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MECHANICAL VIBRATIONS IN OPTICAL DISK DRIVES

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ABSTRACT

Recent trends and the effect of mechanical vibrations in optical disk drives are reviewed in this paper. The transition from CD drives to high density DVD drives and the development of writable optical disk drives require tighter mechanical tolerance. The demand for faster access time and higher data transfer rate also leads to critical mechanical problems to limit the tracking and focusing servo performance. The current mechanical issues to limit the performance of the drives and various technologies to overcome the mechanical problems are introduced. Vibrations of disk-spindle system, actuator and suspension designs of the optical pick-up, and general mechanical designs for the fast and stable access mechanism are considered.

1. INTRODUCTION

Development of current and future optical disk drives depends on market requirements and technology progress. In CD-ROM drives, the demand for higher data transfer rate hasten the advent of CD-ROM with 32 times the transfer rate of the original drive. DVD (digital versatile disk) was originally conceived as a high capacity storage device for the playback of movies, and then the DVD family such as DVD-Video, DVD-ROM and DVD-RAM (random access memory) has been introduced to meet the requests of both the movie and computer industries. DVD has the same 120mm diameter as audio CDs and CD-ROM and it is basically a higher-capacity and dual-layer version of CD. Using the shorter wavelength and the larger NA (numerical aperture) lens, DVD can store about 4.7 GB on a single layer. Although the first generation of DVD-ROM drives, shipped last year, has not fully penetrated the sales markets, we already expect the coming of the third generation of DVD-ROM this year. Various writable optical disk drives such as CD-R/RW, DVD-RAM and MO drives are also expected to grow rapidly for many applications.

The transition from CD drives to high density DVD drives and the development of writable optical disk drives greatly increase the potential for errors. In addition to the transition to high-density storage devices, the demands for faster access time and higher data transfer rate cause many mechanical problems. Structural vibrations of mechanical strongly required for the development of the drives with higher density and higher performance. In this paper, thecomponents in the optical disk drives are the major sources for the errors. Reducing the mechanical vibrations is trends of the optical disk drives and the mechanical problems to limit the performance of the current optical disk drives are reviewed. In particular, mechanical issues in the disk-spindle system and the optical pick-up system are focused.

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2. TRENDS

2.1. ROM drives: CD-ROM and DVD-ROM

A CD-ROM or DVD ROM drive reads data by focusing

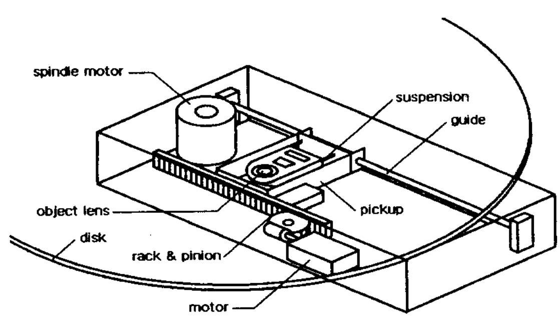


Fig.1 : Configuration of typical CD-ROM drive

laser light on the plastic substrate and then detecting reflected light as the disk rotates. The detected light fluctuates with the presence or absence of pits along the track because the pits are less reflective than other points on the reflective layer. The typical CD/DVD-ROM drive consists of the loading system, the feeding system, PCB (Printed Circuit Board), and the frame. The loading system includes a disk tray and a loading motor for loading/unloading a CD/DVD disk. The feeding system includes key mechanical components such as an optical pick-up, a feeding mechanism, a spindle motor and a disk clamper. The optical pick-up reads data written on the disk surface, and it includes a laser diode, an object lens, a suspension and VCM actuators (Fig. 1). The feeding motor and mechanism move the optical pick-up carriage. The feeding mechanism uses a rack-pinion, a feed screw or a linear motor.

Key characteristics of CD and DVD are compared with the current 3.5 inch HDD with 10 kTPI in the Table 1. The minimum pit diameter of a DVD disk is 0.4 μm which is less than half that of the CD-ROM (0.83μm). This is achieved by using red laser with a shorter wavelength (650 nm) and a higher NA lens (0.6). This allows linear bit density to be increased from 43 Kbit/in to 96 Kbit/in. Track density is also increased from 16,000 TPI to 34,000 TPI. Recently, some companies developed blue laser with a shorter wavelength for the next generation optical storage.

