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Magnetic disk device and method for manufacturing magnetic disk device

Abstract

A magnetic disk device includes a plurality of disk-shaped magnetic disks **30**, spacers **80**, a hub **90**, a clamp **70**, and a fastening member **72**. Each of the magnetic disks **30** includes a through-hole in a center section thereof. Each of the spacers **80** includes a through-hole in a center section thereof, and is disposed among the magnetic disks **30**. The hub **90** is inserted into the through-holes of the magnetic disks **30** and the spacers **80**. The clamp **70** presses and holds the magnetic disks **30** and the spacers **80**. The fastening member **72** fastens the clamp **70** to the hub **90**. The clamp **70** is fastened to the hub by the fastening member **72** with a torque of from 5 cN.Math.m to 45 cN.Math.m.

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Background/Summary

TECHNICAL FIELD
(1) The present disclosure relates to a magnetic disk device and a method for manufacturing the magnetic disk device.
BACKGROUND ART
(2) The amount of data used by individuals has increased due to the spread of smartphones and smart household appliances. This enormous amount of data is sent over the internet and stored in magnetic disk devices (hard disk drives, HDD) in data centers. There is a need for magnetic disk devices that have increased capacity in order to store this enormous amount of data.
(3) For example, Patent Literature 1 describes a substrate for a magnetic recording medium in which, in order to reduce the thickness of a housing that accommodates the magnetic recording medium, a portion, that is a predetermined distance from an inner circumferential edge of at least one side of a disk-like resin substrate including a through-hole at a center thereof, has a shape that is thicker than a portion outside the predetermined distance.
CITATION LIST
Patent Literature
(4) Patent Literature 1: Unexamined Japanese Patent Application Publication No. 2009-54254
SUMMARY OF INVENTION
Technical Problem
(5) One example for increasing the capacity of a magnetic disk device is the technological trend of increasing the number of magnetic disks mounted in the magnetic disk device and expanding the data area per each magnetic disk device. However, the dimensions of magnetic disk devices are defined by standards and, as such, modifications such as reducing the thickness of the magnetic disks are required to increase the number of mounted magnetic disks. When the thickness of the magnetic disk is reduced, rigidity declines and impact resistance declines. For example, the magnetic disk is more likely to deform when subjected to an impact such as when the HDD is

dropped. That is, there is a trade-off relationship between increasing the capacity of the magnetic disk device and the impact resistance of the magnetic disk device.
(6) The present disclosure is made with the view of this type of situation, and an objective of the present disclosure is to provide a magnetic disk device that has excellent impact resistance and high data capacity, and a method for manufacturing the magnetic disk device.
Solution to Problem
(7) In order to achieve the objective described above, a magnetic disk device according to a first aspect of the present disclosure includes: a plurality of disk-shaped magnetic disks, each including a through-hole in a center section thereof; a spacer that is disposed among the magnetic disks and that includes a through-hole in a center section thereof; a hub inserted into the through-holes of the magnetic disks and the spacer; a clamp pressing and holding the magnetic disks and the spacer; and a fastening member that fastens the clamp to the hub, wherein the clamp is fastened to the hub by the fastening member with a torque of from 5 cN.Math.m to 45 cN.Math.m.
(8) It is preferable that the clamp is fastened to the hub by the fastening member with a torque of from 20 cN.Math.m to 45 cN.Math.m.
(9) It is preferable that the clamp is fastened to the hub by the fastening member with a torque of from 20 cN.Math.m to 35 cN.Math.m.
(10) It is preferable that each of the magnetic disks has a size of an inner diameter of 25 mm, an outer diameter of from 95 mm to 97 mm, and a thickness of 0.35 mm to 0.635 mm, the spacer has a size of an inner diameter of 25 mm, an outer diameter of from 32 mm to 33 mm, and a thickness of from 1.6 mm to 1.8 mm, and a distance from a center of the fastening member to a protrusion center provided on the clamp is 5 mm.
(11) It is preferable that a first contact length in a radial direction of the magnetic disks and the clamp is greater than or equal to one-half of a second contact length in the radial direction of the magnetic disks and the spacer.
(12) It is preferable that a plurality of the spacer is stacked and layered between the magnetic disks.
(13) It is preferable that a plurality of the spacer is stacked and layered between a magnetic disk, of the magnetic disks, contacting the clamp and a magnetic disk adjacent to the magnetic disk.
(14) It is preferable that each of the magnetic disks has a thickness of 0.48 mm or less.
(15) It is preferable that each of the magnetic disks has a thickness of 0.36 mm or less.
(16) In order to achieve the objective described above, a method for manufacturing a magnetic disk device according to a second aspect of the present disclosure that achieves the objective described above, the magnetic disk device including a plurality of disk-shaped magnetic disks, each including a through-hole in a center section thereof, a spacer that is disposed among the magnetic disks and that includes a through-hole in a center section thereof, a hub inserted into the through-holes of the magnetic disks and the spacer, a clamp pressing and holding the magnetic disks and the spacer, and a fastening member that fastens the clamp to the hub, includes: fastening the clamp to the hub by the fastening member with a torque of from 5 cN.Math.m to 45 cN.Math.m.
Advantageous Effects of Invention
(17) According to the present disclosure, a magnetic disk device can be provided that has excellent impact resistance and high data capacity.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1**A is a top view illustrating a magnetic disk device according to an embodiment;
(2) FIG. **1**B is a side view illustrating the magnetic disk device;
(3) FIG. **2** is a cross-sectional view illustrating magnetic disks and spacers of the magnetic disk device according to the embodiment;

(4) FIG. **3** is an enlarged cross-sectional view illustrating the magnetic disks and the spacers of the magnetic disk device according to the embodiment;
(5) FIG. **4** is a drawing illustrating a case in which an impact is applied to a magnetic disk of the magnetic disk device according to the embodiment;
(6) FIG. **5** is an enlarged cross-sectional view illustrating magnetic disks and spacers of a magnetic disk device according to a modified example; and
(7) FIG. **6** is an enlarged cross-sectional view illustrating magnetic disks and spacers of a magnetic disk device according to a modified example.

DESCRIPTION OF EMBODIMENTS

(8) In the following, a magnetic disk device (hard disk drive, HDD) according to various embodiments of the present disclosure is described while referencing the drawings.

(9) A magnetic disk device **100** of the present embodiment is a box-type recording/playback device and, as illustrated in FIGS. **1**A and **1**B, includes a housing **10**, a base **20**, a plurality of magnetic disks **30** that are stacked and disposed, a head stack assembly **40**, a voice coil motor **50**, a load/unload ramp **60**, a clamp **70**, and non-illustrated necessary members such as a spindle motor, a circuit board, and the like. Additionally, as illustrated in FIGS. **2** and **3**, the magnetic disk device **100** includes a plurality of spacers **80** disposed among the plurality of magnetic disks **30**, and a hub **90** that rotates the plurality of magnetic disks **30** around a rotational axis Z.

(10) Returning to FIG. **1**, the dimensions of the magnetic disk device **100** are set by common standards. For example, a 3.5 inch magnetic disk device having dimensions complying with SFF-8301 standards are preferably used in data centers. In these standards, a height H of the housing **10** is set to 26.1 mm, a width W is set to 101.6 mm, and a depth D is set to 147 mm.

(11) The housing **10** is typically made from a metal, and has a cubic box shape in which one face is open. The base **20**, the magnetic disks **30**, the head stack assembly **40**, the voice coil motor **50**, the load/unload ramp **60**, the clamp **70**, and the necessary members such as the spindle motor, the circuit board, and the like are sealed in the housing **10** by a non-illustrated top cover.

(12) The base **20** is disposed on the bottom of the housing **10** and is a portion on which the voice coil motor **50**, the spindle motor, the circuit board, and the like are mounted. In many cases, the base **20** and the housing **10** are integrated.

