A TEST FACILITY FOR TIE POSITION CONTROL SYSTEM OF JLC

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ABSTRACT

In order to develop an alignment system for the Japan Linear Collider (JLC), we have constructed a test facility to study the position control system with multiple degrees of freedom for a massive body. The facility consists of solid actuators and capacitance microsensors. The results show that a damping of 18 dB or more was obtained up to 10 Hz at each axis in a three-degrees-of-freedom system, whose stage is directly supported by the actuators.

INTRODUCTION

It is commonly recognized that a submicron alignment system will be required for the final focusing magnets of the future e+e- collider. As found in a recent study, JLC beams at interaction point will have to be as small as 1.4 nm in vertical and 230 nm in horizontal size to have enough luminosity.[1)] On the other hand, ground motion on the order of 100 nm is expected even deep underground and the vibration due to the cooling water pulsation is also expected. Therefore they become serious problems especially in vertical direction. In the ground motion, high-frequency components are usually small in displacement amplitude and if they are detected effectively, they can be easily reduced by a conventional, or passive damping method. But lower-frequency components below 10 Hz should be reduced by an active method.

We have already proven by a single-axis-control system that active alignment is possible[2)], and so we have begun a fundamental study to develop a position control system with multiple degrees of freedom for a massive body using solid actuators like piezoelectric devices or giant magnetostrictive devices. In this report we will describe a test facility which we have constructed, its components, and the results of the test.

TEST FACILITY

The test facility is schematically illustrated in Fig.1, and Fig.2 shows its photograph. Since vertical specifications are quite strict, we constructed a controllable stage with three degrees of freedom: vertical direction y(y-axis translation), roll θ_z(z-axis rotation), and pitch θ_x(x-axis rotation). The upper stage weighs 10 kg and there is a GO kg load on the stage. The upper stage is directly supported by the three actuators on the lower stage which simulates ground motion by piezo transducers. For the position control actuator, we use stack-type piezo transducers, the driving voltage for which is 100 V for an expansion of 15 μm. As piezoelectric device has some drawbacks, for example being unsuitable for use in humid environments, we also consider a giant magnetostrictive device for the actuators to eliminate the above disadvantages. If loads are too heavy to be directly supported by the actuators, those weights must be supported by air springs or other elastic components. Therefore we also consider an air spring supporting structure.

The upper stage position is measured by three capacitance microsensors(ADE Corporation's MicroSense) with an accuracy of 2 nm for a 1 μm displacement. Each microsensor is located near each of the actuators in order to reduce the interference with other actuators.

For the controller, we use a 32-bit microcomputer and the sampling time is 1 msec.

TEST

The vibration-proof table supports all the components, and the surface of the table is to be the reference surface. The lower stage gives disturbing motion to the upper stage with an arbitrary waveform. The capacitance microsensor measures the distance from the under surface of the upper stage to the vibration-proof table surface. The CPU of the controller performs coordinate transformation from the position of the measured three points to the vertical displacement, rolling, and pitching of the load center. As control starts, the CPU also calculates the reaction force required to keep the upper stage stable and then drives the piezo transducers of the control actuators.

Table 1 shows the results of the test with disturbances of sine wave vibrations in each axis individually. The amplitude of disturbance of the y-axis is 1 μm, and those of 8, and 8, are 5 μrad.

A damping of 18 dB or more was obtained in each axis up to 10 Hz. However, over 50 Hz, there existed cases of amplified disturbances. It was because of the natural frequencies of the stage. Fig.3 shows typical damping characteristics observed on the oscilloscope, when a 10 Hz sine wave of 1 μm amplitude was added as vertical disturbance, and Fig.4 shows the damping when a 10 Hz sine wave of 5 μrad was added as roll disturbance.

To investigate the response to random-frequency vibrations, a white noise with a cutoff frequency of 10 Hz was added as disturbance. Fig.5 shows the response in the time domain, and Fig.6 and 7 show typical FFT results of uncontrolled and controlled responses on the y-axis, respectively. Similar damping characteristics against sine wave disturbance were obtained. Fig.8 shows the response to a white noise with a 5 Hz cutoff when the upper stage was supported by some air springs. Since the air spring supporting structure was rather complicated, the natural frequency of the stages became lower. As a result, the damping characteristics deteriorated.

