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A NEW METHOD OF DETERMINING VIBRATION CRITERIA FOR A PRECISION EQUIPMENT USING FEQUENCY RESPONSE FUNCTION

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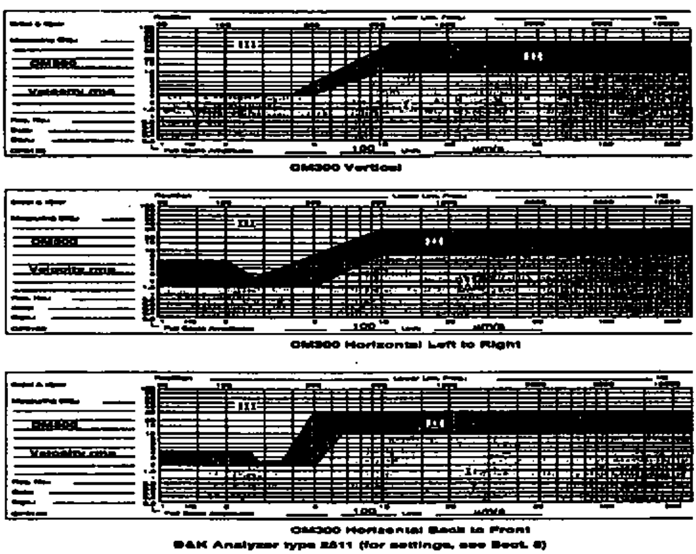
1. INTRODUCTION

As the development of the manufacturing proceeds, it becomes essential to use the high accurate equipment in various fields like R&D, Inspection Process, etc. Recently, FA control equipment, High density computer system are being used, All efforts are be exerted in various fields due to their weak anti-vibration characteristics. Especially, with the increasing necessity of highly accurate manufacturing, the use of inspection equipment has been increased, so the mass production of giga class memory chips seems possible before the end of this century. The anti-vibration and vibration isolation design must be considered in those equipments which have the work resolution, 0.1–0.25μm because they are vulnerable to small vibration which aries from inside or outside. In case of manufacturing the factories of giga class memory chip, the clean room which the equipments as like photo aligner, stepper and mask machine are installed, is required to maintain its vibration criteria less than 0.1μm.
In spite of almost vibration free installation requirement, the factories are exposed to various kinds of vibrations due to huge fan system and its utilities inside the factories. So we need to pay our attention to the vibration criteria of the equipments. This problem is important to both equipment manufacturers and its buyers because it is the matter of cost itself.

The informations between the manufacturer and users of the equipment sometimes become ambiguous problem to each other. In fact, the vibration informations submitted by equipment manufacturer as Fig.1 (a),(b) and (c) have some uncertainities from the viewpoint of th engineers of the structure design. It is desirable for the manufacturer to issue the the vibration criteria at least in Fig. 1 (c), but it may be one of the reasons that it is hard to decide the vibration criteria like Fig.1 (c). As Fig. 2, it requires time and effort to assure the reliable data by analytical modeling because the data required is ultimately small value while the structure of the equipment is complicated.



※.Region I : Vibration up to this level do not need special attention. The microscope may therefore be installed without delay.

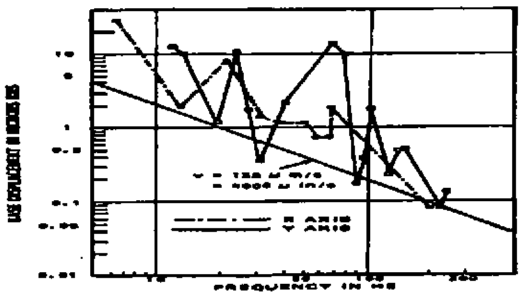
Region II : Vibration in area may affect high resolution. If no better alternative site is available, reduction of the vibration level is possible by other means.

Region III : The site is definitely unsuitable, installation is not recommended.

