mm) is relatively thicker than the two beam members 25, 27 (here being 0.03) of the spring beam. The thickness of the narrow webs 34 is, in this embodiment, less than that of the rest of each beam member, here being 0.03 mm, while the thickness of each beam member 25, 27 is 0.04 mm.

The mounting block 31 is a solid square block having a mounting hole 33 through which the spring beam 30 is attached to an actuator arm. The mounting block 31 is usually made of aluminium. The top beam member 25 and the bottom beam member 27 of the spring beam have apertures 36 located at appropriate locations along their lengths to reduce the overall weight of the spring beam. The apertures are of different shapes and dimensions. The largest of the apertures is positioned at the first ends 2 of the two beam members between the narrow webs 34. Other apertures of different shapes and dimensions are positioned from the middle portions to the second ends 4 of the two beam members 25, 27. The support member 29 is orthogonal to the mounting block 31 and the elongate axes of the two beam members 25, 27.

Figures 4a, 4b and 4c illustrate the plan, side and perspective views of a second embodiment, being a spring beam 40 having two identical beam members 41, 43 which are generally flat and elongate. The main difference between the second and the first embodiment is that the support member is a hollow triangular column which is connected between the inner surfaces of a top beam member 41 and a bottom beam member 43. The angular formation of the edges at the tip of the triangular column minimises the impact of air-flow thereby improving the aerodynamic performance of the spring beam 40.

The two beam members are generally the same as in the first embodiment, but with a different arrangement of apertures and lacking the tapered second ends 4. The

triangular column has three flat rectangular sides 45, 47. Typically, the lengths and breadths of the three sides are equal. In this embodiment, the triangle is equilateral, although it could alternatively be non-equilateral isosceles triangle. The outer surface of a first one of the sides 45 of the triangular column 41 is flush with the second ends 4 of the top beam member 41 and bottom beam member 43. The point of intersection of the other two sides 47 of the triangular column is between the first side of the column and the mounting block, on the longitudinal axes of the two beam members 25, 27. An access head 35 is attached to the underside of the second end 4 of the second beam member 27, below the triangular column. The apertures 36 are differently shaped in comparison to those of the previous embodiment.

Figures 5a, 5b and 5c illustrate the plan, side and perspective views of a spring beam 50 of a third embodiment. The third embodiment is very similar to the second embodiment, except that the mounting block 31 is thinner than the height of the support member. The top beam member 54 is at an angle to the bottom beam member 56, whilst the bottom beam member 56 remains flush and in line with the lower surface of the mounting block 31. The top edge of the first side 53 of the triangular column is parallel to the bottom edge, but the top edges of the other two sides 55 are at angles to their bottom edges so as to coincide with the angle of the top beam member 54.

Figures 6a, 6b and 6c illustrate the plan, side and perspective views of a spring beam 60 of a fourth embodiment. The fourth embodiment is similar to the third embodiment, except that the second ends 4 of the top beam member 57 and the bottom beam member 59 both extend from the bottom edge of the mounting block 31 with the top beam member 57 at an angle to the bottom beam member 59 and to the bottom edge of the mounting block 31, this angle being steeper than that in the third embodiment.

Figures 7a, 7b, and 7c illustrate the plan, side and perspective views of a spring beam 70 of a fifth embodiment. The construction of the spring beam is similar to the second embodiment, except that the support member has been rotated through 180 degrees. The point of intersection of the second and the third sides 47 of the triangular column faces away from the mounting block 31, whilst the first side 45 of

the triangular column is still flush with the second ends 4. The ends of the triangular column are open, not being covered by the first and second beam members.

- 5 The stiffness co-efficient k of a spring beam of the above embodiments is determined by the equation (1):

$$k = \frac{3EI}{l^3} \dots\dots\dots(1)$$

where E is the Young's modulus, I is the area moment of inertia, and l is the beam length extending between first and second ends.

