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3.5″ SPINDLE MOTOR FOR HARD DISK DRIVE

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1. FOREWORD

Recently the application of HDD has spread from large computers to office computers and personal computers and to word processor, facsimile, and many other fields. The spread of its application range and increase in demand are accompanied by a stronger demand for smaller and denser HDD. Viewed from the side of HD, the extension of the 5.25" and 3.5" class, designated the low end, is noticeable and of these, the share of 3.5" HD is increasing rapidly.

Fuji Electric put its efforts into motors for the information processing industry and advanced development of a spindle motor for HDD as part of these efforts. We have now succeeded in developing a spindle motor for 3.5" HDD as shown in *Fig. 1* and has built an automated production plant and is producing this new motor.

An Fuji Electric spindle motor for 3.5" HDD and its production line are outlined here.

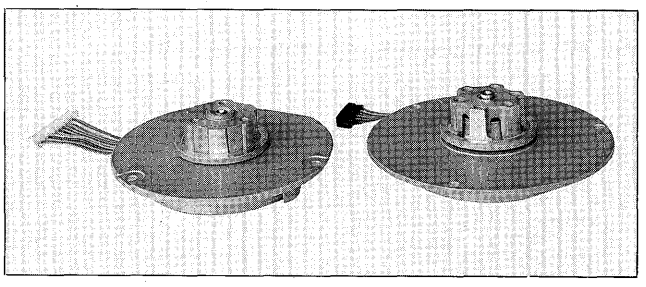
2. USER NEEDS AND DEVELOPMENT POINTS

The popularity of the personal computer is accompanied by development of small HDD at a noticeably high speed. One of the important technologies supporting this miniaturization is the direct-drive mechanism and its application to 10.5" and 3.5" is spreading.

In the low end class (10 to 20 MB), 5.25" size was typical, but the appearance of 3.5" size 20 MB will signify that it will become the mainstream instead of 5.25" in the future. This is because high density recording systems and ultraprecision control have been made possible by advances in media manufacturing technology. With the appearance of the 3.5" HDD in which miniaturization with the same storage capacity as this 5.25" HDD, there are many points which are convenient to the user. Temporarily, 5.25" and 3.5" size will shift to the form in which they have the same storage capacity, but this realizationship will be arranged serially in the near future.

Naturally, to increase the recording capacity of the disk, the spindle motor used with the 3.5" HDD must have a higher mechanical precision and speed precision than the 5.25" size. Miniaturization is mechanically weak and there are also many technological problems relating to construction and mechanical strength.

Fig. 1 Spindle motor for 3.5" HDD



The specific technological key points are bearing composition technology, ferrofluidic seal application improvement technology, and new materials application technology. Balancing the performance demanded from the disk drive and motor manufacturing technology and cost is also necessary.

3. FEATURES OF FUJI SPINDLE MOTOR FOR 3.5" HDD

(a) Low noise

A spindle motor for HDD, of course, must generate very little noise itself. Especially, care must be given to resonance with the disk drive. Fuji Electric reduces the noise by exhaustive vibration and noise analysis of the motor itself and vibration and noise analysis with the motor installed in the disk drive at development.

(b) High torque at low current

Suppressing losses is very important from the standpoints of stable maintenance of mechanical precision and miniaturization of the drive circuit. The electrical and magnetic configuration is also good and high torque is generated by a low current.

(c) Low cogging torque

Cogging torque is the alternating torque generated by a permanent magnetic when not conducting. To start and stop smoothly, a special innovation which reduces the cogging torque by reducing the torque ripple was made in

the magnetic circuit configuration. Since this also makes the forward rotation vibration before stopping low, smooth stopping is also possible.

(d) Low temperature tilt

The hub tilt change relative to the motor mounting circuit due to changes in the environmental temperature must be small. For this reason, each part is specially treated and detailed structural considerations are given. Therefore, the temperature tilt is small and mechanical precision is extremely stable.

(e) Stable quality

High performance and high quality are maintained by stable production and special management by clean environment and automated facilities.

4. FUJI STANDARD SPECIFICATIONS AND CONSTRUCTION

For a simple introduction of the composition of the HDD and the spindle motor assembled to it, an HDD composition example is shown in *Fig. 2*. *Table 1* shows the standard specifications of the spindle motor.