(13) As illustrated in FIGS. **2** and **3**, the magnetic disks **30** are disk-shaped media that are for magnetically recording information and that have a through hole in a center section thereof. Each of the magnetic disks **30** includes a substrate, an underlayer, a magnetic layer, a protective layer, and a lubricant layer. The magnetic disks **30** rotate around the rotational axis Z. Perpendicular magnetic recording (PMR), or shingled magnetic recording (SMR) is preferably used as the magnetic recording method. In order to realize even higher capacity, technologies such as heat assisted magnetic recording (HAMR) and microwave assisted magnetic recording (MAMR) have been developed. An aluminum alloy substrate or a glass substrate is preferably used as the substrate. The aluminum alloy substrate and the glass substrate are described later in detail.

(14) A thickness Td of each of the magnetic disks **30** is preferably 0.2 mm or greater, and is more preferably 0.35 mm or greater. Additionally, the thickness Td of each of the magnetic disks **30** is 1.75 mm or less, is preferably 0.635 mm or less, is more preferably 0.50 mm or less, is even more preferably 0.48 mm or less, and is yet even more preferably 0.36 mm or less. It is preferable that an outer diameter 2×Rd of each of the magnetic disks **30** is from 95 mm to 97 mm, and an inner diameter is 25 mm. Additionally, a number N of the magnetic disks **30** of the magnetic disk device **100** of the present embodiment is preferably from 8 to 16. One example for increasing the capacity of the magnetic disk device **100** is the technique of increasing the number of mounted magnetic disks **30** and expanding the data area per each magnetic disk device **100**. However, as described above, the dimensions of the magnetic disk device **100** are set by standards, and the space for mounting the magnetic disks **30** is limited. As such, the thickness of each of the magnetic disks **30** is reduced in order to increase the number of mounted magnetic disks **30**.

(15) Returning to FIG. **1**, the head stack assembly **40** includes an arm **41**, and a head **42** attached to a tip of the arm **41**. When recording using HAMR, a laser element is mounted on the head **42** and, when recording using MAMR, a microwave generating element is mounted on the head **42**.
(16) The voice coil motor **50** is a driving motor that rotates the head stack assembly **40**.
(17) The load/unload ramp **60** is a component made from resin. The load/unload ramp **60** is mounted at a position closest to the magnetic disks **30** on the outer circumference side of the magnetic disks **30**, and is for retracting the head **42** when the magnetic disk device **100** is not in operation.
(18) The clamp **70** is formed from a metal, such as an aluminum alloy or the like, that is not a ferromagnetic material. As illustrated in FIGS. **2** and **3**, the clamp **70** includes, on a surface opposing an upper surface of the magnetic disks **30**, a protrusion **71** that contacts the uppermost magnetic disk **30** of the magnetic disks **30**, and presses, holds, and fixes pluralities of magnetic disks **30** and spacers **80** on the hub **90**. The surfaces of the clamp **70** may also be subjected to a coating treatment such as Ni—P plating or the like. The magnetic disks **30** are placed in a fixed state by the clamp **70** due to the protrusion **71** of the clamp **70** press-contacting the upper surface of the uppermost magnetic disk **30** of the magnetic disks **30**. An inner diameter side portion of the upper surface of the uppermost magnetic disk **30** of the magnetic disks **30** is clamp-fixed by the protrusion **71** and, as such, separation of the magnetic disks **30** when high-speed rotating and processing data is prevented. The clamp **70** is fixed to the hub **90** by a fastening member **72**. In one example, a screw, a hexalobed (hexagonal star) screw, or the like is used as the fastening member **72**. A coarse, 0.4 mm pitch or the like is used as the pitch of the fastening member **72**. Examples of the material of the fastening member **72** include stainless steel and the like. A first contact length L**1** in a radial direction of the magnetic disk **30** and the protrusion **71** is preferably greater than or equal to one-half of second contact length L**2** in the radial direction of the magnetic disks **30** and the spacers **80**. In the radial direction, a distance L**3** from the center of the fastening member **72** fixing the clamp **70** to the center of the protrusion **71** is preferably set to from 4.0 to 6.5 mm. Additionally, a hole diameter d**1** of the clamp **70** for inserting the fastening member **72** is preferably set to from 2.0 to 3.5 mm. Moreover, a height t**1** of the protrusion **71** is preferably set to from 0.1 to 0.5 mm.
(19) The spacers **80** are ring-shaped thin plates, and are disposed among the plurality of magnetic disks **30**. As a result of the spacers **80** being disposed among the magnetic disks **30**, the magnetic disks **30** are strongly fixed to the hub **90** of the spindle motor by the clamp **70**. The role of the spacers **80** is to secure gaps among the plurality of magnetic disks **30**, and to contact and adhere to the magnetic disks **30** to transmit the rotational driving force of the hub **90** to the magnetic disks **30** that do not directly contact the hub **90** or the clamp **70**.
(20) Regarding the thickness Ts of each of the spacers **80**, it is preferable that the gaps between the magnetic disks **30** are narrow because, in such a case, many magnetic disks **30** can be mounted in the limited space. However, space for operating the head stack assembly **40** is needed on the surfaces of the magnetic disks **30**. In particular, in the high capacity technologies of HAMR and MAMR described above, when recording using HAMR, a laser element must be mounted on the head **42** and, when recording using MAMR, a microwave generating element must be mounted on the head **42**. Consequently, miniaturization of the head stack assembly **40** is not easy. Each of the gaps among the magnetic disks **30**, that is, the thickness Ts of each of the spacers **80**, must be at least 1 mm or greater, is preferably 1.5 mm or greater, and is more preferably 1.6 mm or greater. Additionally, the thickness Ts of each of the spacers **80** is preferably 1.8 mm or less so that as many of the magnetic disks **30** as possible can be mounted in the magnetic disk device **100**.
(21) Regarding the shape of the spacers **80**, it is desirable that the flatness of both sides of each of the spacers **80** is low. Furthermore, it is desirable that chamfering for the purpose of deburring is performed on the front and rear surfaces and inner-outer circumference edge surfaces (hereinafter, spacer inner-outer circumferences) of the spacers **80**. This is because, when stacking the magnetic