Table 1 : Specifications of CD, DVD and Current 3.5 inch HDD

Feature	CD	DVD	3.5" HDD
Storage(MB)	680	4700(one layer)	
Disk dia.(mm)	120	120	90
Disk Thick.(mm)	1.2	1.2 (2x 0.6)	0.8
Min. pit leng. (μm)	0.83	0.4	-
Laser waveleng.(nm)	780	635-650	-
N.A.	0.45	0.6	-
Track pitch(μm)	1.6	0.74	2.54
Track density(TPI)	16,000	34,000	10,000
Bit density(BPI)	43,000	96,000	
Rotation speed(rmp)	6000-7000(32X)	2400-5600 (4X)	7200/10,000
Max.Focus.Tolerance(μm)	1.0	0.5	-
Max.Track.Tolerance(μm)	0.1	0.05	0.13

Since the first CD-ROM was developed in 1984, the drive has experienced a speed race and short life cycles to fulfill the customer's desire for higher data transfer rates. During the last two years the transfer rate of the CD-ROM drive was increased from 8X (8 times the transfer rate of the original CD-ROM) to 32X drive. The 32X or 40X is expected to be last CD-ROM generation because mechanical problems become critical at the spin speeds and industry interest is shifting to DVD-ROM drives. The first generation of DVD drives plays back at a maximum data rate of 11 Mbit/s. Even though the drive's rotation speed is less than that of a 4X CD-ROM drive, this roughly corresponds to the data rate of a 9X CD-ROM drive. DVD-ROM drives are also expected to take a similar speed race to achieve higher data transfer rates. Some major electronics companies expect to start shipping 4X DVD-

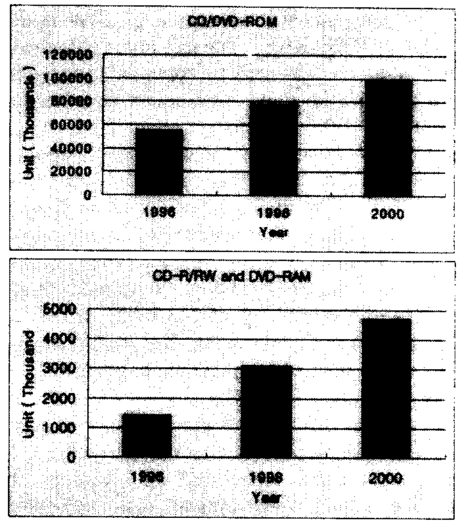


Fig. 2: Worldwide shipment forecasts of optical disk drives (source : 1997 Disk/Trend report)

ROM this year, whose data transfer rate is higher than that of 32X CD-ROM drives. 100 million CD-format ROM drives including DVD-ROM is expected to sell in 2000 by Disk/Trend reports (Fig. 2(a)).

The optical disk drives originally read disks at a constant linear velocity (CLV). In general, the CLV control will always lengthen the access time. As the spindle motor speed is increased, read-only disks are played back at a constant angular velocity (CAV). It is because the CLV type requires high-speed rotation at inner data tracks to keep the linear velocity constant. Several mixed methods using CAV at inner data tracks and CLV at outer ones are also used. For this reason, the current CD-ROM gives the maximum data transfer rate (like 32X Max). Table 2 gives rotational speeds and data transfer rates of several drives.

Table 2: Rotational speeds and Data Transfer Rates of CD and DVD

	1X CD	32X-max CD	1X DVD	4X DVD
Speed Control	CLV	CAV , Mixed	CLV	CLV or CAV
Rotational Speed(rpm)	200-500	6000-7000	600-1400	2400-5600
Data transfer rate(MB/s)	0.15	4.8max	1.35	5.4

2.2 Writable Drives: CD-R/RW, DVD-RAM and MO drives

Writable versions of CD format drives have grown rapidly. Currently, write-once CD-R drives are widely used in business and professional applications. However, the write-once drives are being replaced by writable CD-RW drives that started to sell in 1997. The first rewritable DVD-RAM was announced early this year and then the writable DVD is forecasted to be the majority a few years later. The DISK/TREND report forecasts that 4.7 million writable optical disk drives would be sold in 2000 (Fig. 2(b)).

