

SPECIFICATION

A pivot thrust bearing device and a motor comprising the same

FIELD OF THE INVENTION

The present invention relates to a pivot thrust bearing device, wherein the end of a rotating shaft is slidably supported by a bearing portion. More particularly, the invention relates to a pivot thrust bearing device suited for a compact precision spindle motor or the like for use in a magnetic disc storage, for example.

PRIOR ART

Recently, spindle motors suited for high-precision, high-speed rotating magnetic discs of magnetic disc storages have been demanded to meet the needs for high recording speed and high recording density. Usually, the magnetic discs are directly secured to the outer periphery of the rotor of the spindle motor, and directly driven by the spindle motor. This spindle motor uses a pivot thrust bearing device, wherein a stationary thrust bearing portion supports the sliding surface of the end of a rotating shaft connected with the rotor. In order to precisely maintain the rotation of the magnetic discs at high speed, a displacement in the axial direction of the disc must be

decreased as small as possible. For this purpose, the displacement of the rotating shaft of the spindle motor in the thrust direction with the passage of time must also be decreased as small as possible. The displacement of the rotating shaft is caused by wear of the sliding surface at the end of the rotating shaft, that is, by a dimensional change in the axial direction. If the displacement of the rotating shaft of the motor used for the magnetic disc storage occurs, the position of the magnetic surface of the disc is changed in the axial direction, thereby adversely affecting high recording density to be required.

Conventionally, a system of supporting a rotating shaft with a fluid radial bearing has been adopted in the bearing devices for the above-mentioned application. In this case, it is also required to decrease a change in length in the thrust direction of the rotating shaft with the passage of time. In the bearing device, dynamic pressure is generated by the fluid force of a lubricant between the sliding surfaces due to the rotation of the rotating shaft, thereby to achieve a noncontact condition between the rotating shaft and the bearing portion as disclosed in Japanese Patent Provisional Publication 6-38442.

In addition, as means for decreasing the displacement

in the thrust direction of the rotating shaft of a spindle motor with the passage of time, the inventors of the present invention have proposed a bearing device, wherein carbon and a metal element selected from among metals of groups IVa, Va and VIa in the periodic table are directly ion-implanted to the sliding surface of the rotating shaft made of steel, and the ion-implanted surface of the rotating shaft slides with the thrust bearing portion via lubricant components, as disclosed in Japanese Patent Provisional Publication 7-052133.

Furthermore, the inventors of the present invention have proposed a bearing device, wherein the rotating shaft is made of steel having a Vickers hardness of Hv 500 or more on the surface, the dosage of titanium to the ion-implanted surface is 2.5×10^{17} ions/cm² or more, and the bearing portion for supporting the rotating shaft is made of metal or ceramics having a Vickers hardness of Hv 500 or more on the sliding surface, as disclosed in Japanese Patent Provisional Publication 7-198537. This device has proved that variations in the displacement in the thrust direction of the rotating shaft are decreased, and that a low specific wear rate can be achieved.

In the ideal lubrication condition of this kind of

bearing device, as disclosed in the above-mentioned Japanese Patent Provisional Publication 6-38442, dynamic pressure is generated to the sliding surface by the fluid force of the lubricant due to the rotation of the rotating shaft so that the dynamic pressure can float and support the rotating shaft, with the rotating shaft not making contact with the thrust bearing portion. However, if the lubricant film between solids, i. e. the rotating shaft and the bearing portion, is as thin as the level of the surface roughness of the solids, the boundary lubrication condition develops, and solid contact occurs at many positions on the sliding surface. As a result, the amount of wear at the sliding surface of the rotating shaft is larger than that under fluid lubrication condition.

In actual usage circumstances, a thrust load due to a driven member, such as a magnetic recording medium, is applied to the sliding surface of the rotating shaft and the sliding surface of the thrust bearing portion. Therefore, even in the case of the fluid bearing, a mixed lubrication condition including a boundary lubrication condition develops frequently. It is thus difficult for the fluid thrust bearing device to obtain a stable noncontact condition.

Furthermore, the bearing device disclosed in the above-mentioned Japanese Patent Provisional Publication 7-052133 by the inventors of the present invention, wherein the rotating shaft slides with the bearing portion via a lubricant just as in the case of the spindle motor, is characterized in that the sliding between the surface of the rotating shaft and the surface of the thrust bearing portion, being in a mixed lubrication condition, is stabilized with the passage of time.