disks **30** and the spacers **80**, there is a concern about burrs on the spacer **80** inner-outer circumferences contacting the magnetic disks **30** and causing scratches.
(22) It is desirable that a material that reduces the thermal expansion coefficient difference between the spacers **80** and the magnetic disks **30** is selected as the material of the spacers **80**. When the thermal expansion coefficient difference between the magnetic disks **30** and the spacers **80** is great, misalignments between the spacers **80** and the surfaces of the magnetic disk **30** occur when the environmental temperature changes during operation of the magnetic disk device **100**, and such misalignments cause read/write errors. When the magnetic disks **30** include aluminum alloy substrates, aluminum is preferably used for the spacers **80**. When the magnetic disks **30** include glass substrates, glass, stainless steel, titanium, or the like is preferably used for the spacers **80**. Furthermore, it is desirable that the spacers **80** are conductive for the purpose of preventing static charge on the magnetic disks **30** and/or the spacers **80**. When glass is used for the spacers **80**, it is desirable that a metal film such as Ni—P plating or the like is provided on the front and rear surfaces and the side surface of each of the glass spacers **80**.
(23) Next, a case is described in which a plurality of the magnetic disks **30** is mounted in the magnetic disk device **100**. As illustrated in FIGS. **2** and **3**, Rd is an outer radius of the magnetic disks **30**, Td is the thickness of each of the magnetic disks **30**, Rso is an outer radius of the spacers **80**, Ts is the thickness of each of the spacers **80**, and T is a stacked height of the magnetic disks **30** and the spacers **80**. The inner diameter of the magnetic disks **30** and the inner diameter of the spacers **80** are equivalent, and an inner radius of the magnetic disks **30** equals an inner radius Rsi of the spacers **80**. In one example, the inner diameter of the magnetic disks **30** and an inner diameter 2Rsi of the spacers **80** are 25 mm. Additionally, an outer diameter 2Rso of the spacers **80** is preferably from 32 mm to 33 mm.
(24) Here, a magnetic disk device **100** is considered in which the height H of the housing **10**, which is compliant with SFF-8301, is 26.1 mm. When N of the magnetic disks **30**, each having the thickness Td, and (N−1) of the spacers **80**, each having the thickness Ts are alternately stacked in the magnetic disk device **100**, the stacked height T thereof, namely $T=N\times Td+(N-1)\times Ts$, must be lower than 26.1 mm. However, in addition to the magnetic disks **30** and the spacers **80**, other components such as the base **20**, the circuit board, the spindle motor. the clamp **70**, the hub **90**, the top cover, and the like are also mounted in the space inside the magnetic disk device **100**. As such, the stacked height T of the magnetic disks **30** and the spacers **80** is preferably 20 mm or less, and is more preferably 19 mm or less. As described above, a lower limit value of the thickness Td of each of the magnetic disks **30** is 0.3 mm, a lower limit value of the thickness Ts of each of the spacers **80** is 1 mm, and an upper limit value of the stacked height T of the magnetic disks **30** and the spacers **80** is 20 mm. As such, an upper limit value of the number N of magnetic disks **30** is 16. Additionally, in order to realize high capacity of the magnetic disk device **100**, the number N of the magnetic disks **30** is preferably 8 or greater.
(25) The hub **90** is formed from a metal, such as an aluminum alloy or the like, that is not a ferromagnetic material, has a shape in which a small diameter section **91** and a large diameter section **92**, which have cylindrical shapes, are connected in the direction of the rotational axis Z, and is rotated by the spindle motor with the rotational axis Z as a center axis. A diameter of the small diameter section **91** is the same as the inner diameter of the magnetic disks **30** and the inner diameter 2Rsi of the spacers **80**. The large diameter section **92** and the clamp **70** sandwich and fix the magnetic disks **30** and the spacers **80**.
(26) As described above, the magnetic disks **30** are disk-shaped media for magnetically recording information, and each include a substrate, an underlayer, a magnetic layer, a protective layer, and a lubricant layer. An aluminum alloy substrate or a glass substrate is preferably used as the substrate.
(27) Aluminum Alloy Substrate
(28) A conventionally used Al—Mg alloy such as JIS5086 alloy or the like, which has high strength, is preferably used for the aluminum alloy substrate. Alternatively, an Al—Fe alloy, which

has high rigidity, is preferably used for the aluminum alloy substrate.
(29) Specifically, the Al—Mg alloy is an aluminum alloy that contains from 1.0 to 6.5 mass % of Mg; further contains one or two or more of 0.070 mass % or less of Cu, 0.60 mass % or less of Zn, 0.50 mass % or less of Fe, 0.50 mass % or less of Si, 0.20 mass % or less of Cr, 0.50 mass % or less of Mn, and 0.20 mass % or less of Zr; and in which the balance consists of aluminum, unavoidable impurities, and other trace elements. Examples of the other trace elements include Be, Sr, and the like and, provided that the content of each trace element is 0.1 mass % or less, these trace elements do not inhibit the effects of the present disclosure.
(30) The Al—Fe alloy is an aluminum alloy that contains Fe, which is a required element, and one or two of Mn and Ni, which are selective elements, the sum of the contents of the Fe, Mn, and Ni having a relationship of from 1.00 to 7.00 mass %; further contains one or two or more of 14.0 mass % or less of Si, 0.7 mass % or less of Zn, 1.0 mass % or less of Cu, 3.5 mass % or less of Mg, 0.30 mass % or less of Cr, and 0.20 mass % or less Zr; and in which the balance consists of aluminum, unavoidable impurities, and other trace elements. Examples of the other trace elements include Be, Sr, and the like and, provided that the content of each trace element is 0.1 mass % or less, these trace elements do not inhibit the effects of the present disclosure.
(31) Next, a method for manufacturing the aluminum alloy substrate is described.
(32) Firstly, an ingot is fabricated by a semi-continuous casting method, and the fabricated ingot is hot rolled and cold rolled to fabricate a plate material of a desired thickness. Alternatively, a plate material is fabricated by continuous casting, and the fabricated plate material is cold rolled to fabricate a plate material of a desired thickness. The ingot may be subjected to a heat treatment for the purpose of homogenizing the structure. The plate material may be subjected to a heat treatment prior to the cold rolling, during the cold rolling, and after the cold rolling for the purpose of improving workability and the like.
(33) Next, the plate material fabricated as described above is punched using a press machine, and disk-shaped blanks having desired inner diameter and outer diameter dimensions are fabricated. Then, the blanks are stacked, a load is applied to the stacked blanks, and heat treatment is performed for the purpose of reducing the flatness of the blanks.
(34) Next, the inner diameter section and the outer diameter section of each of the blanks are turned on a lathe, and T-subs having desired inner diameter and outer diameter dimensions and a chamfer of a desired length are fabricated. Furthermore, the surfaces of both sides of each of the blanks may be ground and T-subs having a desired thickness may be fabricated. Furthermore, the T-subs may be subjected to a heat treatment for the purpose of eliminating the machining distortion generated in the material due to the grinding.
(35) Next, the surfaces of both sides of each of the T-subs are ground using a grinding machine, and G-subs of a determined thickness are fabricated. Furthermore, the G-subs may be subjected to a heat treatment for the purpose of eliminating the machining distortion generated in the material due to the grinding.
(36) Next, M-subs are fabricated by forming a plating of a desired thickness on all surfaces, including the front surface, the rear surface, the end surfaces, the side surface, and the chamfer surface, of the G-subs. Firstly, the G-subs are subjected to pre-processing for the purpose of enhancing plating adhesion. Next, plating is performed. Ni—P electroless plating is preferably used as the plating. Furthermore, the M-subs may be subjected to a heat treatment for the purpose of eliminating the internal stress of the Ni—P electroless plating.
(37) Next, the surfaces of both sides of each of the M-subs are polished using a polishing machine, and substrates, that is, aluminum alloy substrates, of a desired thickness are fabricated. The lower limit value of the thickness of the each of the aluminum alloy substrates fabricated by this method is 0.3 mm. This lower limit value is due to the thickness of a component called a carrier that holds the aluminum alloy substrate when polishing on the polishing machine. The thickness of the carrier can be selected as desired provided that it is greater than or equal to the thickness of each

workpiece, namely the aluminum alloy substrate. However, when the carrier is excessively thin, strength is insufficient and the carrier breaks during polishing. From the perspective of the strength of the carrier, the thickness of the carrier is preferably 0.3 mm or greater. Therefore, the lower limit value of the thickness of each workpiece, namely the aluminum alloy substrate, is 0.3 mm. Note that a carrier made from a resin such as aramid resin, epoxy resin, or the like is preferably used as the carrier. The carrier may include a fibrous reinforcing material such as carbon fiber, glass fiber, or the like for the purpose of enhancing strength.

(38) Next, the underlayer, the magnetic layer, the protective layer, and the lubricant layer are formed on the front surface and the rear surface of each of the aluminum alloy substrates. Thus, the magnetic disks **30** are obtained.

(39) Glass Substrate

(40) An aluminosilicate glass, which has high hardness, is preferably used for the glass substrate. Specifically, the aluminosilicate glass contains from 55 to 70 mass % of SiO.sub.2 as a main component; one or two or more of 25 mass % or less of Al.sub.2O.sub.3, 12 mass % or less of Li.sub.2O, 12 mass % or less of Na.sub.2, 8 mass % or less of K.sub.2O, 7 mass % or less of MgO, mass % or less of CaO, 10 mass % or less of ZrO.sub.2, and 1 mass % or less of TiO.sub.2; and the balance consists of unavoidable impurities and other trace elements.