SUMMARY

A test of an active position control system with three-degrees-of-freedom for heavy weight was performed with a combination of solid actuators and capacitance microsensors. Against a sine wave vibration of 1 μm amplitude in vertical direction and 5 μrad amplitude in roll or pitch, a damping of 18 dB up to 10 Hz was obtained by a direct actuator supporting system. Now we are preparing for a test of heavier loads and every six-axis control system. At the same time, we are studying a multi-axis laser measurement system, which can achieve a long distance measurement and take the place of capacitance microsensors,

REFERENCE

1) K.Yokoya, Proceedings of the First Workshop on Japan Linear Collider, KEK, October 24-25, 1989, p 26

2) N.Ishihara et al., Particle Accelerators, vol.31. 1990, pp57-62

Table 1. Damping after position control against disturbance of 1μ m amplitude in vertical direction, 5μ rad amplitude in roll, pitch.

Frequency(Hz)	y (dB)	θ_z(dB)	θ_x(dB)
0.1	-27	-27	-27
0.3	-27	-27	-27
0.5	-27	-27	-27
1	-27	-27	-27
3	-25	-25	-25
5	-24	-24	-24
10	-18	-18	-19
30	-8.9	-10	-12
50	-4.1	-0.56	2.4
100	6.6	1.7	4.4