However, although the above-mentioned bearing system has succeeded in decreasing the specific wear rate of the sliding surface of the rotating shaft in a mixed lubrication condition to less than 10^{-11} mm²/N, variations among components in the specific wear rate are still large. Even though the effect of the dosages of titanium and carbon to the surface of the rotating shaft on the specific wear rate, and the effect of hardness of the sliding surfaces of the rotating shaft and the bearing portion on the specific wear rate have already been clarified in Japanese Patent Provisional Publication 7-198537, the effect of the dosage of carbon in proportion to the dosage of titanium has not yet been clarified.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a pivot thrust bearing device, wherein the displacement of the rotating shaft in the thrust direction is controlled and the variations in the displacement are decreased.

Another object of the present invention is to provide a spindle motor comprising such a pivot thrust bearing device, which can operate precisely at high speed with low electric power consumption.

In the pivot thrust bearing device of the present invention, with respect to the ion-implanted surface of the sliding surface of the rotating shaft made of steel, by ensuring the dosage of titanium ions and the proportion of the dosage of carbon ions to the dosage of titanium ions to have at least a certain value each, the sliding surface formed with a hardened surface layer having higher resistance to wear reduces the amount of wear due to sliding contact with the sliding surface of the bearing portion for an extended period of time, and then the rotating shaft is prevented to the utmost from being shortened in the thrust direction.

More specifically, the pivot thrust bearing device of the present invention is characterized in that the dosage of titanium ions to the ion-implanted surface is 2.5×10^{17} ions/cm² or more, and that the dosage of carbon ions is 1.6 times

or more the dosage of titanium ions.

The specific wear rate at the sliding surface of the rotating shaft having the particular proportion of the dosage of carbon to the dosage of titanium can be decreased to 10^{-11} mm²/N or less in a mixed lubrication condition, whereby a change in the length of the rotating shaft after use for an extended period of time, that is, a displacement in the thrust direction can be decreased significantly, and its standard deviation can also be minimized.

The thrust bearing device of the present invention is widely used for bearing devices which operates in a mixed lubrication condition wherein a liquid lubricant is provided between the sliding surface of the rotating shaft and the thrust bearing portion.

This kind of thrust bearing device is ideally suited for the rotors of compact motors, especially drive motors for magnetic disc storages and rotation drive motors for polygon mirrors of copiers.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in detail below referring to the accompanying drawings.

FIG. 1 is a conceptual sectional view showing a pivot thrust bearing device of the present invention;

FIG. 2 is a vertical sectional view showing a magnetic disc storage driven by a motor comprising the pivot thrust bearing device which may be embodied by the present invention.

FIG. 3 is a graph showing the relationship between the dosage of ions and the amount of wear on the sliding surface at the end of the rotating shaft of the pivot thrust bearing device in accordance with an embodiment of the present invention.

FIG. 4 is a graph showing the standard deviation of the amount of wear in the embodiment shown in FIG. 3.

EMBODIMENT OF THE INVENTION

FIG. 1 shows an example of a conceptual structure of the pivot thrust bearing device of the present invention. The bearing device comprises a rotating shaft 1a, a bearing portion 2 for supporting the rotating shaft 1a, and a lubricant 3 provided between the rotating shaft and the bearing portion. The bearing portion 2 comprises a thrust bearing portion 2a for supporting a load in the thrust direction with the end surface of the rotating shaft 1a used as a sliding surface, and a radial bearing portion 2b, having the shape of a cylinder or a ring, for supporting the outer peripheral surface of the rotating shaft 1a inside the

hollow portion in a sliding condition. In FIG. 1, the thrust bearing portion 2a and the radial bearing portion 2b are made separately and put together. However, the thrust bearing portion 2a and the radial bearing portion 2b of the bearing portion 2 may be integrated into one piece.

The pivot thrust bearing device of the present invention can be preferably applied to a motor. For this application, it is convenient when the rotating shaft 1a is connected to the rotor 1 of the motor coaxially and directly. A spindle motor capable of comprising such a pivot thrust bearing device can be applied to movement drive of the disc of a magnetic disc storage, for example.