(41) Next, a method for manufacturing the glass substrate is described.

(42) Firstly, a glass material prepared in a predetermined chemical composition is dissolved, and a direct press method is used to press-mold the molten ingot from both sides to fabricate glass base plates having a desired thickness. The method used to fabricate the glass base plates is not limited to the direct press method, and a float method, a fusion method, a redraw method, or the like may be used.

(43) Next, the glass base plates are cored in an annular shape, and the inner diameter section and the outer diameter section are polished. Thus, annular glass plates having desired inner diameter and outer diameter dimensions and a desired chamfer length are obtained.

(44) Next, the surfaces of both sides of each of the annular glass plates are ground using a grinding machine, and annular glass substrates having a desired thickness and flatness are obtained.

(45) Furthermore, the surfaces of both sides of each of the annular glass substrates are polished using a polishing machine, and substrates, that is, glass substrates, of a desired thickness are fabricated. During the polishing, a chemical strengthening treatment using a sodium nitrate solution, a potassium nitrate solution, or the like may be carried out.

(46) The lower limit value of the thickness of each of the glass substrates fabricated by this method is 0.3 mm. This lower limit value is due to the thickness of a component called a carrier that holds the glass substrate when polishing on the polishing machine. The thickness of the carrier can be selected as desired provided that it is greater than or equal to the thickness of each workpiece, namely the glass substrate. However, when the carrier is excessively thin, strength is insufficient and the carrier breaks during polishing. From the perspective of the strength of the carrier, the thickness of the carrier is preferably 0.3 mm or greater. Therefore, the lower limit value of the thickness of each workpiece, namely the glass substrate, is 0.3 mm. Note that a carrier made from a resin such as aramid resin, epoxy resin, or the like is preferably used as the carrier. The carrier may include a fibrous reinforcing material such as carbon fiber, glass fiber, or the like for the purpose of enhancing strength.

(47) Impact Resistance

(48) When the magnetic disk device **100** is subjected to an impact from outside, as illustrated in FIG. **4**, the magnetic disks **30** flex, and the magnetic disks **30** collide with the load/unload ramp **60**, for example. As described above, the load/unload ramp **60** is a resin component that is mounted at a position closest to the magnetic disks **30** on the outer circumference side of the magnetic disks **30**, and is for the purpose of retracting the head **42** when the magnetic disk device **100** is not in operation. When the magnetic disks **30** collide with the load/unload ramp **60**, a portion of the

load/unload ramp **60** chips off, thus producing foreign matter, scratching the magnetic disks **30**, and the like, which causes failures. As the rigidity of the magnetic disks **30** increases, the amount of flexing decreases and the probability of failure decreases. That is, as the rigidity of the magnetic disks **30** increases, the impact resistance increases.

(49) Fluttering Resistance

(50) During operation of the magnetic disk device **100**, the magnetic disks **30** rotate at high speed. In one example, the rotation speed is 7200 RPM. When the magnetic disks **30** rotate at high speed, a turbulent flow is generated in the gas inside the device including the magnetic disks **30**, and the magnetic disks **30** vibrate. This vibration phenomenon is called fluttering. When the magnetic disks **30** vibrate, the position accuracy of the head **42** decreases, which causes read errors. As the rigidity of the magnetic disks **30** increases, the amount of vibration decreases, and the probability of read errors decreases. That is, as the rigidity of the magnetic disks **30** increases, the fluttering resistance increases. Note that a technique is known for filling the inside of the magnetic disk device **100** with helium instead of air for the purpose of reducing the turbulent flow of gas inside the magnetic disk device **100**.

(51) Rigidity of Magnetic Disks

(52) The impact resistance of the magnetic disks **30** is expressed by the magnitude of the amount of flex of the magnetic disks **30** when the magnetic disks **30** are subjected to acceleration caused by impact. The fluttering resistance of the magnetic disks **30** is expressed by the magnitude of the amount of flex of the magnetic disks **30** when the magnetic disks **30** are subjected to the turbulent flow of gas generated by the high speed rotation of the magnetic disks **30**. That is, the impact resistance and the fluttering resistance of the magnetic disks **30** are determined by whether the magnetic disks **30** easily flex.

(53) Torque when Tightening Clamp

(54) The clamp **70** is fastened to the hub by the fastening member **72** with a torque of from 5 cN.Math.m to 45 cN.Math.m. It is preferable that a T6 to T8 size hexalobed screw or the like is used as the fastening member **72**. Note that a member having a bolt diameter of M2 or the like is used. An upper limit value of the torque when tightening is 45 cN.Math.m, is preferably 40 cN.Math.m, and is more preferably 35 cN.Math.m. When the upper limit value of the torque when tightening is set to these values, the impact resistance of the magnetic disk device **100** can be enhanced. Specifically, when the upper limit value of the torque when tightening is set to these values, it is possible to prevent gaps from forming in a portions of contact sections of the magnetic disks **30** and the spacers **80**. When gaps cannot form in portions of the contact sections of the magnetic disks **30** and the spacers **80**, deformation of the magnetic disks **30** is prevented even when the magnetic disk device **100** is subjected to an impact from outside, and the impact resistance of the magnetic disk device **100** is excellent. Meanwhile, a lower limit value of the torque when tightening is 5 cN.Math.m, is preferably 20 cN.Math.m, and is more preferably 25 cN.Math.m. When the torque when tightening is set to these values, the magnetic disks **30** and the spacers **80** can be sufficiently fastened. When the lower limit value of the torque when tightening is less than 5 cN.Math.m, the fastening member **72** may loosen.

(55) Ratio of First Contact Length L**1** to Second Contact Length L**2**

(56) The first contact length L**1** in the radial direction of the uppermost magnetic disk and the clamp **70** is preferably greater than or equal to one-half of the second contact length L**2** in the radial direction of the magnetic disks **30** and the spacers **80**. When the first contact length L**1**/the second contact length L**2** is set to one-half or greater, the impact resistance can be enhanced. When the first contact length L**1**/the second contact length L**2** is set to one-half or greater, the contact section of the uppermost magnetic disk and the clamp **70** increases, and gaps between the magnetic disk **30** and the clamp **70** can be reduced. When the gaps are reduced, deformation of the magnetic disks **30** is prevented even when the magnetic disk device **100** is subjected to an impact from outside, and the impact resistance of the magnetic disk device **100** is excellent. Therefore, the first contact

length L**1**/the second contact length L**2** is preferably set to one-half or greater, and is more preferably set to 0.9 or greater. From the perspective of impact resistance, it is preferable that the first contact length L**1**/the second contact length L**2** is close to 1.0. However, the weight of the clamp increases as the first contact length L**1**/the second contact length L**2** approaches 1.0 and, as such, an upper limit is preferably set to about 0.95.

(57) Method for Manufacturing Magnetic Disk Device

(58) As illustrated in FIG. **2**, in a method for manufacturing the magnetic disk device, in a disposing step, the magnetic disks **30** and the spacers **80** are disposed on the hub **90** and, in a fastening step, the clamp **70** is fastened to the hub **90** by the fastening member **72** with a torque of from 5 cN.Math.m to 45 cN.Math.m. Specifically, in the disposing step, the magnetic disks **30** and the spacers **80** are alternately stacked and disposed on the hub **90**. In the fastening step, the clamp **70** is mounted on the hub **90** on which the magnetic disks and the spacers **80** are disposed, and the clamp **70** is fastened to the hub **90** using a hexalobed screw as the fastening member **72**. As a result, the magnetic disks **30** and the spacers **80** are fixed to the hub **90**. In the fastening step, the upper limit value of the torque when tightening the clamp **70** using the fastening member **72** is, as described above, 45 cN.Math.m, is preferably 40 cN.Math.m, and is more preferably 35 cN.Math.m. Additionally, the lower limit value of the torque is 5 cN.Math.m, is preferably 20 cN.Math.m, and is more preferably 25 cN.Math.m. Note that, in FIG. **1**, six fastening members **72** are used, and the torque when tightening is preferably the same for all of the fastening members **72**. The tightening torque can, for example, be adjusted using a Kanon idling torque driver manufactured by Nakamura Mfg. Corporation. Additionally, the tightening torque can be measured using, for example, a torque driver manufactured by Tohnichi Mfg. Co.