- 10 The torsion frequency of the spring beam is determined by the equation (2):

$$\omega_n = \frac{(2n+1)\pi}{2l} \sqrt{\frac{GJ}{J_0}} \dots\dots\dots(2)$$

$$n = 0, 1, 2, \dots\dots$$

where n is the mode of torsion, G is the shear modulus, J is the torsional area moment of inertia, J_0 is the mass moment of inertia, and l is the beam length.

- 15 By appropriately selecting the physical dimensions, the spring beams of the above embodiments can be designed to have improved performance such as, tolerance to vibrations at off-track modes including bending and torsion, especially in high density applications. The improved spring beam is found have increased natural frequencies of off-track modes without adversely affecting the flying capabilities of
20 the actuator arm.

- Table I & Table II summarise the results of simulations conducted for frequency characteristics such as, bending modes (e.g. first bending, second bending, third bending) and torsion modes (e.g. first torsion, second torsion, third torsion) of the
25 conventional single layer spring beam of Figures 2a-2c as against the two layered spring beam of the first and fifth embodiment.

"First bending mode" refers to the state in which the spring beam vibrates (due to bending) without any node.

"Second bending mode" refers to the state in which the spring beam vibrates (due to bending) with one node.

"Third bending mode refers" to the state in which the spring beam vibrates (due to bending) with two nodes.

- 5 "First torsion mode" refers to the state in which the spring beam vibrates (due to torsion) without any node.

"Second torsion mode" refers to the state in which the spring beam vibrates (due to torsion) with one node.

- 10 "Third torsion mode" refers to the state in which the spring beam vibrates (due to torsion) with two nodes.

"Sway" refers to the state in which the load beam swings from one side to another side.

"node" refers to a point with no vibrations.

15 **TABLE I**

Parameter	Conventional (Fig. 2a-2c)	First embodiment (Fig. 3a-3c)	Fifth embodiment (Fig. 7a-7c)
Thickness of spring beam member (mm)	0.07	0.04	0.035
Distance between beam members	-	1.0	1.0
Width at first end of beam members (mm)	4.12	4.12	4.12
Width at second end of beam members (mm)	0.9	0.95	0.95
Length of spring beam (mm)	10	10	9.1
Stiffness (N/m)	31.2	31.36	33.4
First Bending Mode (kHz)	0.707	0.551	0.615
Second Bending Mode(kHz)	3.738	1.875; 2.815	2.232; 2.933
Third Bending Mode(kHz)	10.070	5.996	6.659
1 st torsion mode (kHz)	10.35	7.546; 7.611	7.184;7.227
2 nd torsion mode (kHz)	21.358	16.308;16.504	14.988;15.111
3 rd torsion mode (kHz)	37.342	26.594; 27.086	24.433;26.644
Sway & 3 rd /4 th torsion mode (kHz)	38.376 (Sway & 3 rd Torsion)	35.256 (4 th torsion mode) 36.375 (Sway)	35.362 (4 th Torsion mode) 36.654 (Sway & 4 th torsion mode)

Table II

Parameter	Second embodiment (Fig. 4a-4c)	Third embodiment (Fig. 5a-5c)	Fourth embodiment (Fig 6a-6c)
Thickness of spring beam layer (mm)	0.035	0.04	0.04
Distance between layers at tip	1.0	1.0	1.0
Width at first end of layers (mm)	4.12	4.12	4.12
Width at second end of layers (mm)	1.0	1.0	1.0
Length of spring beam (mm)	9.25	9.25	8.0
Stiffness (N/m)	28.5	28.8	31.4
First Bending Mode (kHz)	0.512	0.488	0.53
Second Bending Mode(kHz)	2.518	2.757	3.559
Third Bending Mode(kHz)	6.477	7.313	9.436
1 st torsion mode (kHz)	6.814	7.796	8.382
2 nd torsion mode (kHz)	13.739	15.716	18.320
3 rd torsion mode (kHz)	22.552	25.522	30.376
Sway mode (kHz)	26.918	26.434	35.241

Comparing the performance with the conventional spring beam (single layer), although the torsion frequencies are a bit lower, the first three torsion modes of the two layered spring beams of the above embodiments do not generate any off-track errors owing to the presence of the support member. In fact, the first torsion mode with obvious off-track vibrations occurs at 35kHz. The two layered embodiments not only reduce the off-track motion but also reduce the amplitudes of the out-of-plane vibrations, thereby helping in maintaining consistent flying height while accessing data from a disc.