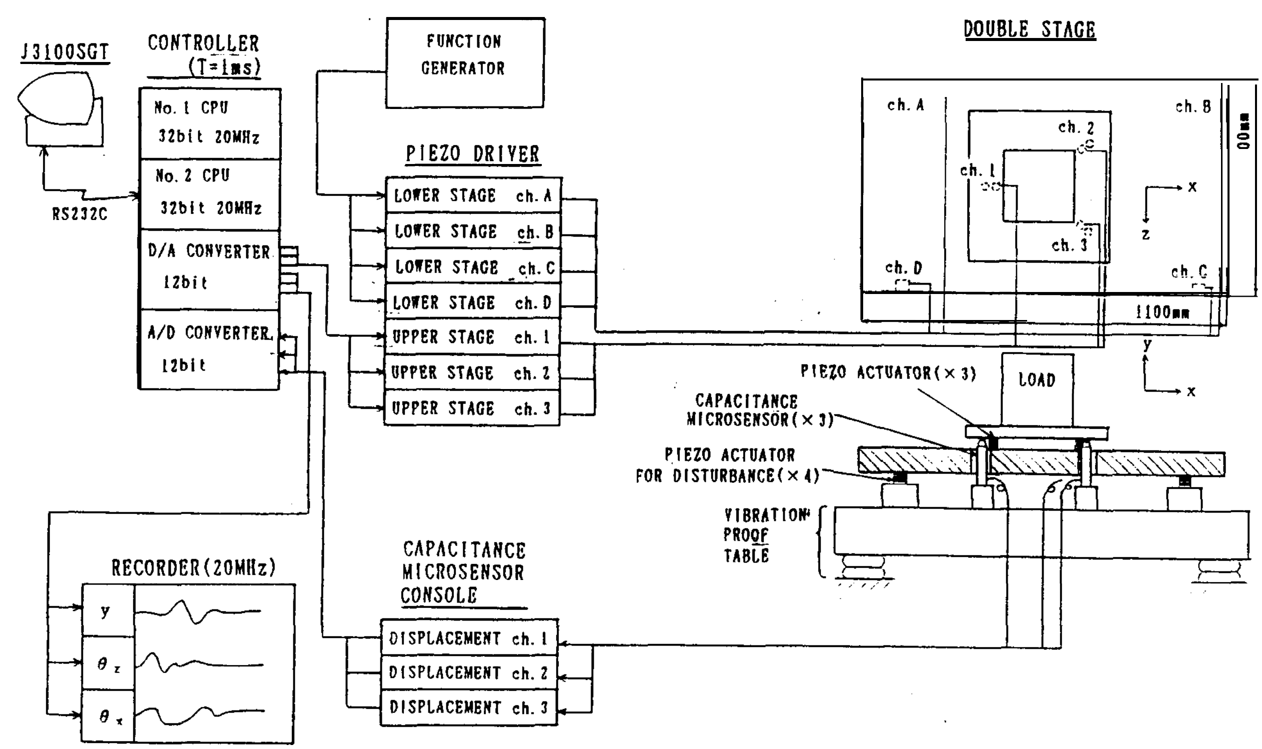

Fig. 1 Schematic illustration of test facility

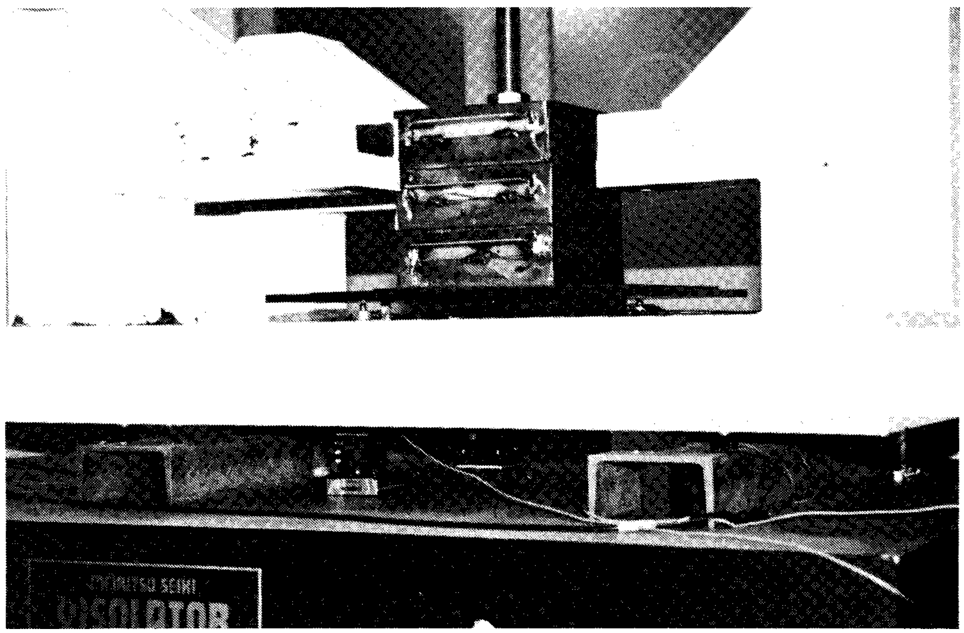

Fig. 2 Photograph of test facility .