(59) Thus, according to the magnetic disk device **100** of the present embodiment, the torque when tightening the clamp **70** is appropriately adjusted and, due to this, impact resistance can be enhanced without reducing the recording area. As a result, a 3.5 inch magnetic disk device in which magnetic disks, formed from aluminum alloy substrates and glass substrates that have excellent impact resistance and high data capacity, are mounted can be provided. Additionally, the first contact length L**1** in the radial direction of the uppermost magnetic disk **30** and the clamp **70** is greater than or equal to one-half of the second contact length L**2** in the radial direction of the magnetic disks **30** and the spacers **80** and, as such, the magnetic disk device **100** can enhance the impact resistance without reducing the recording area. By installing the magnetic disk device **100** in a data center, the capacity of the data center can be increased. Additionally, the concept of the present embodiment that the impact resistance can be enhanced without reducing the recording area by appropriately adjusting the torque when tightening the clamp **70** and by setting the first contact length L**1** to one-half of the second contact length L**2** or greater is not limited to the 3.5 inch magnetic disk device **100**, and can be applied to magnetic disk devices **100** of all sizes. The type of the magnetic disks **30** is not limited to the magnetic disks **30** formed from the aluminum alloy substrate and the glass substrate, and any type of magnetic disks **30** can be used.

Modified Examples

(60) In the embodiment described above, an example is described in which the spacers **80** are disposed, without stacking, between the magnetic disks **30**. A configuration is possible in which a plurality of the spacers **80** are stacked and layered, as illustrated in FIG. **5**. Typically, one of the spacers **80** is inserted between the magnetic disks **30**, but two or more of the spacers **80** can be stacked and layered to enhance the impact resistance. Note that, although it is preferable that a greater number of the spacers **80** are provided, when the number of the spacers **80** is excessive, the number of mounted magnetic disks **30** decreases. As such, the upper limit of the number of the spacers **80** is set to three. Additionally, when, as illustrated in FIG. **6**, the number of all of the spacers **80** is set to two or more, the number of mounted magnetic disks **30** decreases. As such, it is preferable that only the spacer **80** that contacts the uppermost magnetic disk **30** (the magnetic disk **30** that contacts the clamp **70**) where deformation is likely to be great is set to two or more of the

spacers **80**. Note that increasing the thickness Ts of each of the spacers **80** is also effective but, in such a case, the design of the spacers **80** must be modified and is impractical. As such, it is preferable to stack and layer a plurality of the spacers **80**.
(61) In the embodiments described above, an example is described in which the magnetic disk device **100** is a 3.5 inch magnetic disk device. However, the magnetic disk device **100** may be a device other than a 3.5 inch device. For example, the magnetic disk device **100** may be a 2.5 inch magnetic disk device.
Examples
(62) In the following, the present disclosure is described in further detail using examples, but the present disclosure is not limited to these examples.
(63) Tightening Torque when Fastening Clamp, and Amount of Flex of Magnetic Disks
(64) Plated aluminum alloy substrates having the compositions illustrated in Table 1 and glass substrates having the composition illustrated in Table 2 were fabricated as magnetic disk substrates **31**. The substrate size was an inner diameter of 25 mm, an outer diameter of 97 mm, and a thickness of 0.50 mm. Aluminum spacers having an inner diameter of 25 mm, an outer diameter of 32 mm, and a thickness of 1.7 mm were used for the spacers **80**. A clamp in which the distance L**3** illustrated in FIG. **3** from the center of the fastening member **72** to the center of the protrusion **71** is 5 mm, a hole diameter d**1** illustrated in FIG. **3** of the clamp **70** for inserting the fastening member **72** is 2 mm, and the height t**1** illustrated in FIG. **3** of the protrusion **71** is 0.2 mm was used as the clamp **70**. A T6 size hexalobed screw having a bolt diameter of M2 was used as the fastening member **72**.
(65) TABLE-US-00001 TABLE 1 SINGLE RELATIVE SIDE VALUE OF ALLOY COMPOSITION (MASS %) PLATING TIGHTEN- MAXIMUM Al + UN- THICK- ING AMOUNT AVOIDABLE NESS TORQUE OF FLEX Fe Mn Ni Mg Zn Cu Cr Zr Be Si IMPURITIES (μm) (cN .Math. m) (%) EXAMPLE 1 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 30 96.0 EXAMPLE 2 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 40 97.5 EXAMPLE 3 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 5 30 96.3 EXAMPLE 4 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 5 40 98.9 EXAMPLE 5 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 10 30 96.2 EXAMPLE 6 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 10 40 96.3 EXAMPLE 7 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 10 99.3 EXAMPLE 8 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 30 97.3 EXAMPLE 9 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 40 98.1 COM- 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 50 100 PARATIVE EXAMPLE 1 COM- 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 5 50 100 PARATIVE EXAMPLE 2 COM- 0.69 0.91 1.67 0.00 0.33 0.02 0.00 0.00 0.0000 0.06 BALANCE 10 50 100 PARATIVE EXAMPLE 3 COM- 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 50 100 PARATIVE EXAMPLE 4 COM- 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 60 101.1 PARATIVE EXAMPLE 5
(66) TABLE-US-00002 TABLE 2 CHEMICAL COMPOSITION (MASS %) RELATIVE TRACE VALUE OF ELEMENTS TIGHTEN- MAXIMUM AND UN- ING AMOUNT AVOIDABLE TORQUE OF FLEX No. SiO.sub.2 Al.sub.2O.sub.3 ZrO.sub.2 Na.sub.2O K.sub.2O MgO CaO TiO.sub.2 Li.sub.2O IMPURITIES (cN .Math. m) (%) EXAMPLE 63.0-69.0 12.0-18.0 0.0-0.5 9.0-11.0 0.1-0.5 0.5-1.5 1.0-3.0 0.0-0.5 3.0-5.0 BALANCE 30 97.4 10 EXAMPLE 63.0-69.0 12.0-18.0 0.0-0.5 9.0-11.0 0.1-0.5 0.5-1.5 1.0-3.0 0.0-0.5 3.0-5.0 BALANCE 40 98.3 11 COM- 63.0-69.0 12.0-18.0 0.0-0.5 9.0-11.0 0.1-0.5 0.5-1.5 1.0-3.0 0.0-0.5 3.0-5.0 BALANCE 50 100 PARATIVE EXAMPLE 6
(67) Next, as illustrated in FIG. **4**, one magnetic disk substrate **31** was fixed on the hub **90** by the spacers **80** and the clamp **70**, and these components were installed in an impact testing device. The tightening torque used when fixing the magnetic disk substrate **31** in Examples 1 to 9 and

Comparative Examples 1 to 5 is illustrated in Table 1, and the tightening torque used when fixing the magnetic disk substrate **31** in Examples and 11 and Comparative Example 6 is illustrated in Table 2. The tightening torque was adjusted using a Kanon idling torque driver manufactured by Nakamura Mfg. Corporation. The torque was measured using a torque driver manufactured by Tohnichi Mfg. Co. The amount of flex caused by impact of an outer circumferential position (a distance r**1** from a substrate center: 44.2 mm) of the magnetic disk substrate **31** and an inner circumferential position (a distance r**2** from the substrate center: 23 mm) of the magnetic disk substrate **31** was measured by a capacitive distance sensor by applying an impact at an acceleration of 55 to 60 G and an action time of 2.7 to 3.0 ms.