Based on phase-change technology, CD-RW is thought to be a bridge to DVD-RAM. The CD-rewritable media uses a layer of inorganic material that can be caused to switch between a crystalline and amorphous state through laser generated heat. While limited to about 1,000 write-rewrite cycles, CD-RW is suitable for many applications such as back-up a hard disk or editing audio and image. While the reflectivity of CD-R media is sufficient to work with all types of CD drives, the reflectivity change of CD-RW media is insufficient to allow recorded disks to be read by older CD-ROM drives. Therefore, "multiread" specification defines how the sensitivity of CD-ROM drives should be modified to ensure compatibility. Key technologies used in DVD-RAM are mentioned in the paper by Satoh et al. [1].

Magneto-Optical (MO) drives are a possible alternative and contender for the writable CD format drives [2]. MO disk systems combine the technology of traditional magnetic media, like HDD, with optical disk technology. MO technology allows users to pack large data on a disk that looks similar to a floppy disk. A MO drive writes data on the disk using a read/write head assisted by a laser. The laser heats up the disk surface to its Curie point. Then, the read/write head passes over the disk, polarizing those areas heated by the laser. Because the laser can be focused on a much narrower field than a traditional magnetic head, a very high data density is possible. Recently, the ASMO (Advanced Storage Magneto Optical) disk format with recording density of 6.1 GBytes has been released to compete with DVD-RAM drives. In the ASMO drives, a flexible disk with 120mm-diameter and 0.6 mm-thickness is made to rotate inside a cartridge. Table 3 gives specifications of the three writable optical disk drives.

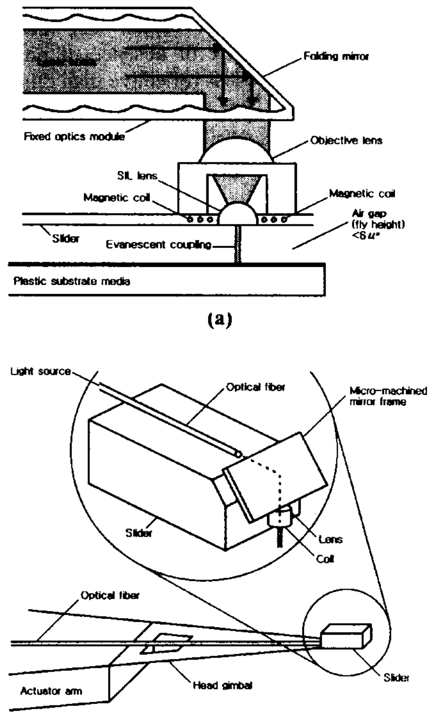
Table 3 : Specifications of Writable Optical Disk Drives

	CD-RW	DVD-RAM	ASMO
Recording Type	Phase -Change	Phase -Change	Magneto-Optic
Storage density	650 MB	2.6 GB	6.1 GB
Disk diameter	120 mm	120 mm	120 mm
Disk thickness	1.2 mm	1.2 mm	0.6 mm
Track pitch	1.6 μm	0.74 μm	0.6 μm

2.3. New Optical Storage: Near-Field Recording and OAW Technologies

Superparamagnetic limit, where magnetic media becomes unstable and conventional Winchester-type recording technology fails, is somewhere between 20 and 40 GB/in^2 recording density. Two types of new recording technologies to advance the increase of the areal density beyond the superparamagnetic limit have been recently introduced by Terastor and Quinta.

The object lens used in CD/DVD systems must be located some distance from the disk to focus laser light on the recording layer. A recording system without a protective substrate where the lens is in contact with the recording layer, is called a near-field system. A very small spot size



(a)

(b)

Fig.3 : New optical storage devices

can be produced by near-field systems to increase storage capacity. Near-field recording technology by Terastor combines design elements from several fields, such as magnetic recording, optical recording, consumer electronics and microscopy [3]. The key elements of Terastor's technology include: (1) a flying optical head; (2) near field recording; (3) first-surface recording; and (4) crescent recording (Fig. 3(a)). In particular, the flying optical head that is similar to a hard disk drive's flying head, allows the head to be placed close enough to the recording media. A laser-based flying head flies at a distance less than 0.15μm. The distance is less than the wavelength of laser light. The laser spot diameter is 0.26μm and track density can be increased up to 70,000 TPI.