(a) CM300(Transmission Electron Microscopes) Vibration Sensitivity Graph

Equipment	Vibration Criteria
Auto Probe (model M5, Park Scientific Instruments)	• Frequency range 0.5~10Hz displacement <0.2㎛, Frequency range>10Hz velocity 60㎛/s,
IMS 6F	• >5㎛ (frequency range 0.4~ 200Hz)
Microbeam Ion Gun (model 06-650, Physical Electronics)	• Velocity less than 6.35㎛/s over the range 1 to 100Hz as measured with one-third octave bandwidth (Based on BBN † † Criteria D)
SEM	• 1Hz : less than 2.5㎛ p-p 2Hz : less than 1.5㎛ p-p 3Hz : less than 2.0㎛ p-p 5Hz : less than 3.0㎛ p-p 10Hz upward : less than 3.0㎛ p-p

(b) The Vibration Criteria of Precision Equipation



※. Solid curve corresponds to vertical, dotted curve to horizontal base vibration. Line represents constant velocity which is approximate lower bound to data.(Data from Perkin-Elmer document MLD 00254 "Macralign Sensitivity to Floor Vibration and Acoustic Disturbances. ")

(c) Vibrational base displacements resulting in 0.1 micron image motion.

Fig. 1 Example of Vibration Criteria for Precision Equipment

As the vibration restriction of the high accurate equipment is decided through the vibration test, all equipment must be tested because sensitive amount of vibration must be decided with not identical equipment specimens, Sometimes, the tight restriction of vibration by assumption make it difficult to design the structure of the building resulting in high construction costs.

In this paper, the study on more simple and new method for deciding the vibration criteria using Frequency Response Function(FRF) is included, and its effectiveness has been demonstrated by Hard Disk Drive system.

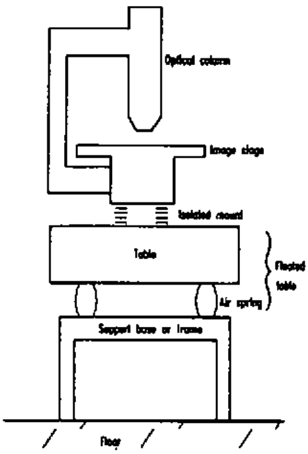


Fig. 2 Typical piece of optical equipment

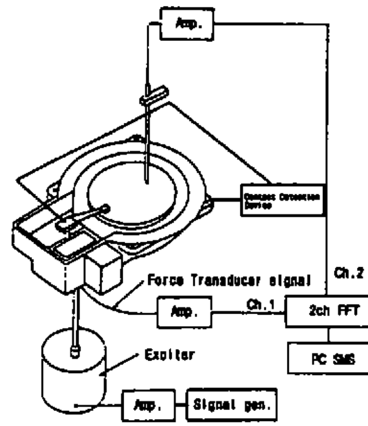


Fig. 3 Layout of the vibration performance test

2. DECISION OF VIBRATION CRITERIA

The methods to decide the permissible vibration amplitude have such difference as followings:

- Vibration environmental test : Vibration environment where the equipments are installed is suggested, user oriented, and decides only the proper state of the equipment.
- Vibration performance test : Vibration environment of the equipments, manufacture oriented, and decides the vibration criteria of the equipments.

Vibration environment test is applied to the equipments installed in severe vibration environment such like ship, automobile and airplane, otherwise the vibration performance test is applied to high accurate equipments such like semiconductor production/inspection equipments.

2.1 Vibration performance test

The method to decide the permissible vibration criteria of the high accurate is similar to the method which uses the exciting measurements and analysis system, but it is different from the vibration environment test in the aspect that it decides the magnitude and frequency of the vibration. Fig.3 shows the layout of the exciting measurement and analysis and Fig.4 shows the flowchart of the vibration performance test.

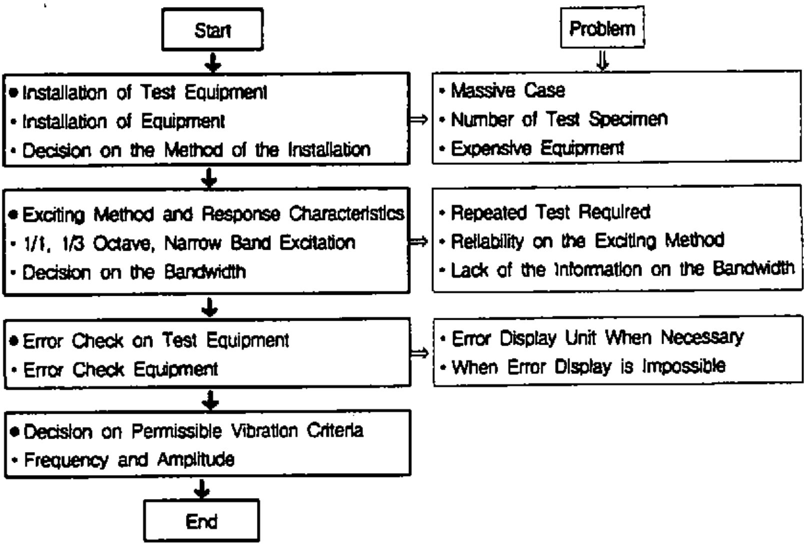


Fig. 4 Flowchart of the vibration performance test.