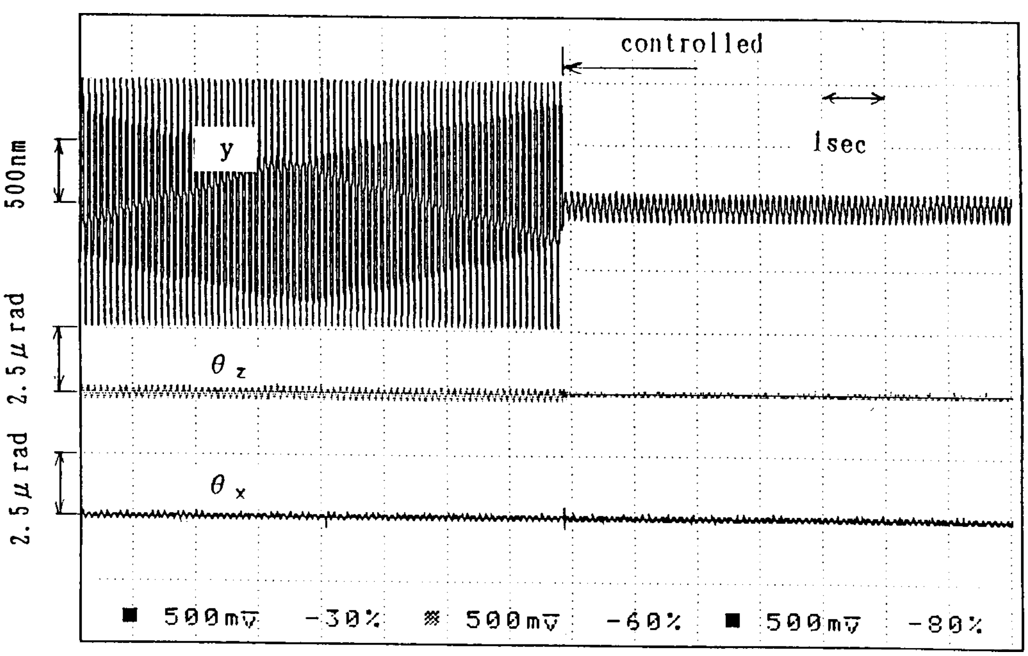

Fig. 3 Typical damping characteristics on the oscilloscope. Sine wave disturbance with $1\,\mu$ m amplitude were added in vertical direction at 10 Hz.

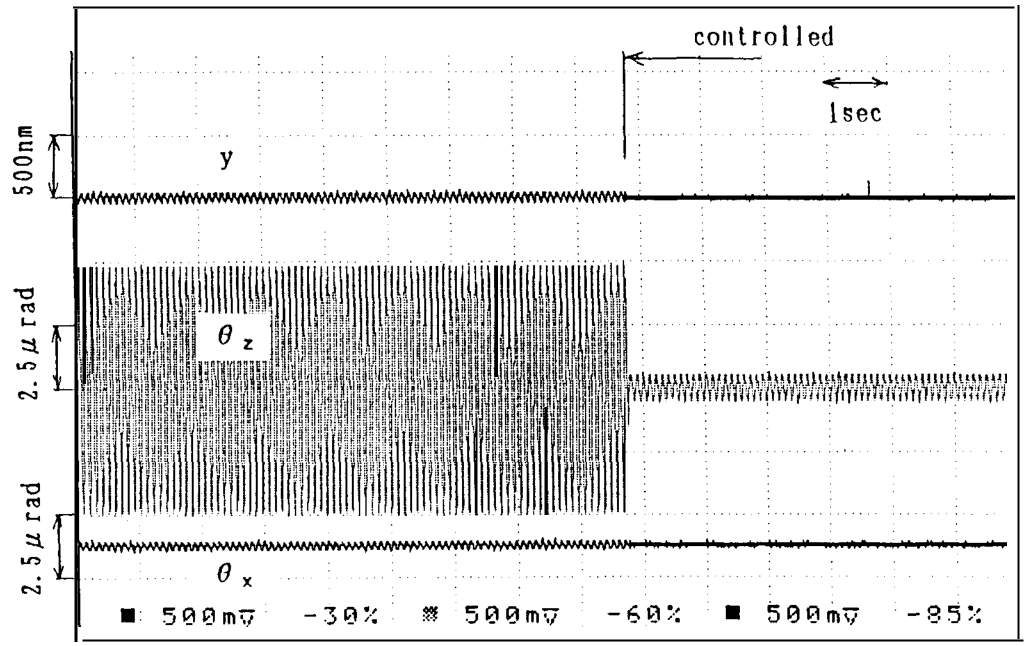

Fig.4 Typical damping characteristics on the oscilloscope.
Sine wave disturbance with 5μ rad amplitude were added in roll direction at 10 Hz.