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Figures 8a, 8b and 8c illustrate the plan, side and perspective views of a spring beam 80 in accordance with a sixth embodiment. The elongate spring beam 80 has two generally flat and elongate beam members, a top beam member 71 and a bottom beam member 73. Each of the beam members 71, 73 is identical. A mounting hole 77, 79 is provided close to each end of both beam members for mounting the spring beam 80, at both ends, to an actuator arm. The widths of the two beam members 71, 73 vary along the length of the spring beam 80. The widths at the centre are at their minimum and the widths gradually increase towards the ends. The two beam members are waisted at the centres. The beam members 71, 73 also have bilateral symmetry. An access head 35 is mounted on the bottom surface of the bottom beam member 73, below the support member 75.

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The two beam members 71, 73 are attached to each other through a first mounting block 81, a second mounting block 83 and a support member 75. The first and second mounting blocks 81, 83 are identical and are located one at each end of the beams, between the two beam members 71, 73. Each mounting block is a flat
 5 parallelepiped plate. The two mounting blocks 81, 83 have centrally located mounting holes 77, 79 for mounting both ends of the spring beam onto the underside of an actuator arm.

The support member 75 is a hollow cylinder in this embodiment, located halfway
 10 through the lengths of the two beam members. The hollow cylinder extends from one side of the beam to the other. The height of the hollow cylinder is equal to the thickness of the mounting block 81, 83. The widths of the two mounting blocks match the widths of the ends of the two beam members. The two beam members 71, 73 extend integrally from the mounting blocks 81, 83 to form the spring beam 80
 15 with a unitary structure having top and bottom beam members which are spaced apart equally through their lengths.

The top beam member 71 and the bottom beam member 73 have apertures 85 through those beam members, at appropriate locations along their lengths to reduce
 20 the overall weight of the spring beam. The number and dimensions on both halves are equal to maintain symmetry about the centre.

Figures 9a, 9b, and 9c illustrate the plan, side and perspective views of a spring beam 90 of the seventh embodiment, which is a variation of the spring beam of the
 25 sixth embodiment. The difference is in the shape of the two beam members 87, 89. The width of the two beam members is the same at their centres as at their ends. Those beam members are, however, waisted in the region midway between each end and the centres. Apertures 101 are also differently shaped when compared to those of the sixth embodiment. An access head 35 is mounted on the bottom
 30 surface of the bottom beam member 73, below the support member 75.

Figure 10a is a diagram showing an example of how the spring beam 80 of the sixth embodiment may be attached to an actuator arm 103. Figure 10b is an enlarged view of a portion 105 shown in figure 10a.

- The bottom surface of the actuator arm 103 has a pair of arm protrusions 107, 109. The arm protrusions are separated by the same distance as that between the two mounting holes 77, 79 of the spring beam 80. An access head 35 is mounted on the bottom surface of the bottom beam member 73, below the support member 75. A
- 5 spring 111 is mounted between the underside of an actuator arm and the top surface of the top beam member 73, above the support member 75. A spring may also or alternatively be located between the lower surface of the bottom spring beam member 73 and the top surface of the access head 35.
- 10 Figures 11 and 12 are graphs with the results of experiments, of amplitude and phase responses of a conventional single layered spring beam as against the frequency of a double layered spring beam of the first embodiment of the present invention. The first peak in the conventional spring beam occurs at 3.31 kHz whereas, for the double layered spring beam of the present invention, the first peak
- 15 occurs at a higher frequency of 5.54 kHz.

The stiffness co-efficient k of a spring beam of the sixth and seventh embodiments is determined by the equation (3):

$$k = \frac{192EI}{l^3} \dots\dots\dots(3)$$

- 20 where E is the Young's modulus, I is the area moment of inertia, and l is the beam length between the first and second ends.