2.2 The FRF method

Aligner, Stepper, SEM, TEM are the high accurate equipments used in the semiconductor production lines and there are high density HDD, CD Driver, CD production equipment, medical operation, inspection equipment in other fields. The structural characteristic of these equipments is that those equipments are consist of projection part(optical column) and Target part. The vibration criteria in this structure is dependent on the relative vibration amplitude between projection part and target part. And this relative vibration amplitude can be decided by measuring the point mobility of these two points. The point mobility of the structure is measured experimentally because the structure is related to the dynamic characteristics of the whole system. Fig. 6 shows that the relative displacement between point p, q is decided by the components of the flexible mode of the whole structure which extracts the rigid body components. The permissible vibration criteria is decided by the relative displacement between point, p and q. The relative vibration displacement is restricted by the accuracy of the manufacturing/inspection. In case of the electro-telescope such like SEM or TEM, the resolution and magnification factor decide the vibration criteria. In case of the telescope which has 10 thousands magnification factor, the target image can be distinguished when it maintains its vibration criteria less than 0.1μm. That implies that the image is overlapped with the relative vibration greater than 0.05μm. In case of HDD, the vibration criteria is dominantly restricted by the relative vibration between the media part and head part. Fig.5 shows the flowchart that the permissible vibration criteria is decided using FRF method.

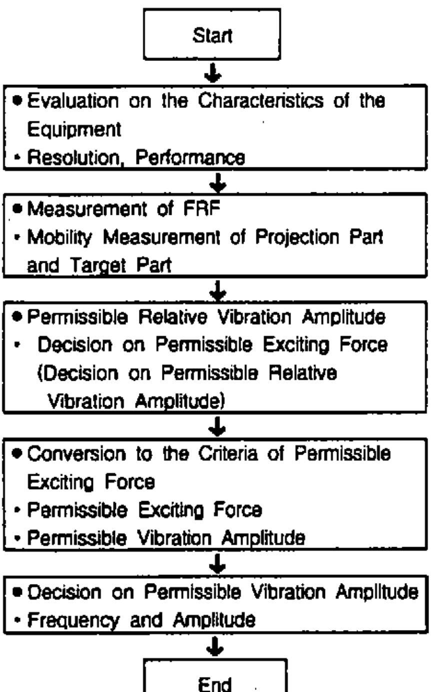


Fig.5 Flowchart of the permissible vibration criteria using FRF method.

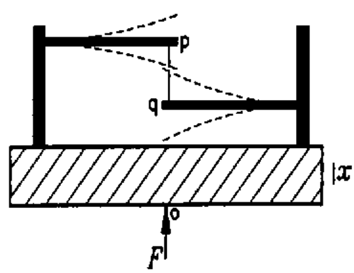


Fig. 6 Schematic diagram of relative vibration displacement

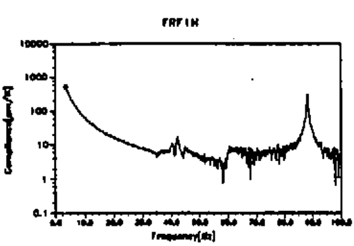
2.3 Application to HDD

The two methods of deciding the permissible vibration criteria by vibration performance test and FRF method are compared. The comparison and evaluation of the two different methods are focused. The data read-writing function is performed between the media and the head, spinning at high speed, floating approximately 0.3–0.5μm. To avoid the physical contact between the head and media, the value of the relative permissible vibration amplitude must be less than 0.3㎛. In this experiment, the electric setup was designed to check the physical contact between head and media and the gap between the head and media was set to 98㎛ for experimental convenience. Fig. 7 shows the comparison of the permissible vibration values of HDD that are obtained from vibration performance test and FRF method.

In performing the vibration environment test, the frequency bandwidth of the exciting force is the important factor. Narrow band exciting is time consuming requiring the repeated experiment, while 1/3 Octave band exciting lacks in reliability.

The permissible vibration by FRF method is decided by simply measuring each point mobility of the head and media part. The component of the rigid body mode must be subtracted because the relative vibration displacement is decided by the flexible modes of the head and media part in the exciting test. In case of the vibration which the head and the media part move to opposite direction, 180 degree phase difference ocurs and each FRFs are summed. FRF of the relative vibration displacement can be obtained by absolute value summing each FRFs.