Since the rotating shaft of the pivot thrust bearing device is required to have mechanical strength and surface hardness of its own, it is made of steel, preferably hardened steel having a Vickers hardness of Hv 500 or more. In particular, the rotating shaft is made of martensitic stainless steel which is specially heat-treated and hardened. SUS 420J2 steel specified in Japanese Industrial Standard (JIS) can be taken as an example of such a stainless steel.

The end surface of the rotating shaft in accordance with the present invention has a sliding surface which is

curved to have a spherical surface and polished. The sliding surface is hardened by heat treatment, and usually has a hardness of about Hv 400 to 800. By finishing the sliding surface, it is prepared to have appropriate surface roughness.

By the double implantation of titanium ions and carbon ions, a surface-hardened layer is formed on the sliding surface of the rotating shaft. In the present invention, the dosage of titanium ions to the sliding surface should be 2.5×10^{17} ions/cm² or more, and it is ensured that the dosage of carbon ions should be 1.6 times or more the dosage of titanium ions.

The lower limit of the dosage of titanium ions is determined at 2.5×10^{17} ions/cm² as described above, because a dosage less than the lower limit is not enough to decrease the displacement of the rotating shaft in the thrust direction or to decrease variations in the displacement. In addition, the dosage of carbon ions to the ion-implanted surface is 1.6 times or more the dosage of titanium ions as described above so that surface-hardening precipitates obtained by the reaction of the carbon and titanium can be fully formed in the metal structure just under the ion-implanted surface. The hardening phase is

probably made of very fine precipitates of titanium carbide, TiC. Accordingly, it is estimated in the present invention that because of the proportion of the dosages of the above-mentioned two components, the amount of the precipitates is increased, the hardness of the ion-implanted surface is raised, the coefficient of friction on the surface is decreased, and the sliding surface is less worn. In other words, a very thin hardened surface layer including the precipitates formed in the sliding surface provides high resistance to wear when the sliding surface makes contact with the sliding surface of the bearing portion, whereby the sliding surface has less wear, and the rotating shaft is prevented from being shortened.

It is observed that the effect of improving the sliding characteristics of the ion-implanted surface becomes further significant by setting the dosage of carbon ions at 1.6 times or more the dosage of titanium ions. By setting the dosage of carbon ions as described above, the sliding characteristics of the ion-implanted surface can be stabilized greatly, and the displacement of the rotating shaft in the thrust direction and the variations in the displacement during operation for an extended period of time can be decreased further.

The dosage of titanium ions is preferably in the range of 2.5×10^{17} to 1×10^{20} ions/cm². On the other hand, the dosage of carbon ions is in the range of 4.0×10^{17} to 1×10^{21} ions/cm². In addition, the dosage of carbon ions is selectively set at 1.6 times or more, preferably 2.0 times or more the dosage of titanium ions.

An ion-implanted surface is formed on the sliding surface as described below. First, the end of the rotating shaft is ground, and the end surface is formed to have a curved surface having a desired radius of curvature, such as a spherical surface. The surface is then polished so as to have a required surface roughness of R_{max} 0.1 to 0.5 μ m, for example.

In an ion implantation method, an ion gun, a grid electrode for accelerating ions, and an object to be subjected to ion implantation are disposed in a high vacuum chamber. Solid titanium and carbon, which are materials to be implanted in the vacuum and used as a cathode in the ion gun, are vaporized and ionized by discharge. The ions are accelerated at the grid electrode to which a negative high voltage with respect to the cathode is applied, and ion beams are generated. The end surface of the rotating shaft disposed so as to face the cathode is irradiated with the

ion beams, and the ions are implanted to the inner surface phase from the metal surface.

Examples of such a method and an apparatus for carrying out ion implantation are described in Brown, I. G.; "The Metal Vapor Vacuum Arc (MEVVA) High Current Ion Source" IEEE Trans. on Nuclear Science. Vol. NS-32. No. 5 (1985).

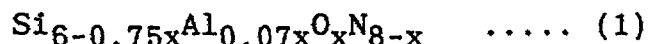
In the ion implantation method, a plurality of rotating shafts are tied in a bundle and their ends are aligned and arranged toward the cathode side as targets. The end surface of each rotating shaft is evenly irradiated with the ion beams having passed through the grid electrode. The dosage of ions is obtained by the product of the ion current passing through the target and the implantation time.

