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ACTIVE MICROTREMOR ISOLATION SYSTEM

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Abstract Recently promlems caused by microseisms are playing an increasing role in advanced science and high technology. Also the alignment of high precision equipment and its isolation from tremors are becoming important subjects in various industrial processes.
To meet these demands, the Research Division of the Takenaka Corporation has developed an isolation system called TACMI, which is different from conventional isolation systems.
TACMI permits isolation free from resonances by ACTIVELY controlling 6 degrees of freedom. It exerts control not only against disturbances from the floor but also against a disturbance internal to the object on the table itself.
TACMI can also reduce micromotions in a relatively calm environment (about 1 gal, 1 μm) by about one order of magnitude.

INTRODUCTION

Increasing sophistication in technologies and industries (e.g. semiconductor integrated circuits, etc.) has brought about highly sophisticated equipment and systems to research, development and production, which are easily damaged by even minute tremors. Securing a safe place to install sophisticated equipment, removing the influence of minute tremors and maintaining a calm state for a long period of time are becoming important.

On the other hand, natural phenomena and the increase of human activity are aggravating the problem by causing more vibrations around us; so that ground and buildings are constantly in motion due to external sources.

Research, development, and production activities require various equipment and systems which themselves cause vibrations, so that a calm environment is becoming more and more difficult to obtain. Even footsteps cause problem.

To respond to such difficult environment for advanced technologies and industries, and to minimize the influence of vibrations, it is necessary to fully investigate and analyze the environment and possibly eliminate the cause of vibrations. In most industrial settings this is not possible. Therefore, buildings should be planned and structured so as to reduce vibration amplifications first, and then vibration countermeasures may be taken.

It is the purpose of this paper to describe the properties of the ACTIVE vibration isolation system TACMI—the last defence against internal and externally generated disturbances.

PROBLEMS OF CONVENTIONAL VIBRATION ISOLATION SYSTEMS

The following is the limits and the basic characteristics of the conventional vibration isolation systems:

The conventional vibration isolation systems basically depend upon the transfer characteristics of masses supported by springs with damping mechanism. The transfer function is shown in Figure 1.

With conventional vibration isolation systems, one cannot expect the isolation to occur below the natural frequency.

To enlarge the vibration isolation range, it is necessary to lower the natural frequency. However, there is a limit to this because by lowering the natural frequency one may make the system unstable.

The conventional passive vibration isolation systems have a resonance area almost at the natural frequency. One cannot avoid the vibration amplification in this area.

Increasing of damping factor to decrease the amplification of resonance will lower the isolation effect in high frequency area.

The conventional passive vibration isolation systems are effective in eliminating disturbances from the floor, but when a force works on the table directly, this force will cause a large vibration.

TACMI SYSTEM

We at the Research Division of the Takenaka Corporation have developed a new system called TACMI (Takenaka Active Control Microtremor Isolation system) using "active" feedback.

This system has a vibration control ability of 6 degrees of freedom (*x*, *y*, *z* axes and their rotations), and can lower microtremors (about 1 gal, 1 μm) to lower than 1/10 in wide frequency range (from a few seconds to some tens of Hz).

Figure 2 shows the basic idea of the vibration isolation system by the active control showing sensors, controller, and drivers.

The active vibration isolation system has the advantage of enabling various response characteristics depending on how the sensed motion is used.

Basic Constitution of TACMI

The TACMI system consists of the following 4 parts (Figure 3):

1) A highly passive vibration isolation table
   The passive vibration isolation table of TACMI itself, which is supported by soft air-springs, can compete with the performance of conventional vibration isolation tables since its natural frequency is as low as 1-3 Hz.
2) Highly sensitive vibration sensors
   High sensitivity and wide dynamic range sensors detect micro-vibrations of the table on which precision equipment will be set.
3) Digital servo-module
   The digital servo-module computes optimal control force, which will cancel the motion of the table by operating the actuators with millisecond time constant.
4) Driving actuators
   The actuators effectively transmit the computed optimal control force to the table, and create a static state as if the table is floating.

We have developed two types of systems using different actuators in consideration of the environment where the system could be installed, and each has the following features:

1) TACMI-1 uses linear motors and is designed to control a high frequency area.
2) TACMI-2 uses air actuators which have high driving power and is designed to have a large loading capacity, i.e. large and heavy machinery or equipment.

Photo 1 and Photo 2 show the layout of the TACMI system.

Figures 4 and 5 depict the mechanical structures of the TACMI systems

Performance of the TACMI System

The active control vibration isolation system TACMI has high efficiency, no resonances and high vibration isolation in wide frequency band (from a few seconds to some tens of Hz).

A definition of TACMI's 6 degrees of freedom is shown in Figure 6.

Figures 7 & 8 are the examples of the measured wave forms and their spectra and demonstrate the systems' ability to isolate.

TACMI exerts control force against direct disturbances and makes the table return to a static state in a short period of time (within

0.1 second).