In this study, the experimental result deals with the case of 180 degree phase difference, which is the most severe case. Fig.7~Fig.11 show the results of the test process.



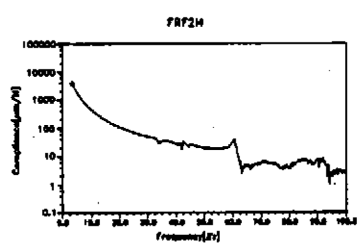


Fig. 7 Mobility Data of Head part Fig. 8 Mobility data of Media Part

Fig. 11 shows the response of HDD excited by the exciter and the response is decided by transfer function.

The following equation is needed to convert the permissible force criteria to the permissible vibration criteria. The equation is derived by using the model like Fig. 12.

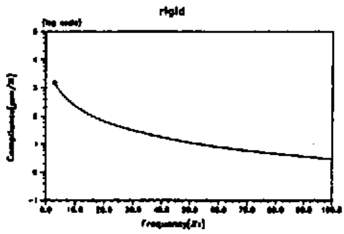


Fig. 9 Mobility data of Rigid Part

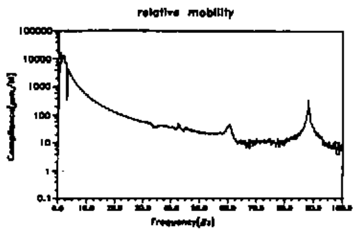


Fig. 10 Relative Mobility data of Head and Media part

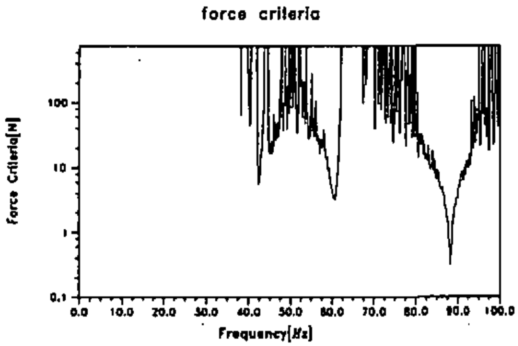


Fig. 11 Vibration Criteria Exciting Force Causing Relative Motion 580μm

$$T_r(\omega)=\sqrt{\frac{1+(2\zeta\frac{\omega_e}{\omega_n})^2}{(1-\frac{\omega_e^2}{\omega_n^2})^2+(2\zeta\frac{\omega_e}{\omega_n})^2}} \tag{1}$$

where,

T_r : transmissibility

ω_n : natural frequency of anti-vibration system

ω_e : exciting frequency

ζ : damping ratio

x is determined by eq.(2) when excited by sinusoidal vibration input.

$$x = T_r \cdot x_0$$

$$\dot{x} = \omega_e^{\,2} \cdot T_r \cdot x_0 \tag{2}$$

At this time, the inertia force(F_m) is applied to HDD.

$$F_m = m \cdot \dot{x} \tag{3}$$

Eq. (4) can be obtain by ordering eq.(2), (3).

$$T_r = \frac{F_m}{m\omega_e^{\,2} x_0} \tag{4}$$

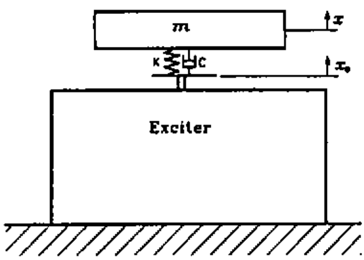


Fig. 12 Modeling for vibration performance test

The transmissibility is 1 when the stinger has enough rigidity and eq.(4) becomes like eq.(5).

$$F_m = m\omega_e^{\,2} x \tag{5}$$

The permissible vibration criteria can be determined like Fig. 12 by substituting Fm with the permissible vibration force criteria and the mass of HDD with m.

3. REVIEW AND RESULTS

The general procedure on the antilibration design of the high accurate equipments is suggested and its effectiveness is demonstrated by applying this procedure to HDD Cell. It is mostly required to obtaining the data about the vibration environment of the structure where the equipment will be installed. Though the vibration of the structure is measured by the user of the equipments, the permissible vibration criteria is normally suggested by the manufacturer. But it is not effective to perform the vibration exciting test on the whole system of the high accurate equipments in the aspects of time and cost. In this point of view, the new FRF method to determine the permissible vibration criteria is very helpful and advisable

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