As an example of ion implantation, the end surface of a stainless steel rod having an outer diameter of 2.5 mm and a spherical end surface with a radius of curvature of 4 mm can be implanted with titanium Ti of the dosage of 5×10^{17} ions/cm² at an acceleration voltage of 70 kV (about 147 keV), and carbon C of the dosage of 1.2×10^{18} ions/cm² at an acceleration voltage of 40 kV (about 40 keV).

On the other hand, the thrust bearing portion for supporting the end surface of the rotating shaft is preferably formed by using ceramics having a high surface

hardness. Ceramics, especially ceramics based on oxides, carbides or nitrides can be used, and its surface is polished and has a desired external shape.

The thrust bearing portion used for the bearing device of the present invention is preferably made of silicon-aluminum oxinitride (hereinafter referred to as SIALON), the general formula of which is represented by formula (1).



wherein X is the number of oxygen in one mole of SIALON represented by formula (1). When $X \leq 6$, decomposition into a silicon nitride phase and an alumina phase is prevented. When X is 6 or less, a compound delivers the properties of both the oxides and nitrides, whereby it can be used as ceramics which has high hardness, large mechanical strength, and chemical and thermal stability.

A lubricant is used for the bearing device of the present invention so that the bearing device serves as a fluid bearing. The lubricant is prepared by including hydrocarbon-based oil such as mineral oil, synthetic oil or the like as the main component, and by appropriately adding additives usually used for bearing lubricants, such as a viscosity index improver, an extreme pressure agent, an oxidation inhibitor, a pour point improver and an

antifoaming agent. Furthermore, greases, fine lubricative powder having a lamellar structure, such as graphite, molybdenum disulfide and boron nitride, and a film of metal, such as a film of indium, copper or lead, may be added at the same time. The concrete composition of the lubricant including the mixtures of those can be determined as necessary depending on the structures of rotating apparatuses, such as motors, including the bearing devices, as well as their operating and load conditions.

The pivot thrust bearing device of the present invention can be widely used as a bearing device which operates in a mixed or noncontact lubrication condition under the load of the value $PV \leq 60 \text{ N/mm}^2 \cdot \text{m/s}$ to the sliding surface, preferably $PV \leq 36 \text{ N/mm}^2 \cdot \text{m/s}$ (for example, $P \leq 750 \text{ N/mm}^2$, and $V \leq 5.1 \times 10^{-2} \text{ m/s}$), the value PV being defined and explained later.

This pivot thrust bearing device of the present invention can be applied to a spindle motor wherein a rotor of the spindle motor coaxially includes the rotating shaft of the bearing device at the end of the rotor so that the rotating shaft can support the rotor.

The spindle motor using the pivot bearing device can be applied for rotating magnetic discs of the above-mentioned

magnetic disc storages.

FIG. 2 is a sectional view showing the magnetic disc storage comprising the pivot thrust bearing device. The storage is equipped with a spindle motor, whose rotor 1 is connected with a rotating shaft 1a supported by the bearing portion 2 mounted on a base 7, and one or more magnetic discs 6 used as magnetic recording media are secured to the outer periphery of the rotor 1 directly and coaxially. The magnetic disc storage is equipped with a magnetic head drive controller which performs movement control by moving a magnetic head 8b close to the magnetic film on the surface of each magnetic disc 6. The controller comprises a load arm 8a having the magnetic head 8b at the end thereof, and a rotary actuator 8 for controlling the rotation of the load arm 8a, and further comprises a control circuit 5 for controlling the spindle motor and the controller in accordance with external command signals.

Taking an example of the bearing device for this kind of spindle motor, the rotating shaft may be made of SUS 420J2 steel and have an outer diameter of 3 mm, and the sliding surface at the end of the rotating shaft may be a spherical surface having a radius of 4 mm. The thrust bearing portion 2a for supporting the rotating shaft may be

provided with a smooth flat surface made of SIALON. The radial bearing portion 2b is not limited to be made of any particular material, but may be formed of copper based alloy.

In this application, the rotating shaft of the thrust bearing device may operate in the condition of a load of 60 gf and a rotation speed of 5400 rpm, while being supported by the thrust bearing portion formed with a flat sliding surface of SIALON having Hv 1000 or more. In such operating conditions, the displacement in the thrust direction is required to be 40 μ m or less at the end of 10000 hours of operation.