Quinta's alternative technology for a next generation storage solution is called optically assisted Winchester (OAW) technology [4]. This includes four major subsystems: (1) an optical switching module; (2) a light-delivery system using optical fibers; (3) a read-write head; and (4) a new type of magnetic media (Fig. 3(b)). The optical switching module includes a laser, collimating optics, beam splitter, signal detectors and the servo-controlled optical switch. Optical fibers deliver light precisely to a selected head/media interface and back to the switching module. The novel head design consists of a miniature slider body, a fine tracking servo mirror, an embedded objective lens and a planar writing coil mounted underneath the slider body. The lens focuses light to a small spot about 0.38μm below the air-bearing surface. In a demonstration, 35,000 TPI, which is over three times higher than provided by current hard disk drives.

3. MECHANICAL ISSUES

The mechanical tolerances and vibrations in the optical disk drives cause positioning errors of an object lens during tracking and focusing motions. In addition to the major sources, the high-density disk in the drives is more susceptible to errors caused by scratches, corrosion and other minor defects. In particular, vibrations of the disk-spindle system and the optical pick-up become the critical mechanical issues in the storage devices. Major sources for the disk vibration are excitations by a rotating unbalance of the disk itself, disk-spindle resonance, the critical speed instability and disk flutter. The structural resonance of the pick-up system is also an important issue because it affects tracking/focusing errors and servo performances. Thus, the technologies of reducing vibrations in both the disk and the pick-up system are strongly required for the development of drives with higher storage density and higher performance.

3.1 Disk Vibrations at High Rotational Speeds

In order to fulfill the customer's desire for faster access times and higher data transfer rates, CD-ROM drives has recently experienced a dramatic increase in rotational speeds. Operating at high spin speeds decrease the rotational latency component of the access time. However, as the speed is increased, disk vibration in the drives becomes a critical mechanical issue. It is because the rotational speed in the current 32X/40X CD-ROM drives is close to a critical speed. Furthermore, the exciting force by a rotating unbalance of the disk mass is too large to be neglected at the current operating speed.

Mode Splitting and Critical speed

It is well known that mode splitting and critical speed are two interesting phenomena in the vibration analysis of a rotating disk. The natural frequencies ω_{mn} of the modes with m nodal circles and n nodal diameters of the rotating disk become [5,6]

$$\omega_{mn} = \omega_{mn}^{s} \pm n\Omega$$

where ω_{mn}^{s} is the natural frequency from a observer rotating together with the disk and Ω is rotational speed of the disk. The difference between the frequencies of the forward and backward traveling waves is known as mode splitting. When the rotational speed is increased to a certain speed (known as the critical speed) where the backward wave frequency vanishes ($\omega_{mn}^{s} = n\Omega$), the disk experiences unstable motions caused by a static deformation. However, the critical speed that is calculated a stationary disk viewed a rotating reference frame can give a lower bound, because the effect of radial stiffening of the rotating disk affects the frequency of oscillation. This effect is so large for the (0,1) mode, the mode does not exhibit a critical speed in the rotating disk case. The analytical frequency approximations for a mode with n nodal diameter and zero nodal circle, when both bending and centrifugal stresses, are given by

$$(\omega_n)^2 = (\omega_n^s)^2 + \lambda_n \Omega^2$$

where

$$(\omega_n^s)^2 = \frac{\xi_n^4 E t^2}{3\rho(1-\nu^2)}$$

is the natural frequency of a stationary disk clamped at its center. E is Young's Modulus of the disk substrate and t is the disk thickness and ν is the Poisson's ratio. The second term is the natural frequency of a spinning circular membrane. ξ_n and λ_n are numerical parameters given by Southwell [7] as shown in Table 4. Thus, the critical speeds for the rotating disk problem are approximated by

$$\Omega_{cr}^2 = \frac{(\omega_n^s)^2}{n^2 - \lambda_n}.$$

Table 4 : Numerical Parameters

	n=1	n=2	n=3	n=4
λ_n	1.00	2.35	4.05	6.16
ξ_n	1.01	2.29	3.50	4.64

The approximations for the natural frequencies and the critical speeds give lower bounds on the exact ones. For a rotating annular disk with a clamped - free boundary configuration, the lowest critical speed as a function of clamping radius ratio is approximated by [8]

$$\Omega_{cr}(rpm) = \sqrt{\frac{Et^2}{\rho R_o^4}}\left[42.3\left(\frac{R_i}{R_o}\right)^2 + 2.4\left(\frac{R_i}{R_o}\right) + 11.0\right]$$

when $\nu = 0.33$. R_o and R_i are inner and outer diameter of the rotating disk. Using the approximation, the critical speeds of some flexible disks are calculated in Table 5.