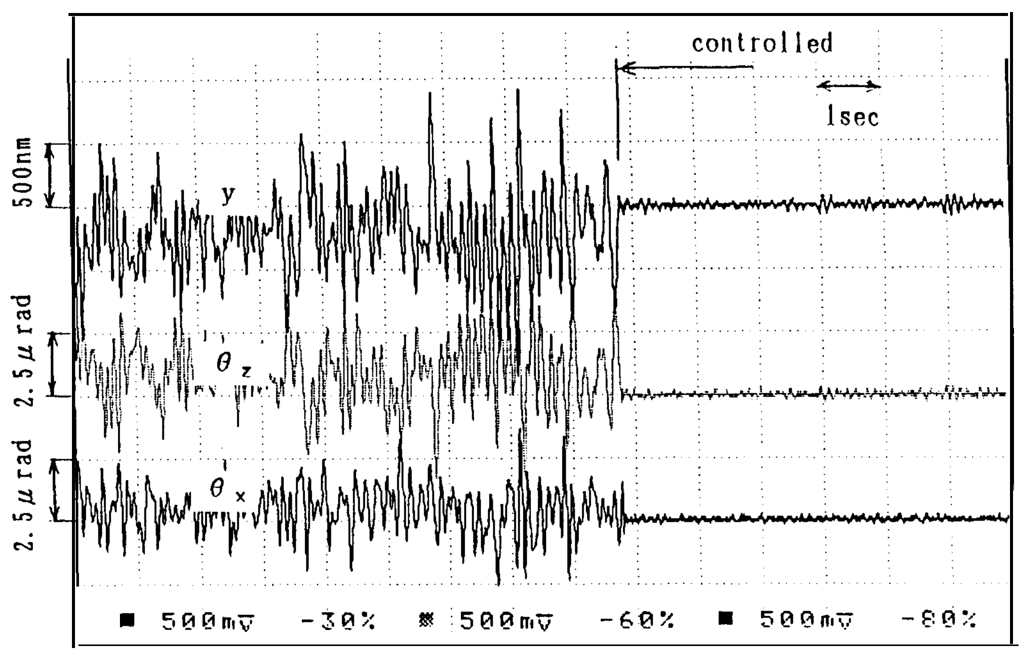

Fig.5 Damping response against white noise with 10 Hz cutoff frequency.
Random disturbances were independently applied to the points of the ch. C and ch. D in Fig. 1

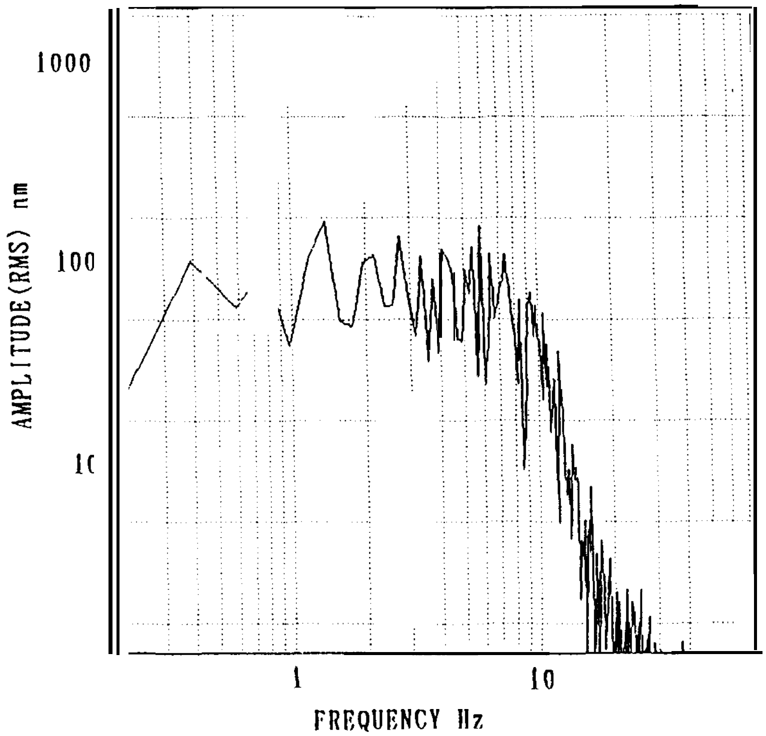

Fig.6 Typical uncontrolled FFT result. White noise disturbance with 10 Hz cutoff were added.