The construction of the 3.5" spindle motor is shown in *Fig. 3*.

This motor is the outer rotor type. The rotor is at the outside of the stator. The rotor magnet is an anisotropic ferrite magnet. The reasons why the motor was made the outer rotor type were (1) the inertial of the rotor is made large to obtain smooth rotation and (2) a large flux must be obtained with the rotor magnet to obtain high torque

Table 1 3.5" Fuji spindle motor standard specifications

Items	Standard Specifications
Capacity	20 MB
No. of Disk	2
Phases & Connection	3 Phase, Star Connection
Driving method	Bi-polar
Poles	4
Voltage	DC 12V ± 10%
Rated Revolution	3600 rpm
Rated Torque	15 g-cm
Rated Current	0.22A (at Winding Current)
Rotation	CCW as viewed from HUB side
Duty	Continuous
Cogging Torque	15 g-cm (p-p)
Accoustic Noise	36 dBA at 1 m (Motor only)
Temperature Tilt	2 μm
Repetitive Runout	10 μm
Non-repetitive Runout	0.5 μm
Cleanliness	100
Index	With magnet for index
Operating Ambient Temperature	0~65°C
Operating Ambient Humidity	10~90% RH
Storage Ambient Temperature	−40~+80°C
Storage Ambient Humidity	5~90% RH
Hub-Grounding Ball Resistance	10Ω

Fig. 2 HDD composition example

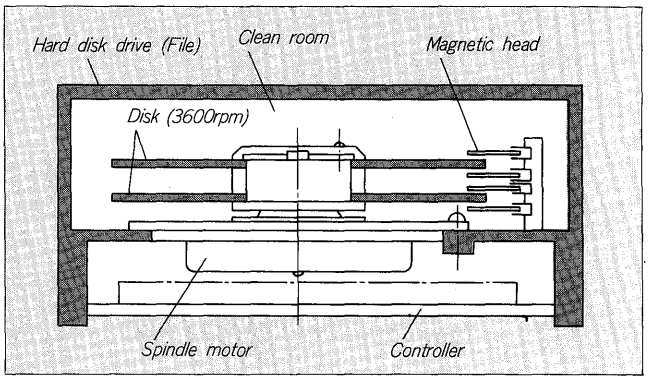
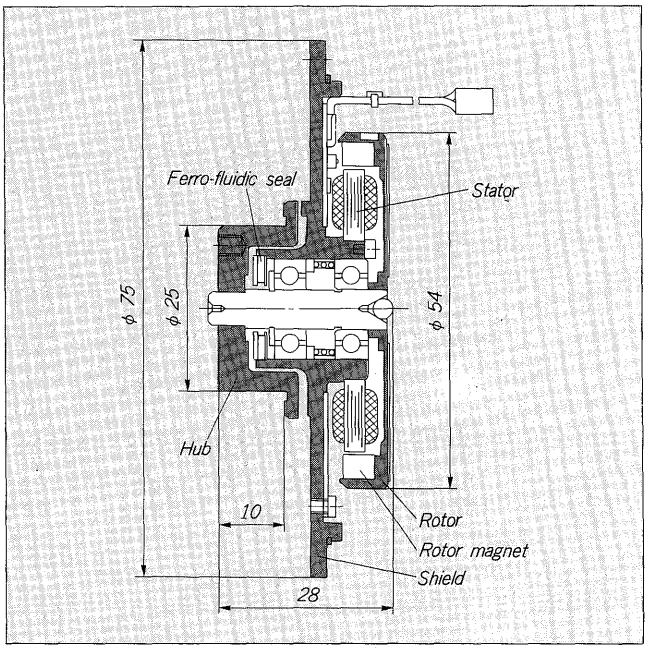


Fig. 3 3.5" spindle motor construction



and the rotor magnet was made as large as possible. The hub mounts the disk and extremely high mechanical precision is demanded.

Rotating the spindle motor generates an outgas with the bearing grease as its main component. When this outgas flows out at the hub side, it collects in the gap (submicron) between the magnetic head and disk and produces head crush. To prevent this, the flow of outgas to the hub side is locked by a ferrofluidic seal.