The specific wear rate at the sliding surface at the end of the rotating shaft of the bearing device is obtained by the following calculations. In the above-mentioned conditions, the radius of the contact circle making contact with the flat surface of SIALON is 24 μ m due to elastic deformation of the sliding surface at the end, the maximum contact surface pressure is 45 kgf/mm² at the center of the end surface of the shaft, and the sinking of the rotation shaft is 0.11 μ m. These are obtained by making calculations on the basis of the Helzian contact theory. In this kind of bearing device, it is difficult to attain a

noncontact condition at the thrust bearing portion where the rotating shaft is rotated in use of a lubricant. Thus the rotating shaft must slide in a mixed lubrication condition.

On conditions that the rotation speed of the rotating shaft is 5400 rpm, and that the displacement of the rotating shaft due to wear is $40 \mu\text{m}$ per 10000 hours of rotation in contact with the flat surface of SIALON, the radius of the contact circle can be evaluated to be $540 \mu\text{m}$. It is also estimated in the condition that the amount of wear is 0.02 mm^3 in volume, and the average sliding radius is about $200 \mu\text{m}$ during the operation time, and therefore, the specific wear rate of about $1 \times 10^{-11} \text{ mm/N}$ can be obtained. For this reason, the specific wear rate is required to be $1 \times 10^{-11} \text{ mm/N}$ or less in order to have a displacement of $40 \mu\text{m}$ or less under the condition above.

A more concrete application of the present invention is described below. The rotating shaft is formed from a stainless steel (SUS 420J2 steel) rod having an outer diameter of 3 mm. A titanium ion dosage of $5 \times 10^{17} \text{ ions/cm}^2$ and a carbon ion dosage of $1.2 \times 10^{18} \text{ ions/cm}^2$ are implanted (at a dosage proportion of 2.4) to the end surface of the rotating shaft formed into a spherical surface having a radius of curvature of 4 mm so as to form an ion-implanted

surface. The rotating shaft is set vertically so that the ion-implanted surface slides with the surface made of SIALON having a surface hardness of Hv 1350. Sliding is carried out at a vertical load (a load in the thrust direction) of 50 gf, a sliding speed of 8×10^{-3} m/s, and a PV value of 2.5 N/mm² · m/s in a mixed lubrication condition. In this case, the coefficient of friction at the end surface is in the range of 0.02 to 0.03.

The PV value above mentioned is defined as the product of average sliding surface pressure P (N/mm²) and average sliding speed V (m/s). The average sliding surface pressure P is obtained by dividing a thrust-direction load by the area of a contact circle obtained from the Hertzian contact theory. The average sliding speed V is half of the product of the circumference of the contact circle obtained from the contact theory and the rotation speed.

Furthermore, when the thrust bearing device is used for a spindle motor, with the rotating shaft having the Ti and C doped sliding surface connected to the rotor of the motor and the SIALON disc used as the thrust bearing portion, the displacement after 300 hours of rotation is about 1.4 μ m at a thrust-direction load of 60 gf and at a rotation speed of 5400 rpm.

When the end surface was not subjected to ion implantation and measurement was carried out in the same conditions, the coefficient of friction at the undosed sliding surface was about 0.6. In addition, when the rotating shaft with the sliding surface undosed was used for a thrust bearing device, the displacement after 300 hours of rotation was about $14.8 \mu\text{m}$ in the same conditions, a very large value.

EXAMPLE

A rotating shaft was made of martensitic stainless steel (SUS 420J2 steel) and formed to have a diameter of 3 mm. It had a surface hardness of HV 651. Its end was formed to have a spherical surface having a radius of 4 mm. The surface roughness of the end surface was prepared so as to have an R_{max} of 0.1 to $1.0 \mu\text{m}$.

Titanium Ti ions and carbon C ions were implanted to the above-mentioned end surface of the rotating shaft by using the MEVVA ion beam generator. While the dosage of Ti ions is maintained at a constant value of 5×10^{17} ions/cm², the dosage of C ions was set at six levels: 0.8 times the Ti dosage (4×10^{17} ions/cm²), 1.0 times (5×10^{17} ions/cm²), 1.6 times (8×10^{17} ions/cm²), 2.4 times (12×10^{17} ions/cm²) and 3.0 times (15×10^{17} ions/cm²).