(68) A difference between the outer circumferential position and the inner circumferential position ([amount of flex of outer circumferential position]−[amount of flex of inner circumferential position]) was calculated, and a value obtained by dividing the maximum value of the absolute value by the acceleration ([maximum value of absolute value of difference between amounts of flex]/[acceleration], hereinafter referred to as “maximum amount of flex”) was calculated. The measuring was performed one time for each sample. Then, a relative value of the maximum amount of flex of each tightening torque of Examples 1 to 11, which have the same composition, was calculated with the maximum amount of flex of Comparative Examples 1 to 4, and 6, in which the tightening torque is 50 cN.Math.m, set to 100%. The relative value of the maximum amount of flex was calculated on the basis of Comparative Example 1 for Examples 1 and 2, Comparative Example 2 for Examples 3 and 4, Comparative Example 3 for Examples 5 and 6, Comparative Example 4 for Examples 7 to 9, and Comparative Example 6 for Examples 10 and 11. The relative value of the maximum amount of flex of Comparative Example 5 was calculated with the maximum amount of flex of Comparative Example 4 set to 100%. In Comparative Example 5, the tightening torque was 60 cN.Math.m and, as such, the relative value of the maximum amount of flex was greater than in Comparative Example 4 in which the tightening torque was 50 cN.Math.m. The relative value of the maximum amount of flex calculated in the manner described above is illustrated in Tables 1 and 2. Tables 1 and 2 indicate that the tightening torque of Examples 1 to 11 is from 10 to 40 cN.Math.m, and the relative value of the maximum amount of flex of Examples 1 to 11 is less than 100% relative to the corresponding Comparative Examples 1 to 4, and 6. Thus, it was found that, when the tightening torque is from 10 to 40 cN.Math.m, the relative value of the maximum amount of flex is less than when the tightening torque is 50 cN.Math.m.

(69) Next, aluminum alloy substrates having the composition illustrated in Table 3 were fabricated as the magnetic disk substrate **31**. The substrate size was an inner diameter of 25 mm, an outer diameter of 97 mm, and a thickness of 0.35 mm. The thickness of the prepared substrate was different from that of the aluminum alloy substrates of Table 1. The spacers **80** of Examples 12 and 13 and Comparative Example 7 were aluminum spacers having an inner diameter of 25 mm, an outer diameter of 32 mm, and a thickness of 1.7 mm; the spacers **80** of Examples 14 and 15 and Comparative Example 8 were aluminum spacers having an inner diameter of 25 mm, an outer diameter of 32 mm, and a thickness of 1.6 mm; and the spacers **80** of Examples 16 to 18 and Comparative Examples 9 and 10 were aluminum spacers having an inner diameter of 25 mm, an outer diameter of 33 mm, and a thickness of 1.8 mm. As illustrated in FIG. **3**, clamp in which the distance L**3** from the center of the fastening member **72** to the center of the protrusion **71** was 5 mm, the hole diameter d**1** of the clamp **70** for inserting the fastening member **72** was 2 mm, and the height t**1** of the protrusion **71** was 0.2 mm was used as the clamp **70**. A hexalobed screw having a bolt diameter of M2 and a size of T6 was used as the fastening member **72**.

(70) TABLE-US-00003 TABLE 3 RELATIVE VALUE OF ALLOY COMPOSITION (MASS %) SPACER TIGHTEN- MAXIMUM Al + UN- THICK- ING AMOUNT AVOIDABLE NESS TORQUE OF FLEX Fe Mn Ni Mg Zn Cu Cr Zr Be Si IMPURITIES (mm) (cN .Math. m) (%) EXAMPLE 12 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.7 30 94.9 EXAMPLE 13 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.7 40 97.8

EXAMPLE 14 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.6 30 98.2 EXAMPLE 15 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.6 40 99.0 EXAMPLE 16 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.8 10 99.9 EXAMPLE 17 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.8 30 98.2 EXAMPLE 18 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.8 40 99.2 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.7 50 100 EXAMPLE 7 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.6 50 100 EXAMPLE 8 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.8 50 100 EXAMPLE 9 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 1.8 60 101.9 EXAMPLE 10

(71) Next, as illustrated in FIG. **4**, the magnetic disk substrate **31** was fixed on the hub **90** by the spacer **80** and the clamp **70**, and these components were installed in an impact testing device. The tightening torque used when fixing the magnetic disk substrate **31** in Examples 12 to 18 and Comparative Examples 7 to 10 is illustrated in Table 3. The tightening torque was adjusted using a Kanon idling torque driver manufactured by Nakamura Mfg. Corporation. The torque was measured using a torque driver manufactured by Tohnichi Mfg. Co. Additionally, an amount of flex caused by impact of an outer circumferential position (the distance r**1** from the substrate center: 44.2 mm) of the magnetic disk substrate **31** and an inner circumferential position (the distance r**2** from the substrate center: 23 mm) of the magnetic disk substrate **31** was measured by a capacitive distance sensor by applying an impact at an acceleration of 31 to 33 G and an action time of 3.6 to 3.85 ms.

(72) A difference between the outer circumferential position and the inner circumferential position ([amount of flex of outer circumferential position]−[amount of flex of inner circumferential position]) was calculated, and a value obtained by dividing the maximum value of the absolute value by the acceleration ([maximum value of absolute value of difference between amounts of flex]/[acceleration], hereinafter referred to as “maximum amount of flex”) was calculated. The measuring was performed one time for each sample. Then, a relative value of the maximum amount of flex of each tightening torque of Examples 12 to 18 was calculated with the maximum amount of flex of Comparative Examples 7 to 9, in which the tightening torque is 50 cN.Math.m, set to 100%. The relative value of the maximum amount of flex was calculated on the basis of Comparative Example 7 for Examples 12 and 13, Comparative Example 8 for Examples 14 and 15, and Comparative Example 9 for Examples 16 to 18. The relative value of the maximum amount of flex of Comparative Example 10 was calculated with the maximum amount of flex of Comparative Example 9 set to 100%. In Comparative Example 10, the tightening torque was 60 cN.Math.m and, as such, the relative value of the maximum amount of flex was greater than in Comparative Example 9 in which the tightening torque was 50 cN.Math.m. Thus, it was found that, when the tightening torque is from 10 to 40 cN.Math.m, the relative value of the maximum amount of flex is less than when the tightening torque is 50 cN.Math.m.

(73) Next, aluminum alloy substrates having the composition illustrated in Table 4 and glass substrates having the composition illustrated in Table 5 were fabricated as the magnetic disk substrate **31**. The substrate size of the aluminum alloy substrate was an inner diameter of 25 mm, an outer diameter of 95 mm, and a thickness of 0.635 mm; and the substrate size of the glass substrate was an inner diameter of 25 mm, an outer diameter of 97 mm, and a thickness of 0.5 mm. Aluminum spacers having an inner diameter of 25 mm, an outer diameter of 32 mm, and a thickness of 1.6 mm were used for the spacers **80**. As illustrated in FIG. **3**, clamp in which the distance L**3** from the center of the fastening member **72** to the center of the protrusion **71** was 5 mm, the hole diameter d**1** of the clamp **70** for inserting the fastening member **72** was 2 mm, and the height t**1** of the protrusion **71** was 0.2 mm was used as the clamp **70**. A hexalobed screw having a bolt diameter of M2 and a size of T6 was used as the fastening member **72**.