Fig. 4 shows the construction of the rotor side bearing section. As countermeasures against temperature tilt: (1) The center of the rotor side bearing is shifted in the direction perpendicular to the head direction from the shaft center by a side pressure spring. This construction minimizes the shaft tile in the head direction accompanying the thermal expansion difference of the housing and bearing by temperature changes. (2) Treatment and management of the thermal distortion of each part, including the shield.

(3) Management of the fitting dimensions of the housing and bearing outside diameter part.

Fig. 4 Rotor side bearing section construction

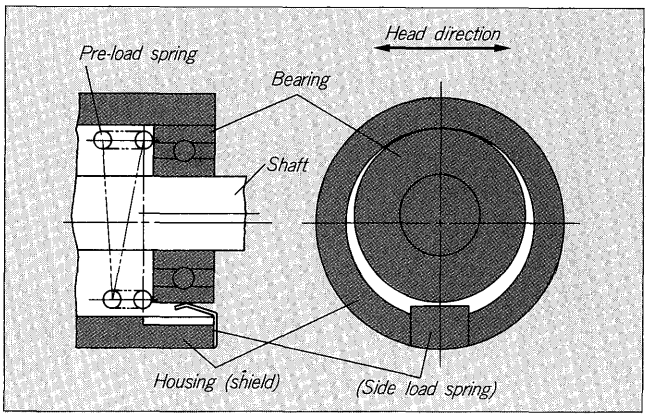
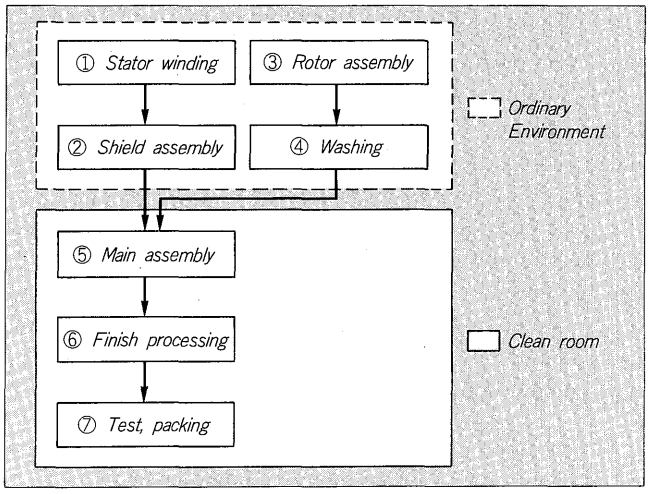


Fig. 5 Assembly processes and environment



5. AUTOMATED MASS PRODUCTION LINE AND RELIABILITY

Each process of the production line of this motor is fully automated with exhaustive labor saving and the supply of stable quality products as key points and is currently operating favorably. This processes and environment of this line are shown in *Fig. 5*. Roughly, it consists of seven processes. Processes (1) to (4) are performed in an ordinary environment and processes (5) to (7) are performed in a clean room (class 1000/100). Automation of the processes and quality control, especially at the rotor assembly and body assembly processes, are outlined below.

5.1 Automatic rotor assembly line

The rotor assembly process is shown in *Fig. 6*. The composition of the assembly line is shown in *Fig. 7*. The rotor consists of four parts and is assembled by four processes. All the processes are fully automated and assembly work is performed by one machine keeper.

The main features of this assembly line as described below.

(a) Small amount coating and intermittent coating of adhesive

The amount of adhesive used at all the processes is 1 mg per spindle motor. Especially, squeezing out of the adhesive at bonding of the segment magnet is prevented by dividing coating into four times.

(b) Segment magnet high precision phase balancing

Since the segment magnet fastening precision has a large affect on the characteristics, bonding and assembly are performed at tight tolerances by precision jigs and assembly method considerations.

(c) High precision press fitting of shaft

Press fitting of the rotor yoke to the shaft demands a center runout precision of 0.03 mm at the outside periphery of the rotor yoke. The shaft holding method and rotor yoke holding jig were improved. Surface runout measurement is also automated and automatic judgement is performed on the line.