The torsion frequency of the spring beam of the sixth and seventh embodiments is determined by the equation (4):

$$\omega_n = \frac{n\pi}{l} \sqrt{\frac{GJ}{J_0}} \dots\dots\dots(4)$$

$n = 1, 2, 3, \dots\dots$

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where n is the mode of resonance, G is the shear modulus, J is the torsional area moment of inertia, J_0 is the mass moment of inertia, and l is the beam length.

- As both the ends of the spring beams 80, 90 of the sixth and seventh embodiments are fixed to the actuator arm 103, the spring beams 80, 90 can suppress off-track vibrations including sway, torsion, and bending-coupled in-plane motions. The spring beams 80, 90 have high sway frequency because of their fixed ends.
- 5 Additionally, the presence of the cylindrical column 75 helps in alleviating the generation of off-track motion especially at lower modes.

Table III summarises the results of simulations conducted for frequency characteristics such as, bending modes (e.g. odd bending modes, even bending modes) and torsion modes (e.g. 1st torsion, 2nd torsion, 3rd torsion) of the spring beam of the sixth embodiment:

The terms "First bending mode", "Second bending mode", "Third bending mode", "First torsion mode", "Second torsion mode", "Third torsion mode", "Sway", and

15 "node" have the same meaning as given before.

"Fourth bending mode" refers to the state in which the spring beam vibrates (due to bending) with three nodes.

"Fifth bending mode" refers to the state in which the spring beam vibrates (due to bending) with four nodes.

20 "Sixth bending mode" refers to the state in which the spring beam vibrates (due to bending) with five nodes.

"Seventh bending mode" refers to the state in which the spring beam vibrates (due to bending) with six nodes.

25 "Eighth bending mode" refers to the state in which the spring beam vibrates (due to bending) with seven nodes.

"Ninth bending mode" refers to the state in which the spring beam vibrates (due to bending) with eight nodes.

30 "Fourth torsion mode" refers to the state in which the spring beam vibrates (due to torsion) with three nodes.

TABLE III

Parameter	Spring beam of seventh embodiment
Thickness of beam members (mm)	0.02
Length of beam members (mm)	12

Width of beam members at centre (mm)	1.2
Width of beam members at ends (mm)	1.5
Distance between beam members (mm)	1mm
Stiffness (N/m)	28.8
1 st bending mode (kHz)	0.653
3 rd bending mode (kHz)	3.473
5 th bending mode (kHz)	9.238
7 th bending mode (kHz)	17.778
2 nd bending mode (kHz)	2.896
4 th bending mode (kHz)	8.599
6 th bending mode (kHz)	17.233
8 th bending mode (kHz)	29.842
1 st torsion mode (kHz)	8.4
2 nd torsion mode (kHz)	17.4
3 rd torsion +	30.4
9 th bending modes (kHz)	30.275
4 th torsion +	29.772
8 th bending modes (kHz)	35.462

Table III summarises the results of simulations conducted for frequency characteristics such as, off-track frequencies (torsion / sway) for the spring beam of the seventh embodiment:

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TABLE IV:

Parameter	Spring beam of Fig. 8a-8c	Spring beam of Fig. 9a-9c
Stiffness N/m	32.1	28.8
Width of the two beam members (mm)	1.5	1.2
Off-track freq. (kHz)	27.989 (Torsion) 31.965 (Sway)	29.772 (torsion, not obvious) 35.462 (torsion, obvious)

The two layered spring beams of the present invention have no obvious off-track motion for the first three torsion modes.

As is evident from table III and table IV, in the spring beam 80, 90 of the sixth embodiment the first torsion mode with obvious off-track motion occurs over 27.989 kHz. In the case of the seventh embodiment, the first torsion mode with obvious off-track motion occurs at 35 kHz.

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Because of the symmetry, the odd bending modes no longer couple with the in-plane motions, thereby eliminating the off-track vibrations of odd-modes. Similarly, due to the presence of the hollow cylindrical column 79, in-plane motions of even bending modes are also suppressed.