Table 5 : Critical Speeds of Memory Disks

	R_o (mm)	R_i (mm)	T (mm)	Ω (rpm)	Ω_{cr} (rpm)
3.5"Floppy	43.0	12.5	0.05	360	724
Iomega ZIP	43.0	12.5	0.05	3600	724
ASMO	60	15	0.6	2000-3000	3560
CD	60	15	1.2	6000-7000	7122

For Floppy and ZIP disks, ρ = 1300 kg/m^3 and E = 4 . For the ASMO and CD disks, ρ = 1200 kg/m^3 and E = 2.7 GPa.

Iomega's ZIP drive operates at 400-500 percent of the critical speed. Fig. 4 shows experimental natural frequencies of a typical CD/DVD disk. The theoretical approximations show a good agreement to the experimental results. The backward frequency of the (0,2) mode is almost zero at 7200 rpm. This confirms that disk vibration is the major mechanical issue for the current 32X CD-ROM drive spinning around 6000-7000 rpm.

It is also known that the frequency of (0,1) mode depends on the bearing stiffness [9]. It is because the precession (rocking) mode is actually one nodal diameter disk mode coupled with shaft's precession and nutation. The gyroscopic motion of the rigid shaft with elastic bearings does not affect other disk modes having higher nodal diameters.

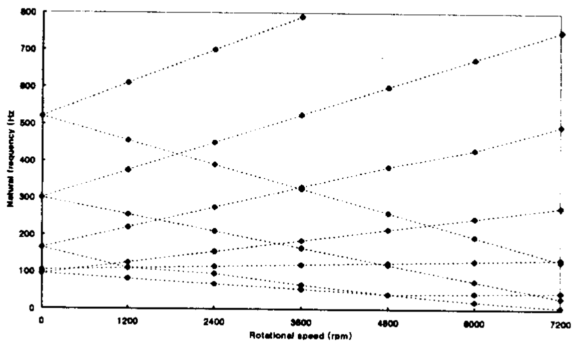


Fig. 4: Experimental natural requencies of a CD/DVD disk

Recently, Renshaw [10] considers the critical speed of a hydrodynamically coupled, rotating flexible disk. It is noted that the coupled critical speed is three to ten times higher than the uncoupled critical speed, as shown in Fig. 5. The dimensionless critical speed is converted into a dimensional value by

$$\Omega_{cr} = \Omega_{cr}^{*}\sqrt{\frac{Et^{2}}{12\rho R_{o}^{4}(1-\nu^{2})}}$$

Even though many papers on the disk-spindle system of HDDs have been published, research on disk vibration of optical disk drives is rare. Studies on the stability of an optical disk rotating at high (even supercritical) speeds are required to keep increasing the disk's spinning rate.

Disk Vibration by Rotating Unbalance of Mass

Small irregularities in the mass distribution of a rotating disk can cause substantial vibration. When the unbalanced mass of a disk rotates with a distance from the rotation center, the induced centrifugal force is proportional to the square of the rotational speed. This gyroscopic effect becomes more severe when a disk having a large mechanical tolerance is loaded on the spindle turntable. Since the optical disk drives repeats the removal and

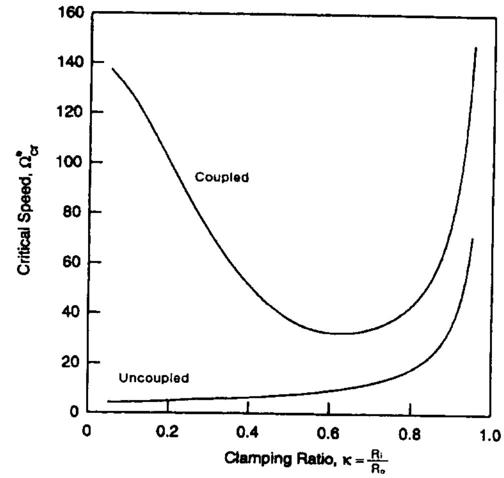


Fig. 5: The uncoupled and hydrodynamically coupled critical speeds [10]

loading cycles of different types of CD/DVD disks on the spindle, the worst case, such as a CD disk with a large unbalance of mass, must be considered in designing the disk-spindle system.