(d) Fully automatic balance correction

Since the allowable residual unbalance is a stringent 0.1 g-cm or less, a balance machine which allows multiple correction is used. This balance correction is minus balance correction by side cutter. The shape of the side cutter is input to a microcomputer and the cutting amount is

Fig. 6 Rotor assembly process

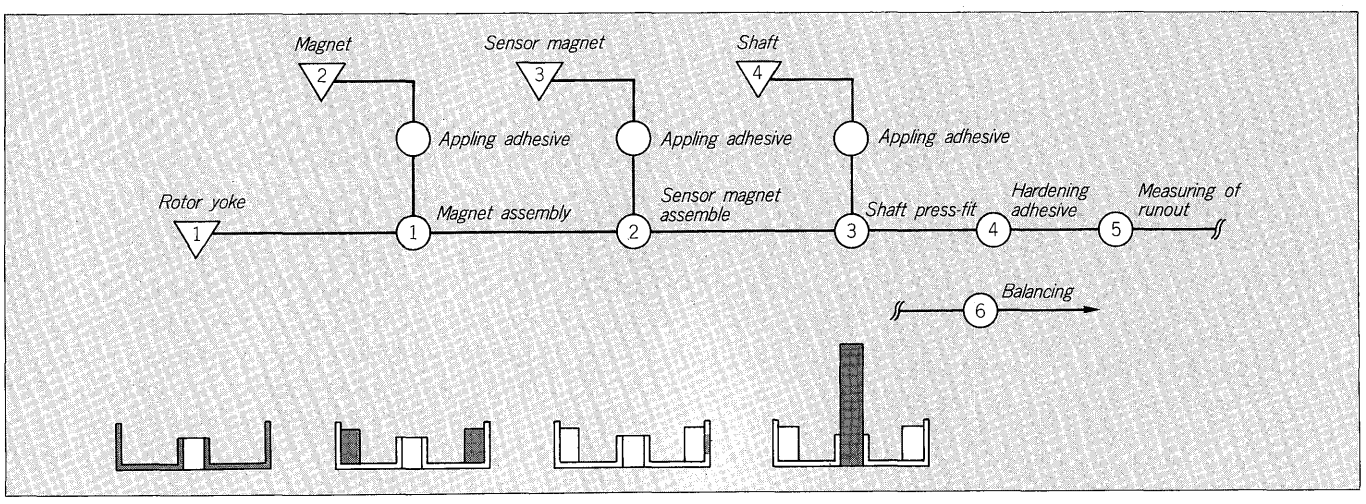


Fig. 7 Automatic rotor assembly

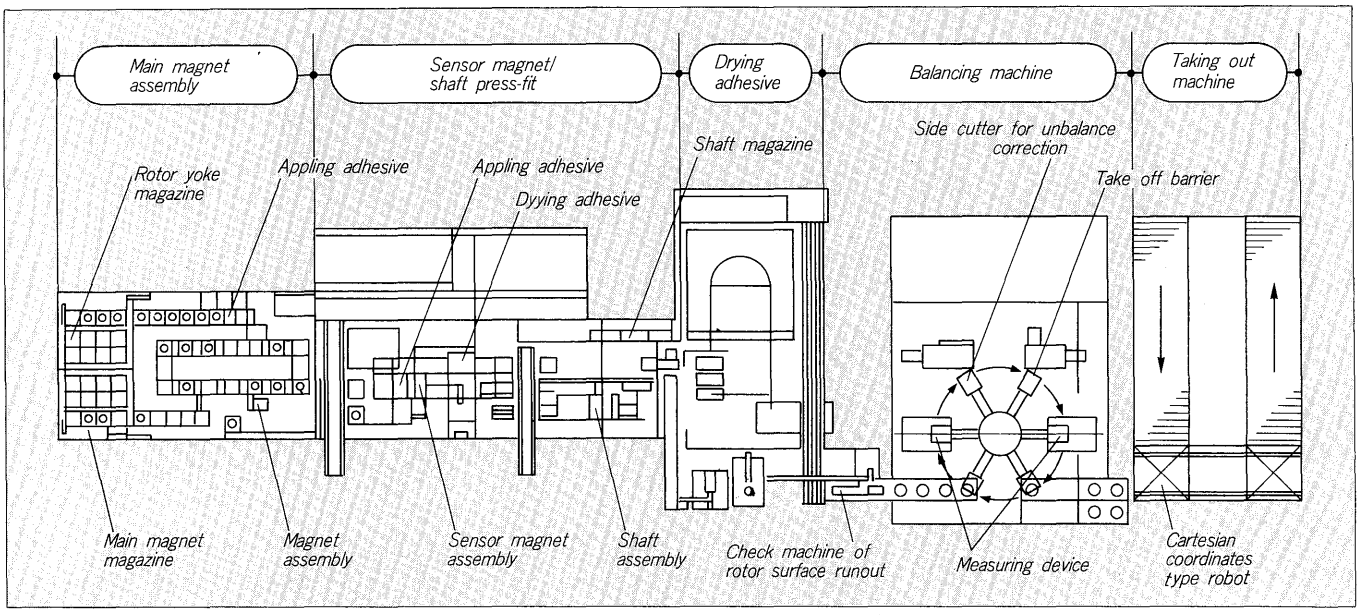


Fig. 8 Magnet assembly equipment

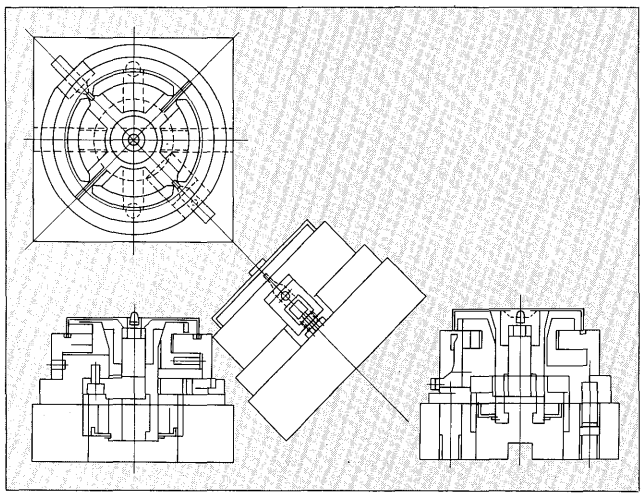
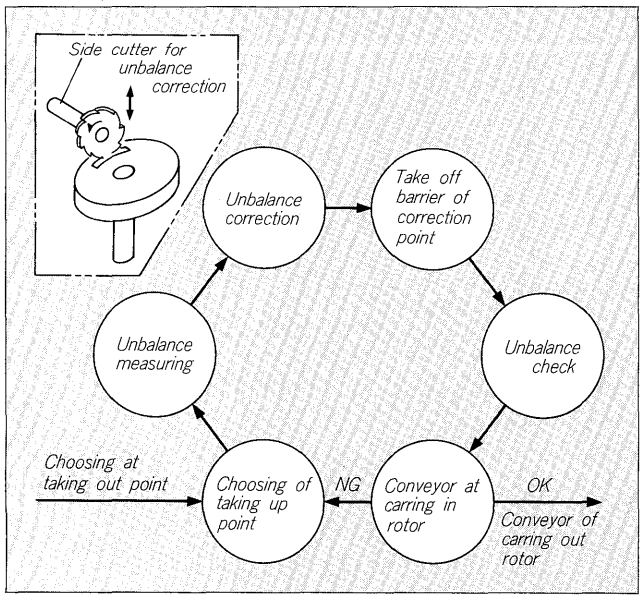


Fig. 9 Rotor unbalance correction process



managed by depth control.

(e) Division and distribution of automatic machines by processing unit

Each assembly machine is divided by process unit and the machines are interconnected by miniconveyor. This system allows taking up and taking out at an intermediate point and can cope with model changes in process units. Also, the entire system is not stopped at machine trouble, etc. and the operating efficiency of the facility is improved.

5.2 Body assembly line

The body assembly parts consists of the seven parts shown in *Fig. 10*. The number of processes is 27. Work is performed on this assembly line by one operator and one machine keeper.