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Since the access head 35 is attached to the middle of the spring beam 80,90, the effective spring beam length is reduced to half of the total beam length. This results in smaller amplitude of up-and-down vibrations, which in turn, helps to maintain consistent flying height while accessing data from a disc.

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Additionally, the presence of the mounting spring 111 helps to reduce the vibration amplitude which, in turn, increase the shock resistance.

Further, as both the ends of the spring beam are directly mounted to the actuator arm the spring beam 80, 90 has better aerodynamic performance since air turbulence which normally occurs at the tip of a load beam are eliminated.

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Modifications may be made to the embodiments of the invention.

For instance, the spring beam shown could be modified to have dissimilar top and bottom beam members. The shape of the top and bottom beam members could be altered. The top and bottom beam members are integral with the mounting block in the embodiment, but could be formed separately and attached to the mounting block, possibly even removably attached. The two beam members could be directly mounted to the actuator arm instead of the mounting block.

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In the third and fourth embodiments, only the top beam member is shown to be angled. Additionally, or alternatively, the bottom beam member could be at an angle. The number, size and the locations of the apertures may be altered.

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The support member is shown as a flat plate, triangular column or cylindrical column. However, it could be other shapes, such as a rectangular, pentagonal, hexagonal column etc. In the sixth and seventh embodiments, other shaped columns are possible, for instance a flat plate or a polygonal column. Support member could be angled to one or both the beam members.

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The width of the support member may be less than, more than or equal to the widths of the top and bottom beam members.

- 5 Apart from hard disc systems, the spring beam of the sixth and the seventh embodiments may also be applied to micro structures that require high in-plane-mode frequencies. For instance, they may be used in positioning systems, bio-medical devices and other electronics devices that have miniature structural components.

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Those skilled in the art will recognise that the invention can be practised, with other modifications, in the light of the information contained herein without departing from the scope of the invention.

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CLAIMS

1. An elongate spring beam for use with an actuator arm of a disc access system, comprising:
 - 5 a first elongate beam member;
a second elongate beam member opposing said first beam member, said first beam member being superposed on said second beam member, said beam members being longitudinally aligned in a spaced-apart relation; and
means for supporting said first and second beam members extending
10 between opposing faces of said first and second beam members and across the width of the spring beam.
2. The spring beam of claim 1, wherein each beam member has a first end and a second end.
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3. The spring beam of claim 2, wherein said means for supporting said first and second beam members is located near to said second ends of said first and second beam members.
- 20 4. The spring beam of claim 1, 2 or 3, wherein said means for supporting said first and second beam members is located substantially halfway along the lengths of said first and second beam members.
5. The spring beam of any one of the preceding claims, wherein the width of
25 said supporting means is less than the width of at least one of said first and second beam members at the position of said supporting means.
6. The spring beam of any one of claims 1 to 4, wherein the width of said supporting means is equal to the width of at least one of said first and second beam
30 members at the position of said supporting means.
7. The spring beam of claim 2 or 3 or of claim 4 when dependent on at least claim 2, wherein the widths of said first and second beam members at said first ends are smaller than the widths at said second ends, and regions between said first and
35 second ends are tapered.

8. The spring beam of any one of the preceding claims, wherein said first and second beam members are substantially parallel to each other.

5 9. The spring beam of any one of claims 1 to 7, wherein said first and second beam members are inclined to each other.

10. The spring beam of claim 9 when dependent on at least claim 2, wherein said first ends are spaced further apart than said second ends.

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11. The spring beam of claim 9 when dependent on at least claim 2, wherein said first ends are spaced closer together than said second ends.

12. The spring beam of claim 11, wherein said first ends are in contact with each other.

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13. The spring beam of any one of the preceding claims, wherein said means for supporting said first and second beam members comprises a flat plate, having two sides.

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14. The spring beam of any one of claims 1 to 12, wherein said means for supporting said first and second beam members comprises a column having a plurality of sides extending between the opposing faces of said first and second beam members.