Compare the wave forms of free vibration and impulsive response when a shock is added to the table in Figure 9 .

The load capacity of TACMI-1 and TACMI-2 is 1 ton.

SUBJECTS FOR THE FUTURE

Because the two TACMI systems that have been described were developed for use in the semiconductor industry, applications to accelerator technology have just begun.

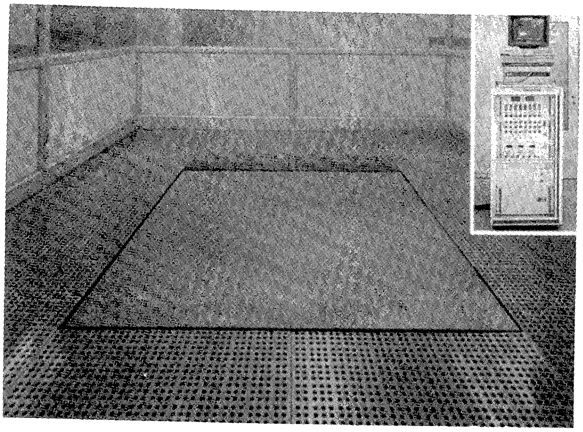

Photo 1 TACMI-1:Incorporating Linear Motor

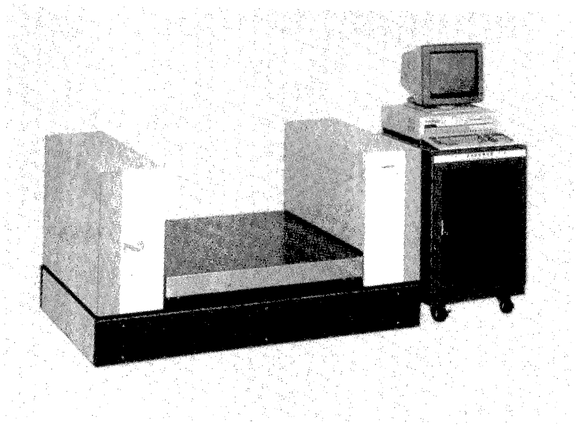

Photo 2 TACMI-2:Incorporating Air Actuator

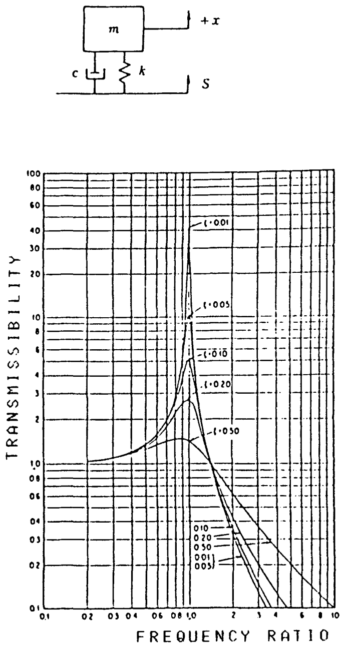

Figure 1:Transfer Function of Conventional Vibration Isolation System

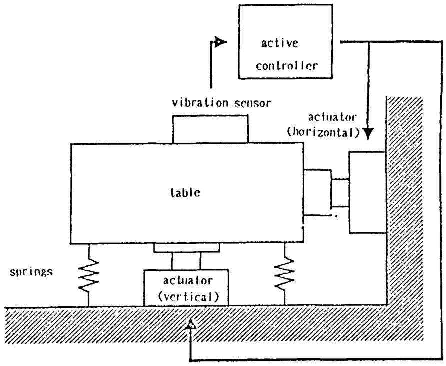

Figure 2:Basic Idea of the Active Control Vibration Isolation System