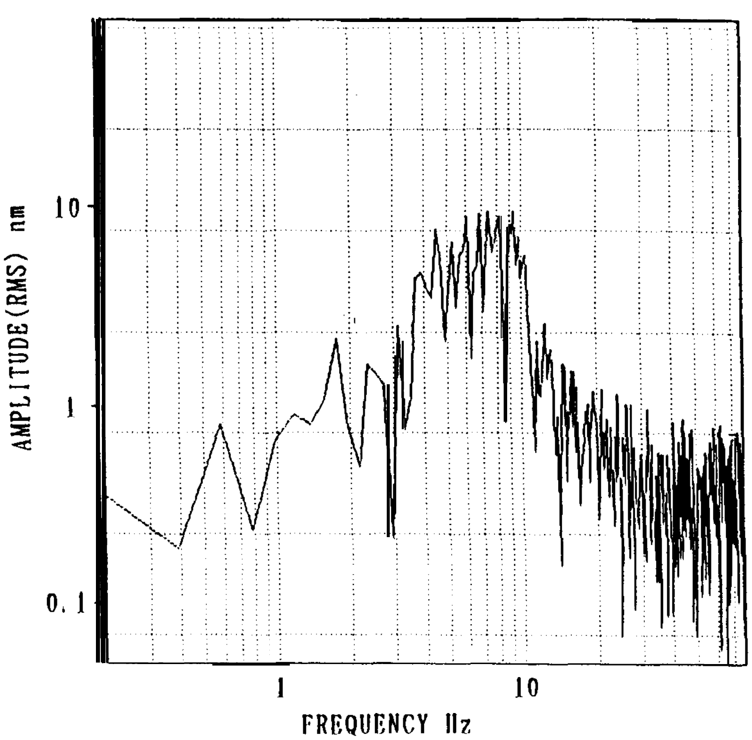

Fig.7 Typical control led FFT result. White noise disturbance with 10 Hz cutoff were added.

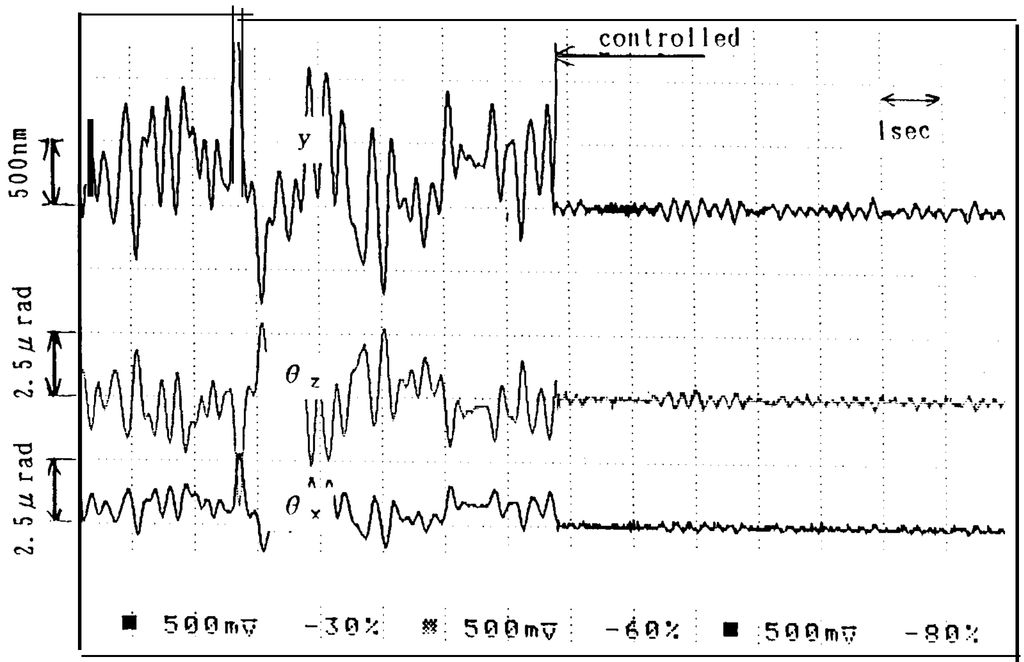

Fig. 8 Damping response against white noise with 5 Hz cutoff frequency. The upper stage is supported by airsprings