Two kinds of mechanical considerations are used to reduce the effect of the rotating unbalance. One is a disk centering mechanism and the other is an auto-balancing mechanism. The disk centering mechanism minimizes the centering error when loading the disk on the spindle turntable. Various shapes of hub is inserted on the turntable to reduce the error. As the spinning speed of the spindle is increased, drive companies start to use a different balancing mechanism to reduce vibrations. In the auto balancing mechanism, several balls are put into the circumferential hole around the magnetic disk clamper so that the additional ball mass is located in the region out of phase with the rotating unbalance of mass (Fig.6). Though these balls are in phase with the unbalance force at low speeds, the balancing mechanism is quite effective for the prevention of disk vibrations at high speeds.

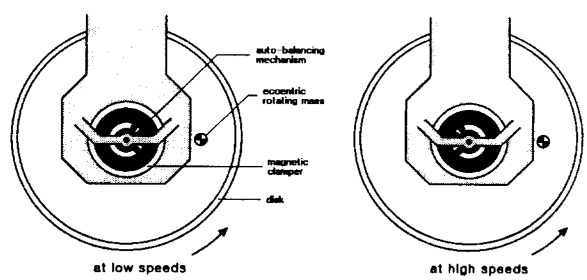


Fig. 6: Auto-balancing mechanism

Disk Flutter

Disk flutter is mainly induced by airflow and the spindle-bearing excitation. It contributes positioning errors and non-repeatable runout which limit the drive performance and density. Since Lennemann [11] studied aerodynamic effect on rotating disk files, many researchers have studied on the air-induced disk vibrations [12-14]. In HDD industries, disk flutter has been a critical issue, in particular, for the development of a HDD rotating beyond 10,000 rpm [15]. When the disk drives operate far below the critical speed, the air-induced disk flutter was not considered to be a significant factor. However, as the rotational speed and track density increase, its effect is significant. The air-exciting force has a broadband frequency. Thus, airflow can excite disk modes out of servo bandwidth and potentially cause positioning errors. The amplitude of disk flutter is strongly related to the material property and size of the disk. The flutter amplitude A_f is known to have the following proportion,

$$A_f \propto \frac{D^5 \Omega^2}{E t^3}$$

Where Ω is the rotational speed, D is the disk diameter, t is the disk thickness and E is Young's Modulus of the disk substrate. Solutions to reduce disk flutter are the use of high modulus substrates and aerodynamic considerations in designing the disk drives [16,17]. The effect of airflow on the vibration of an ASMO disk within a cartridge has been recently studied [18]. Many researchers, for example, Prater [19] and Frees [20], addressed the effect of ball bearing frequencies on disk vibration and TMR in HDD drives. For the optical disk drives, the axial and radial vibrations excited by the inner, outer race and retainer of ball bearings were studied by Tada et al. [21,22].

3.2. Vibrations in Optical Pick-up

High density DVD drives as well as CD-ROM drives require a precise track accessing and focusing. The optical disk drives have the two-stage tracking mechanism consisting of a linear feeding motor and a lens actuator. The lens actuator is suspended on a linear positioning carriage by wires or leaf springs. Tracking servo drives the linear feeding motor having a wide range of motion and then an object lens is precisely driven in a radial direction by VCM in the lens actuator. The use of the two actuators makes it possible to achieve a precise tracking.

The lens actuator has a range of only about 100μm. The lens must be positioned within a tracking error of 0.1μm and a focusing error of 1μm in CD. However, DVD drives with smaller track pitch and smaller working distance of the lens require tighter tracking/focusing accuracy (about 2 times as CD drives). In general, a hard disk drive can accommodate 3σ TMR of about 12-15 % of the track width, as known "the 1/8 rule" [23]. Rewritable CD/DVD drives also require tighter allowable tolerance because positioning errors in writable disks are accumulated by both writing and reading data. The major sources of the errors are the coupled vibrations between tracking and focusing directions and the structural resonance of the optical pick-up. These structural motions should be as small as possible because the pick-up system directly limits the servo performance and the mechanical tolerances of other mechanical parts.