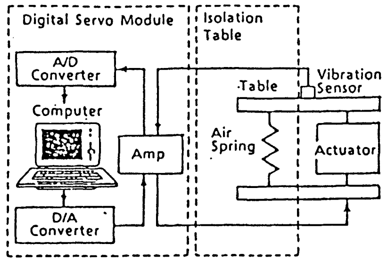

Figure 3:Block Diagram of TACMI System

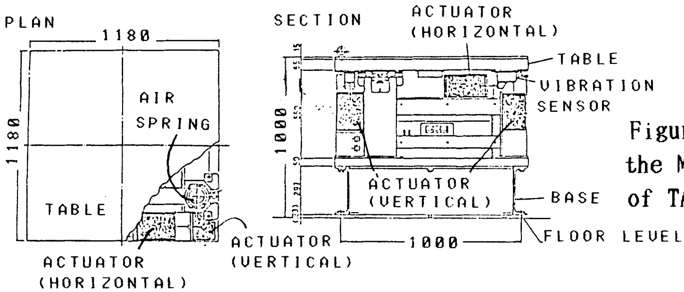

Figure 4:Depiction of the Mechanical Structure of TACMI-1

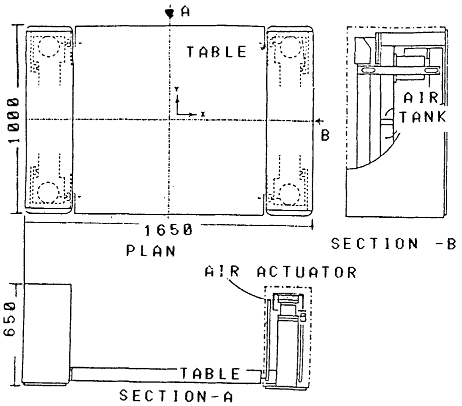

Figure 5:Depiction of the Mechanical Structure of TACMI-2

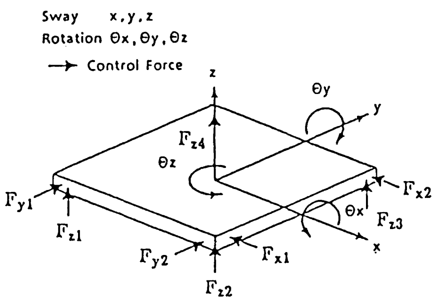

Figure 6:Definition of TACMI's 6 Degree of Freedom

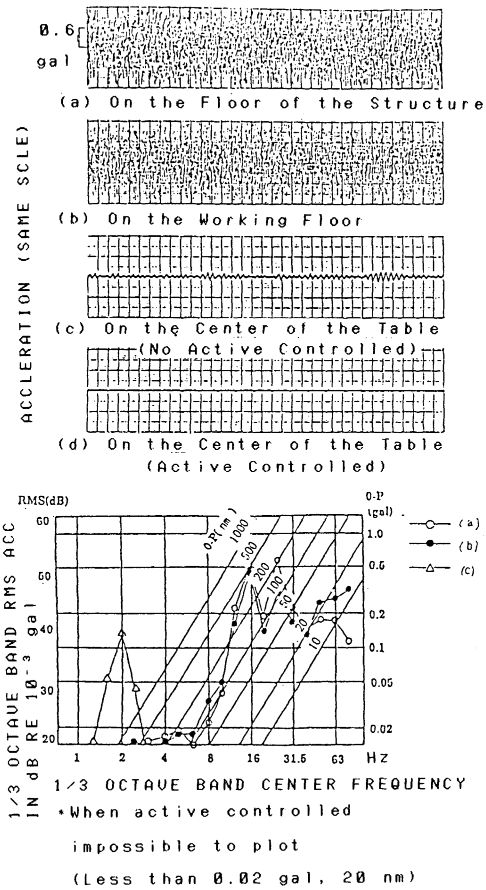

Figure 7
Example of the Measurement Result TACMI-1(Verticlal Motion) Wave Forms (Acceleration) & Their Spectra

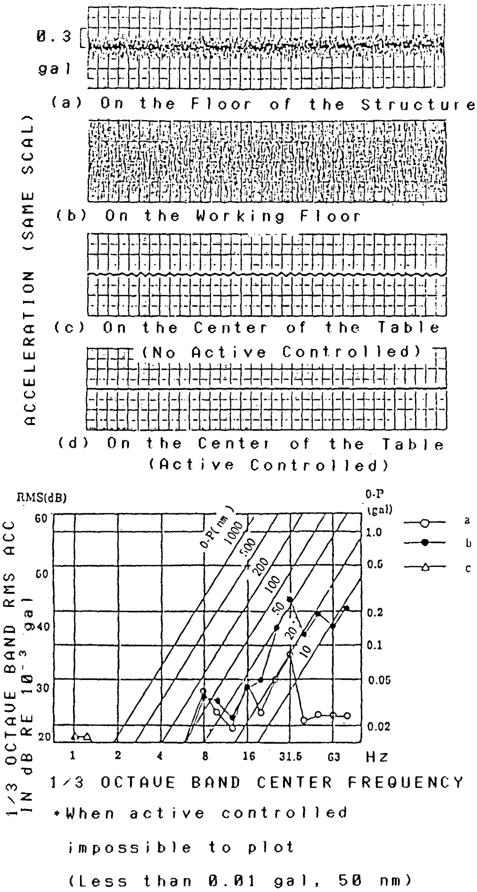

Figure 8
Example of the Measurement Result TACMI-1(Horizontal Motion) Wave Forms (Acceleration) & Their Spectra

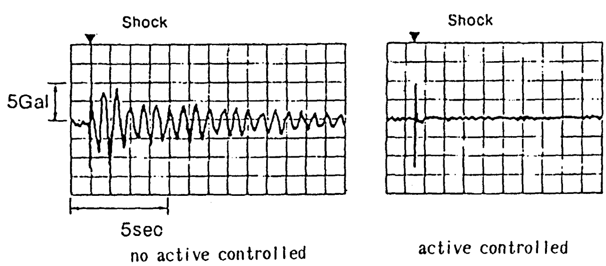

Figure 9:Wave forms of the table when shock was added