A disc made of SIALON was used as a thrust bearing portion for supporting the above-mentioned end surface of the rotating shaft. R_{max} was less than $0.1 \mu m$ and hardness was Hv 1590 at the sliding surface of the disc.

A lubricant was used at the thrust bearing portion. The lubricant was prepared by adding 3 weight % of butyl stearate ester to di-2-ethylhexyl sebacate (Mw 426, viscosity η_{40} 11.3 cps at $40^{\circ}C$).

A sliding test was conducted as described below. The ion-implanted end surface of the above-mentioned rotating shaft secured to a motor rotor was made contact with and supported on the sliding surface of the thrust bearing portion together with the lubricant, and incorporated into a spindle motor. The motor was rotated for 2500 hours at a thrust load of 60 gf and at a speed of 5400 rpm in a mixed lubrication condition. Wear was measured by examining the change in the length of the rotating shaft. The test was conducted by using five samples classified depending on the level of the dosage of carbon C ions. The average of displacements and their standard deviation values were obtained. The results are shown in FIGS. 3 and 4.

Referring to FIG. 3, wear of the sliding surface in the thrust direction decreases with the dosage of carbon ions

increasing while the dosage of titanium ions is maintained constant. At the same dosage of carbon as the dosage of titanium, the specific wear rate is lower than 1×10^{-11} mm/N. The dosage of carbon being 2.4 times or more the dosage of titanium lowers the specific wear rate less than 1×10^{-12} mm/N.

Referring to FIG. 4, the dosage of carbon exceeding 0.8 to 1.0 times the dosage of titanium begins to lower the standard deviation of the displacements of the rotating shaft. The dosage of carbon increasing 1.6 to 2.4 times (8 to 12×10^{17} ions/cm²) of the dosage of titanium lowers the standard deviation of the displacements abruptly. At the dosage of carbon exceeding 2.4 times the dosage of titanium, the standard deviation is very low.

As described above, it is obvious that the dosage of carbon of 1.6 times or more the dosage of titanium enables the specific wear rate to be less than 1×10^{-12} mm/N stably, and the standard deviation also to be lowered significantly.

In this way, with the pivot bearing device of the present invention, the effect of the surface roughness of the sliding surface affecting the lubrication condition can be lessened, abnormal friction due to the surface roughness

can be prevented, and for a motor provided with the bearing device a dimensional change in the rotor of the motor over an extended period of motor operation can be prevented effectively.

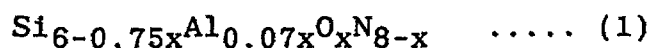


CLAIMS

1. A pivot thrust bearing device comprising a rotating shaft having a sliding surface at the end thereof, a bearing portion having a thrust bearing portion for supporting said sliding surface of said rotating shaft in sliding contact with said sliding surface, and a lubricant provided between said rotating shaft and said bearing portion, being characterized in that:

said rotating shaft is formed of steel, said sliding surface thereof is subjected to implantation of titanium ions and carbon ions, the dosage of titanium ions to the ion-implanted surface is 2.5×10^{17} ions/cm² or more, and the dosage of carbon ions is 1.6 times or more the dosage of titanium ions.

2. A pivot thrust bearing device according to claim 1, wherein said thrust bearing portion is formed of silicon-aluminum oxinitride, the general formula of which is represented by formula (I).



wherein $X \leq 6$.

3. A pivot thrust bearing device according to claim 1 or 2, being used for a spindle motor, wherein a rotor of the spindle motor coaxially includes said rotating shaft at the



end thereof so that said bearing device can support said rotor.

4. A pivot thrust bearing device according to claim 1 or 2, being used in a magnetic disc storage, wherein the rotor of a spindle motor built into the magnetic disc storage coaxially includes said rotating shaft at the end thereof, and one or more magnetic discs used as magnetic recording media are secured to the outer periphery of said rotor directly and coaxially so as to form said magnetic disc storage.

5. A spindle motor provided with said pivot thrust bearing device according to claim 1 or 2, wherein the rotor of said motor coaxially includes said rotating shaft at the end thereof.

6. A magnetic disc storage comprising a motor provided with said pivot thrust bearing device according to claim 1 or 2, wherein said rotating shaft is connected with said rotor of said motor coaxially, and magnetic discs used as magnetic recording media are secured to the outer periphery of said rotor directly and coaxially so as to form the magnetic disc storage.