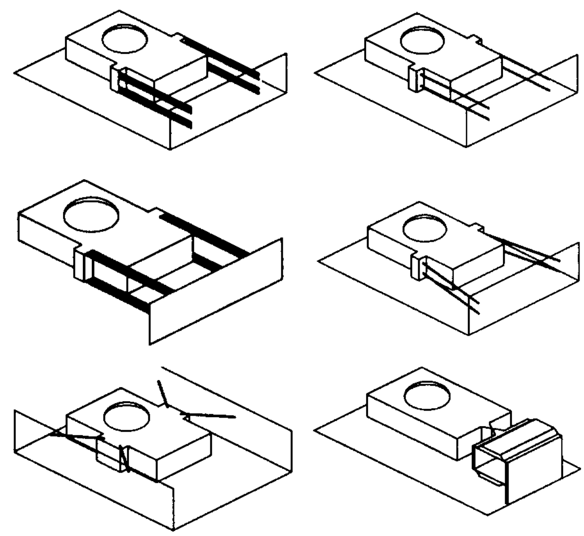


Fig. 7: Several types of pick-up suspension models

Tracking/Focusing Coupled Motions

The two-axis servomechanism in the optical disk drives causes the tracking/focusing coupled vibrations, known as "cross action" [24]. When actuated in one direction, the lens moves in the other direction because of a tilt angle between the disk surface and the focusing axis of lens. The mechanical tolerances and assembly errors of the lens suspension amplify this coupled motion. Optimum values for parameters of the pick-up suspension were determined to reduce the coupling effect using various methods. In general, a lumped parameter model with elastic suspensions for the pick-up suspension system is considered. Many types of the actuator suspension have been proposed to achieve accurate tracking/focusing motions for various optical drives [25-28]. Several suspension models are shown in Fig. 7. The pick-up suspension uses two major types. One is leaf springs and the other wire springs. The leaf-spring type shows better dynamic performance than the wire suspension, especially during tracking motions.

The tracking-induced tilt motion is also related to the mass center of the moving pick-up system. The lens actuator's center of mass is generally different from the pick-up carriage's one. When the lens is actuated, forces generated around the carriage's center of mass induce the pitching

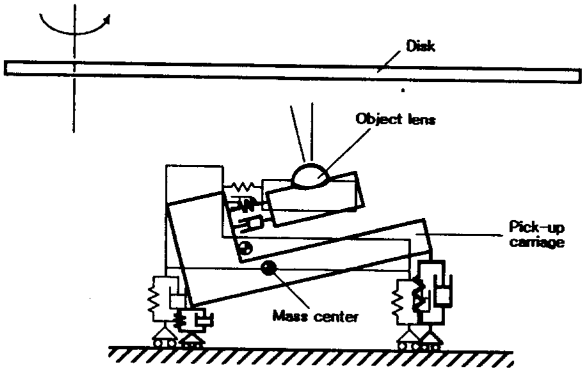


Fig. 8: Pitching motion of the pick-up system

motion of the carriage and affect servo performance (Fig. 8). The pitching motion causing a tilt angle between the disk and the focusing axis can be eliminated by adjusting the driving point of the moving carriage [29].

The development of a DVD disk with two 0.6-mm substrates leads to a new type of optical pick-up lens, because laser beam cannot be focused correctly on a substrate with different thickness. To possess the compatibility with CD and dual-layer DVD, several approaches have been proposed such as a dual lens rotary actuator or a double focus lens and a variable aperture method [30-32].

Structural Resonance

In addition to the coupling effect between tracking and focusing motions, structural resonance of mechanical components affects the performance of its optical servo system. CD-ROM industries require that the first natural frequency of the pick-up must be lower than 50 Hz and higher natural frequencies must be higher than 30 kHz. This hard structural requirement in the pick-up design becomes even tighter in high density DVD and ASMO drives. Structural optimizations considering servo performance are used to meet the tighter design tolerance [33]. Mechanical tolerance in suspension dimensions does not only cause a tilt angle, but it also causes the variations of natural frequencies of the pick-up component. In particular, the frequencies are sensitive to the variations of thickness and width of the spring suspension, rather than the length of the suspension [34]. Thus, reducing the thickness and width tolerances in manufacturing and assembling the suspension is required to avoid undesirable errors.

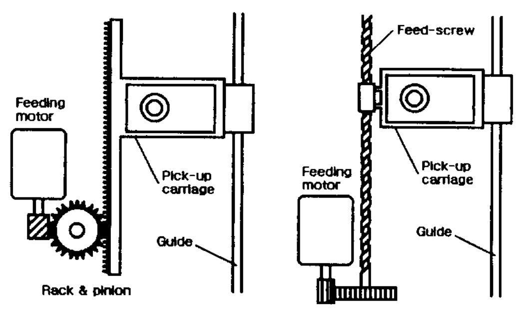
3.3. Other Mechanical Issues

Tilt Adjustment Mechanism

For a given tilt angle between the optical pick-up and disk surface, the aberration of the optical lens is proportional to the substrate thickness and the cube of lens NA. Therefore, the tilt angle in DVD drives using 0.6-mm substrate and 0.6 NA deteriorates the playback signal 1.35 times as provided CD drives. A mechanism to correct the tilt error is definitely required for DVD drives with small track pitch and high NA lens. Two types of the tilt adjustment are used. One is by raising and lowering the guide rails supporting the optical pick-up system, and the other is by controlling the angle of disk-spindle axis. The spindle-adjusting mechanism is easier to adjust the tilt error than the guide-adjusting one, but it weakens the rigidity of the spindle system connected to the drive's main frame, possibly causing undesirable vibrations.