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15. The spring beam of claim 14, wherein said column is cylindrical.

16. The spring beam of claim 14, wherein said column is triangular.

30 17. The spring beam of claim 16 when dependent on at least claim 2, wherein the intersecting portions of a second side and a third side of the column face away from said first ends of said first and second beam members.

16. The spring beam of any one of claims 14 to 17, wherein said column is hollow.

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19. The spring beam of any one of claims 14 to 18 when dependent on at least claim 2, wherein the outer surface of one side of said column is flush with said second ends of said first and second beam members.

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20. The spring beam of any one of the preceding claims, wherein at least one side of said means for supporting said first and second beam members is substantially orthogonal to the elongate axes of said first and second beam members.

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21. The spring beam of any one of the preceding claims, wherein said means for supporting said first and second beam members extends orthogonally from at least one face of the opposing faces of said first and second beam members.

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22. The spring beam of any one of the preceding claims, wherein said first and second beam members are substantially planar.

23. The spring beam of any one of claims 2 and 3 to 22 when dependent on at least claim 2, further comprising a first means for mounting said spring beam, from which said first ends of said first and second beam members extend, said first means for mounting said spring beam having a first mounting hole for mounting the spring beam to the underside of an actuator arm.

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24. The spring beam of claim 23, wherein the thickness of said first means for mounting said spring beam is substantially equal to the distance separating the outer surfaces of said first and second beam members at said first ends.

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25. The spring beam of claim 23 or 24, wherein said first and second beam members are separately and removably attached to said first means for mounting said spring beam.

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26. The spring beam of any one of claims 23 to 25, wherein said first and second beam members are formed integrally with said first means for mounting said spring beam.

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27. The spring beam of any one of claims 23 to 26, further comprising a second means for mounting said spring beam, from which said second ends of said first and second beam members extend, said second means for mounting said spring beam having a second mounting hole for mounting the spring beam to an actuator arm.

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28. The spring beam of claim 27, wherein the thickness of said second means for mounting said spring beam is substantially equal to the distance separating the outer surfaces of said first and second beam members at said second ends.

10 29. The spring beam of claim 27 or 28, wherein said first and second beam members are separately and removably attached to said first or second means for mounting said spring beam.

15 30. The spring beam of any one of claims 27 to 29, wherein said first and second beam members are formed integrally with said first or second means for mounting said spring beam.

20 31. The spring beam of any one of the preceding claims, wherein
said first beam member has opposing first and second surfaces;
said second beam member has opposing first and second surfaces; and
said first surface of said second beam member faces and opposes said
second surface of said first beam member.

25 32. The spring beam of claim 31, further comprising a spring extending from said first surface of said first beam member.

33. The spring beam of claim 31 or 32, further comprising an access head attached to said second surface of said second beam member.

30 34. The spring beam of claim 33, further comprising a spring mounted between said second surface of said second beam member and a surface of said access head.

35 35. An actuator arm to which is attached the spring beam of any one of the preceding claims.

36. A hard disc drive comprising an actuator arm to which is attached the spring beam of any one of claims 1 to 34.

5 37. An electronic device comprising an actuator arm to which is attached the spring beam of any one of claims 1 to 34.

38. A spring beam substantially as herein before described with reference to and as illustrated in accompanying figures 3 to 12.

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39. A method of making an elongate spring beam for use with an actuator arm of a disc access system, comprising the steps of:

providing a first elongate beam member;

15 providing a second elongate beam member opposing said first beam member, said first beam member is superposed on said second beam member, said beam members being longitudinally aligned in a spaced-apart relation; and

connecting a means for supporting said first and second beam members extending between opposing faces of said first and second beam members and across the width of the spring beam.

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40. The method of claim 39 further comprising the step of mounting first ends of said first and second beam members on a first means for mounting said spring beam.

25 41. The method of claim 39 or 40 further comprising the step of mounting second ends of said first and second beam members on a second means for mounting said spring beam 42. The method of any one of claims 39 to 41, wherein the spring beam is as defined in any one of claims 1 to 32.