The main composition of the facility is:

(1) Automatic assembly station 27
(2) Assembly robot 12
(Scalar robot 2, cartesian coordinate robot 10)
(3) Preload conveyor 20 m
(Pallet system)

The following eight points are introduced as the main features of the body assembly line:

(a) In-line magnetizing process

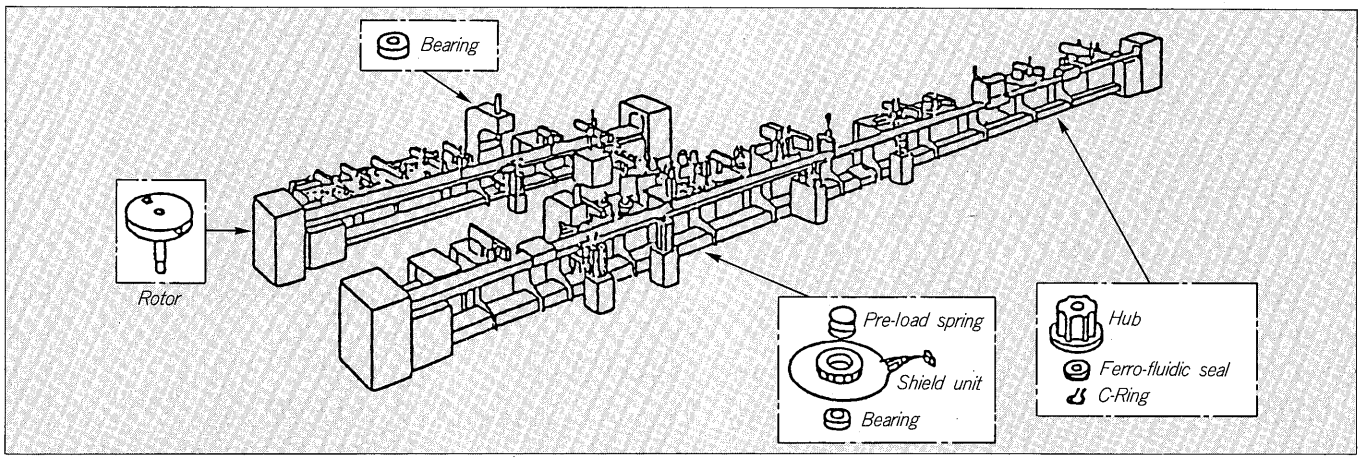
The rotor magnet is magnetized on an automatic assembly line. Measurement and judgement of the magnetic characteristics, irregular rotation, etc. after magnetization are also automated.

(b) Precision assembly and shock-less assembly

The shaft and bearing fitting gap is on the order of μm by diameter. A scalar robot is used and the hand is given a compliance function so that shock is not applied to the bearing. Ample consideration is also given to attraction of the rotor and shield unit by magnetic force.

(c) Dispensing of a small amount of fluid

Fig. 10 Body assembly line



High performance dispenses which dispense 1.5 mg of adhesive and a small amount (4μl ± 10%) of magnetic fluid are used. A dispenser with a special mechanism is also used to reduce the affect of fluid viscosity by temperature, etc.

(d) In-line leak testing

Judgement of pressure difference 100 mmAq small air leaks is performed on the line and magnetic fluid breakdown and sealing defects are detected immediately after injection.

(e) Early detection of facility abnormalities by in-line dimensions measurement

For early detection of parts mounting defects and assembly defects, dimensions measuring equipment is always installed after the parts assembly process. Therefore, defects due to facility of jig trouble can be detected quickly and the generation of defects is prevented naturally.

(f) Shock-less conveyance

To prevent bearing sound defects, shock absorbing measures are taken so that the shock at pallet stopping and the start of carrying at each station is 1G or less.

(g) Line flexibility and trouble countermeasures

Robots are used in the assembly process and parts changes and process changes can also be handled. Since a preload conveyor is used, facility trouble ends at only one processes and work can also be performed with the worker substituting for the facility.

(h) Dust prevention and maintenance of cleanliness

Since the motor is assembled in a clean room, dust generation countermeasures are taken at each facility. Also, to maintain product cleanliness, the construction is such that there are no overhead facilities.

6. CONCLUSION

The Fuji Electric spindle motor for 3.5" HDD was outlined above. Currently, development of in-hub motors for one disk and for four to six disks is complete and market development is being performed in step with the increase of the market need for higher density and smaller size.

The guidance of all users regarding the spindle motor for HDD in the future is solicited.