Feeding Mechanism for High-Speed Seeking

In order to achieve faster access times in CD-ROM drives, the track-seeking motions of the lens should be increased together with the increase of disk rotational speeds. High acceleration of the feeding motor can cause structural resonance and limit the performance of tracking/focusing servos. Vibrations occurring in the driving mechanism should be confined in the feeding parts. The dynamic analysis of the feeding system was studied to reduce the tilting modes of the feeding system by determining the optimal positions of dampers [35]. Typical feeding mechanisms used in the drives are shown in Fig. 9. The rack-pinion type has good transmission efficiency, but it consists of many mechanical components and gives noise at high-speed motions. The feeding screw type reduces noise induced at high speeds. However, its mechanical efficiency is so low that a feeding motor with a large torque is necessary. The linear motor type enables precise and fast feeding motions. However it cannot be used for portable disk drives because of feeding errors caused by gravity.



(a) Rack-pinion type **(b) Feed-screw type**

Fig. 9 : Feeding Mechanisms

Vibration Isolation

The major mechanical parts to induce structural vibrations are the disk-spindle motor, the lens actuator and the feeding motor. As excitation forces generated by these sources are transmitted into various mechanical components, undesirable mechanical resonance occurs. To avoid the problem, the source, the path and the receiver of the excitation forces should be analyzed and modified. As the vibration source, the driving parts should be designed to behave within a desired level. The path, through which the excitation force is transmitted into other mechanical components, should be either isolated or modified. It is also necessary to adjust the natural frequencies of each mechanical component receiving the excitation. For the drives with higher data density and fast access time, mechanical resonance in the drive level, rather than each component level, should be considered [36]. It is because many mechanical components in the drives are coupled together to generate new structural modes. The interaction of structural flexibility with tracking/focusing servo also affects the performance of the drives.

Servo Control

Servo control system in optical disk drives consists of ALPC (automatic laser power control), focusing servo, tracking servo, spindle servo and sled servo. The laser power servo regulates laser output to avoid possible errors caused by the variation of laser output. The servo becomes more complicated with rewritable disks where different levels of laser power are required to read, write, and erase signals. Even with a DVD-ROM drive, laser power and detector sensitivity must be adjusted to accommodate the different reflectivity of various types of disks and various layers on the same DVD. The focusing/tracking servos control the position of the optical pick-up lens to locate and focus laser beam on a specific data track. The spindle servo regulates the spindle's rotational speed to have either a constant linear velocity (CLV) or constant angular velocity (CAV). The current high-speed ROM drives use pure CAV or mixed types where the servo uses CAV at inner tracks and CLV at outer ones. However, writable disks generally use CLV. While it is relatively easy to design the servo system maintaining a constant motor speed, it is more difficult to vary the rotational speed with track position in CLV. Various control algorithms were introduced to increase the spindle servo performance [37]. The sled servo makes the optical pick-up to follow the spiral shaped track by a sled driving motor.

4. CONCLUSIONS

As the storage density and data transfer rates are increased, mechanical issues to limit the tracking/focusing performance become critical. Furthermore, the development of writable optical disk drives such as CD-R/RW, DVD-RAM and ASMO drives leads to tighter mechanical tolerance. The current 32X CD-ROM which experiencing a critical vibration induced by high-speed spinning will not continue its speed race at recent increasing rates. However, the evolution of the CD-ROM drive's rpm increase for higher data transfer rates will be succeeded by DVD-ROM. While the areal density and drive capacity in HDD increase at a certain rate every year, the optical disk drives compete for faster access time and higher data transfer rates in given form factors until a new type of optical storage device is developed. Only with technologies to suppress mechanical vibrations induced in the disk-spindle system and the optical pick-up system, the optical disk drives will continue with rapid advances.

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