(74) TABLE-US-00004 TABLE 4 RELATIVE VALUE OF ALLOY COMPOSITION (MASS %)

MAXIMUM Al + TIGHTENING AMOUNT UNAVOIDABLE TORQUE OF FLEX Fe Mn Ni Mg Zn Cu Cr Zr Be Si IMPURITIES (cN .Math. m) (%) EXAMPLE 19 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 30 95.4 EXAMPLE 20 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 40 97.4 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 50 100 EXAMPLE 11

(75) TABLE-US-00005 TABLE 5 CHEMICAL COMPOSITION (MASS %) RELATIVE TRACE VALUE OF ELEMENTS TIGHTEN- MAXIMUM AND UN- ING AMOUNT AVOIDABLE TORQUE OF FLEX No. SiO.sub.2 Al.sub.2O.sub.3 ZrO.sub.2 Na.sub.2O K.sub.2O MgO CaO TiO.sub.2 Li.sub.2O IMPURITIES (cN .Math. m) (%) EXAMPLE 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 30 97.9 21 EXAMPLE 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 40 99.2 22 COM- 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 50 100 PARATIVE EXAMPLE 12

(76) Next, as illustrated in FIG. **4**, the magnetic disk substrate **31** was fixed on the hub **90** by the spacers **80** and the clamp **70**, and these components were installed in an impact testing device. The tightening torque used when fixing the magnetic disk substrate **31** in Examples 19 and 20 and Comparative Example 11 is illustrated in Table 4, and the tightening torque used when fixing the magnetic disk substrate **31** in Examples 21 and 22 and Comparative Example 12 is illustrated in Table 5. The tightening torque was adjusted using a Kanon idling torque driver manufactured by Nakamura Mfg. Corporation. The torque was measured using a torque driver manufactured by Tohnichi Mfg. Co. The amount of flex caused by impact of the outer circumferential position (the distance r**1** from the substrate center: 44.2 mm) of the magnetic disk substrate **31** and the inner circumferential position (the distance r**2** from the substrate center: 23 mm) of the magnetic disk substrate **31** was measured by a capacitive distance sensor by applying an impact at an acceleration of 51 to 56 G and an action time of 2.7 to 3.0 ms.

(77) The difference between the outer circumferential position and the inner circumferential position ([amount of flex of outer circumferential position]−[amount of flex of inner circumferential position]) was calculated, and the value obtained by dividing the maximum value of the absolute value by the acceleration ([maximum value of absolute value of difference between amounts of flex]/[acceleration], hereinafter referred to as “maximum amount of flex”) was calculated. The measuring was performed one time for each sample. Then, the relative value of the maximum amount of flex of each tightening torque of Examples 19 to 22 was calculated with the maximum amount of flex of Comparative Examples 11 and 12, in which the tightening torque is 50 cN.Math.m, set to 100%. The relative value of the maximum amount of flex was calculated on the basis of Comparative Example 11 for Examples 19 and 20, and Comparative Example 12 for Examples 21 and 22. Thus, it was found that, when the tightening torque is from 30 to 40 cN.Math.m, the relative value of the maximum amount of flex is less than when the tightening torque is 50 cN.Math.m.

(78) Note that, when the maximum amount of flex of the magnetic disk substrate **31** caused by the impact is great, the components in the magnetic disk device collide with the load/unload ramp, for example, and a portion of the load/unload ramp chips off, thus producing foreign matter, scratching the magnetic disks, and the like, which causes failures. The impact resistance increases as the maximum amount of flex of the magnetic disk substrate **31** decreases.

(79) Ratio of First Contact Length L**1** to Second Contact Length L**2**

(80) Next, with the tightening torque set to 40 cN.Math.m, L**1**/L**2** was varied as illustrated in Tables 6 and 7 and the magnetic disk substrate **31** was fixed on the hub **90** by the spacers **80** and the clamp **70**. These components were installed in the same impact testing device as described above and subjected to the same testing. Then, with the maximum amount of flex of Comparative Examples 13 to 15, in which L**1**/L**2** is 0.06, set to 100%, the relative value of the maximum amount of flex of Examples 23 to 25 in which L**1**/L**2** is 1.00 was calculated. The relative value of the maximum

amount of flex was calculated on the basis of Comparative Example 13 for Example 23, Comparative Example 14 for Example 24, and Comparative Example 15 for Example 25. The compositions of Examples 23 to 25 were the same as the compositions of the corresponding Comparative Examples 13 to 15. The relative value of the maximum amount of flex calculated in the manner described above is illustrated in Tables 6 and 7. Tables 6 and 7 indicate that the relative value of the maximum amount of flex of Examples 23 to 25 is less than 100% relative to the corresponding Comparative Examples 13 to 15. The relative value of the maximum amount of flex of Examples 23 to 25 in which L**1**/L**2** is 1.00 is less than the relative value of the maximum amount of flex of Comparative Examples 13 to 15 in which L**1**/L**2** is 0.06 and, thus, it is understood that the impact resistance of Examples 23 to 25 is excellent.

(81) TABLE-US-00006 TABLE 6 SINGLE RELATIVE SIDE VALUE OF ALLOY COMPOSITION (MASS %) PLATING MAXIMUM Al + THICK- AMOUNT UNAVOIDABLE NESS OF FLEX No. Fe Mn Ni Mg Zn Cu Cr Zr Be Si IMPURITIES (μm) L1/L2 (%) EXAMPLE 23 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 1.00 96.2 EXAMPLE 24 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 1.00 95.1 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 0.06 100 EXAMPLE 13 COMPARATIVE 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 0.06 100 EXAMPLE 14

(82) TABLE-US-00007 TABLE 7 RELATIVE CHEMICAL COMPOSITION (MASS %) VALUE OF TRACE MAXIMUM ELEMENTS AND AMOUNT UNAVOIDABLE OF FLEX No. SiO.sub.2 Al.sub.2O.sub.3 ZrO.sub.2 Na.sub.2O K.sub.2O MgO CaO TiO.sub.2 Li.sub.2O IMPURITIES L1/L2 (%) EXAMPLE 25 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 1.00 94.9 COMPARATIVE 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 0.06 100 EXAMPLE 15

Number of Spacers

(83) As illustrated in Tables 8 and 9, with the tightening torque set to 40 cN.Math.m and L**1**/L**2** set to 1.00, the number of spacers **80** was varied and the magnetic disk substrate **31** was fixed on the hub **90** by the spacers **80** and the clamp **70**. These components were installed in the same impact testing device as described above and subjected to the same testing. Then, with the maximum amount of flex of Comparative Examples 16 to 18, in which one spacer **80** was provided, set to 100%, the relative value of the maximum amount of flex of Examples 26 to 28 in which two spacers **80** are provided was calculated. The relative value of the maximum amount of flex was calculated on the basis of Comparative Example 16 for Example 26, Comparative Example 17 for Example 27, and Comparative Example 18 for Example 28. The compositions of Examples 26 to 28 were the same as the compositions of the corresponding Comparative Examples 16 to 18. The relative value of the maximum amount of flex calculated in the manner described above is illustrated in Tables 8 and 9. Tables 8 and 9 indicate that the relative value of the maximum amount of flex of Examples 26 to 28 in which two spacers **80** are provided is less than 100% relative to the corresponding Comparative Examples 16 to 18 in which one spacer **80** is provided and, thus, it is understood that the impact resistance of Examples 26 to 28 is excellent.

(84) TABLE-US-00008 TABLE 8 SINGLE RELATIVE SIDE VALUE OF ALLOY COMPOSITION (MASS %) PLATING MAXIMUM Al + UN- THICK- NUMBER AMOUNT AVOIDABLE NESS OF OF FLEX No. Fe Mn Ni Mg Zn Cu Cr Zr Be Si IMPURITIES (μm) SPACERS (%) EXAMPLE 26 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 2 98.9 EXAMPLE 27 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 2 95.4 COMPARATIVE 0.02 0.00 0.00 4.00 0.31 0.02 0.05 0.00 0.0002 0.02 BALANCE 10 1 100 EXAMPLE 16 COMPARATIVE 0.64 0.33 1.74 1.51 0.33 0.02 0.00 0.01 0.0000 0.06 BALANCE 10 1 100 EXAMPLE 17

(85) TABLE-US-00009 TABLE 9 CHEMICAL COMPOSITION (MASS %) RELATIVE TRACE VALUE OF ELEMENTS MAXIMUM AND UN- NUMBER AMOUNT AVOIDABLE OF OF

FLEX No. SiO.sub.2 Al.sub.2O.sub.3 ZrO.sub.2 Na.sub.2O K.sub.2O MgO CaO TiO.sub.2 Li.sub.2O IMPURITIES SPACERS (%) EXAMPLE 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 2 98.5 28 COM- 52.0-58.0 21.0-27.0 0.0-0.5 0.5-1.5 0.0-0.5 5.0-7.0 7.0-10.0 0.5-1.5 1.0-3.0 BALANCE 1 100 PARATIVE EXAMPLE 18

(86) As described above, setting the tightening torque used when fastening the clamp **70** to the values described above makes it possible to enhance the impact resistance while leaving the thickness of the magnetic disk substrate **31** as-is. This was demonstrated in the Examples described above that used the aluminum alloy substrate and the glass substrate having thicknesses of 0.35 mm, 0.50 mm, and 0.635 mm, and outer diameters of 95 mm and 97 mm; and the spacers having thicknesses of 1.6 mm, 1.7 mm, and 1.8 mm, and outer diameters of 32 mm and 33 mm. Additionally, setting the ratio of the first contact length L**1** to the second contact length L**2** to the values described above makes it possible to enhance the impact resistance while leaving the tightening torque and the thickness of the magnetic disk substrate **31** as-is. Moreover, setting the number of spacers **80** to two makes it possible it enhance the impact resistance while leaving the tightening torque, L**1**/L**2**, and the thickness of the magnetic disk substrate **31** as-is. Note that the magnetic disk substrate **31** differs from the magnetic disks **30** in that the magnetic disk substrate **31** does not include the magnetic layer and the like, but is thought to be equivalent to the magnetic disks **30** with regards to impact resistance and the like. Accordingly, it is understood that, by setting the tightening torque and L**1**/L**2** to the values described above, or by setting the number of spacers **80** to two, a magnetic disk device can be provided that has excellent impact resistance and high data capacity.

(87) The foregoing describes some example embodiments for explanatory purposes. Although the foregoing discussion has presented specific embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined only by the included claims, along with the full range of equivalents to which such claims are entitled.

(88) This application claims the benefit of Japanese Patent Application No. 2021-046121, filed on Mar. 19, 2021, the entire disclosure of which is incorporated by reference herein.

REFERENCE SIGNS LIST

(89) **10** Housing **20** Base **30** Magnetic disk **31** Magnetic disk substrate **40** Head stack assembly **41** Arm **42** Head **50** Voice coil motor **60** Load/unload ramp **70** Clamp **71** Protrusion **72** Fastening member **80** Spacer **90** Hub **91** Small diameter section **92** Large diameter section **100** Magnetic disk device D Depth W Width H Height N Number Z Rotational axis Rd Outer radius Td, Ts Thickness T Stacked height Rsi Inner radius Rso Outer radius

Claims

1. A magnetic disk device comprising: a plurality of disk-shaped magnetic disks, each including a through-hole in a center section thereof; a spacer that is disposed among the magnetic disks and that includes a through-hole in a center section thereof; a hub inserted into the through-holes of the magnetic disks and the spacer; a clamp having a disk body portion, an annular flange portion having a distal surface and extending from the disk body portion, and a protrusion extending from the distal surface of the annular flange portion, the protrusion having a planar surface pressing and holding the magnetic disks and the spacer; and a plurality of fastening members, each fastening member of the plurality of fastening members fastening the clamp to the hub, wherein the clamp is fastened to the hub by the plurality of fastening members with a torque of from 5 cN.Math.m to 45 cN.Math.m; and a first contact length in a radial direction and defined by the planar surface between a first magnetic disk of the plurality of magnetic disks and the clamp is greater than or

equal to ½ a second contact length in the radial direction and defined by contacting surfaces between the first magnetic disk of the plurality of magnetic disks and the spacer.

2. The magnetic disk device according to claim 1, wherein the clamp is fastened to the hub by the plurality of fastening members with a torque of from 20 cN.Math.m to 45 cN.Math.m.

3. The magnetic disk device according to claim 1, wherein the clamp is fastened to the hub by the plurality of fastening members with a torque of from 20 cN.Math.m to 35 cN.Math.m.

4. The magnetic disk device according to claim 1, wherein each of the magnetic disks has a size of an inner diameter of 25 mm, an outer diameter of from 95 mm to 97 mm, and a thickness of 0.35 mm to 0.635 mm, the spacer has a size of an inner diameter of 25 mm, an outer diameter of from 32 mm to 33 mm, and a thickness of from 1.6 mm to 1.8 mm, and a distance from a center of each fastening member of the plurality of fastening members to a protrusion center provided on the clamp is 5 mm.

5. The magnetic disk device according to claim 1, wherein a plurality of spacers is stacked and layered between the magnetic disks.

6. The magnetic disk device according to claim 1, wherein a plurality of spacers is stacked and layered between a magnetic disk, of the magnetic disks, contacting the clamp and a magnetic disk adjacent to the magnetic disk.

7. The magnetic disk device according to claim 1, wherein each of the magnetic disks has a thickness of 0.48 mm or less.

8. The magnetic disk device according to claim 1, wherein each of the magnetic disks has a thickness of 0.36 mm or less.

9. A method for manufacturing a magnetic disk device including a plurality of disk-shaped magnetic disks, each including a through-hole in a center section thereof, a spacer that is disposed among the magnetic disks and that includes a through-hole in a center section thereof, a hub inserted into the through-holes of the magnetic disks and the spacer, a clamp having a disk body portion, an annular flange portion having a distal surface and extending from the disk body portion, and a protrusion extending from the distal surface of the annular flange portion, the protrusion having a planar surface pressing and holding the magnetic disks and the spacer, the planar surface of the protrusion contacting a first magnetic disk of the plurality of magnetic disks and extending parallel to the first magnetic disk of the plurality of magnetic disks when the clamp is fastened to the hub, and a plurality of fastening members, each fastening member of the plurality of fastening members fastening the clamp to the hub, the method comprising: fastening the clamp to the hub by the plurality of fastening members with a torque of from 5 cN.Math.m to 45 cN.Math.m.

10. A magnetic disk device comprising: a plurality of disk-shaped magnetic disks, each including a through-hole in a center section thereof; a spacer that is disposed among the magnetic disks and that includes a through-hole in a center section thereof; a hub inserted into the through-holes of the magnetic disks and the spacer; a clamp pressing and holding the magnetic disks and the spacer, the clamp having a disk body portion, an annular flange portion having a distal surface and extending from the disk body portion, and a protrusion extending from the distal surface of the annular flange portion, the protrusion having a planar surface for contacting a magnetic disk of the plurality of disk-shaped magnetic disks; and a fastening member that fastens the clamp to the hub, wherein the clamp is fastened to the hub by the fastening member with a torque of from 5 cN.Math.m to 45 cN.Math.m; and wherein the planar surface of the protrusion contacts a first magnetic disk of the plurality of magnetic disks and extends parallel to the first magnetic disk of the plurality of magnetic disks when the clamp is fastened to the hub.

11. The magnetic disk device according to claim 10, wherein the protrusion defines a gap between the clamp and the magnetic disk of the plurality of magnetic disks at an inner circumference of the clamp.