

DYNAMIC CHARACTERISTICS OF PARALLEL LINK MECHANISM WITH SIX DEGREES OF FREEDOM USING ELECTRO-HYDRAULIC SERVO CYLINDERS

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ABSTRACT

The Stewart platform type parallel link mechanism with 6 degrees of freedom is a structure which has arranged six single rod hydraulic cylinders parallel between the base platform and the end effector of the controlled object. The both ends of each link are connected with the base platform and the end effector using free joints, respectively. The terminal can rotate freely. By controlling the length of each link by the hydraulic cylinder, the position and posture of the end effector is controlled with 6 degrees of freedom in three-dimensional space.

In this report, the dynamic characteristics between the input and output of one link that comprises the parallel link mechanism is measured. The frequency response is measured for the various center position or attitude of the end effector. The load mass and the amplitude are also changed.

The interference that each link receives from one link is examined by experiment. The frequency response of the interference that each link received is presented.

KEY WORDS

Parallel Link, Six Degrees of Freedom, Electro-Hydraulic Servo Cylinder

NOMENCLATURE

A: amplitude
C: end effector center of gravity
L_m: length of link _m
M: load mass of end effector
P_{s1}: supply pressure to cylinder in push side
P_{s2}: supply pressure to servo valve
x, y, z: coordinate of *C*
^: deviation of variable

INTRODUCTION

The Stewart platform type parallel link mechanism with 6 degrees of freedom is a structure which has arranged six single rod hydraulic cylinders parallel between the base platform and the end effector of the controlled object as shown by Figure 1 and Photo 1 [1],[2],[3]. The both ends of each link are connected with the base platform and the end effector using free joints, respectively. The terminal can rotate freely. By controlling the length of each link by the hydraulic cylinder, the position and posture of the end effector is

controlled with 6 degrees of freedom in three-dimensional space. The parallel link mechanism has high rigidity and high output compared with a serial link mechanism. Since the error is not accumulated, highly precise positioning can be performed. It is widely used for a vibration test machine of many degrees of freedom, a driving simulator for a car, and a flight simulator for an airplane, etc.

In this report, the dynamic characteristics between the input and output of one link that comprises a parallel link mechanism are measured. The frequency

response is measured for the various center position or attitude of the end effector. The load mass and the amplitude are also changed.

The parallel link mechanism comprises so-called interaction system, where the movement of one link influences those of other links through the end effector. The interference that each link received from one link is examined by experiment. The frequency response of the interference that each link receives is presented.

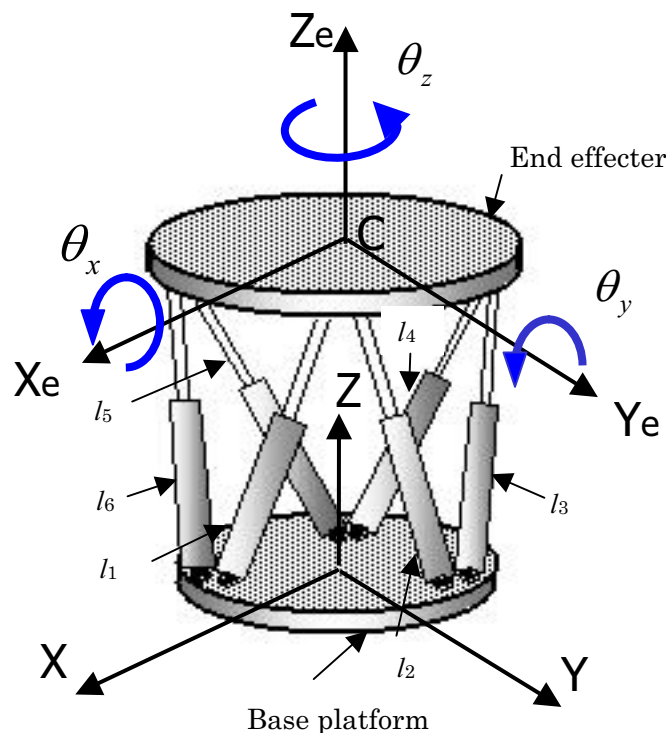


Figure 1 Parallel link mechanism with six degrees of freedom and coordinate system

EXPERIMENTAL DEVICE

A structure of the experimental device is shown by Figure 2.

The desired position and posture of the point C on the end effector are inputted into PC. The desired length of each cylinder is computed from them with inverse kinematics calculation. The center position of operation is made $(x, y, z) = (0, 0, 0)$. Each link length at this time is all $l_i = 327$ mm equally. The desired signal is outputted to the servo amplifier from PC. The cylinder pressure of the push side, P_{s1} is constant. The cylinder expands and contracts with adjusting the pull side pressure by the servo valve. The cylinder (link) length

is measured by a potentiometer and sent to the servo valve as a feedback signal. The signal is also sent to PC and recorded. The control method is P control.

The gain margin is 10 dB. The supply pressure to the servo valve, P_{s2} is 7.3MPa. The supply pressure to the push side cylinder, P_{s1} is 2.1MPa. The sampling time is 10 ms.

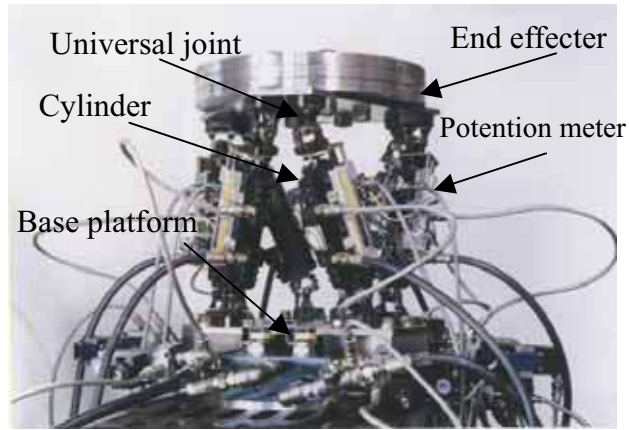


Photo1 Experimental device

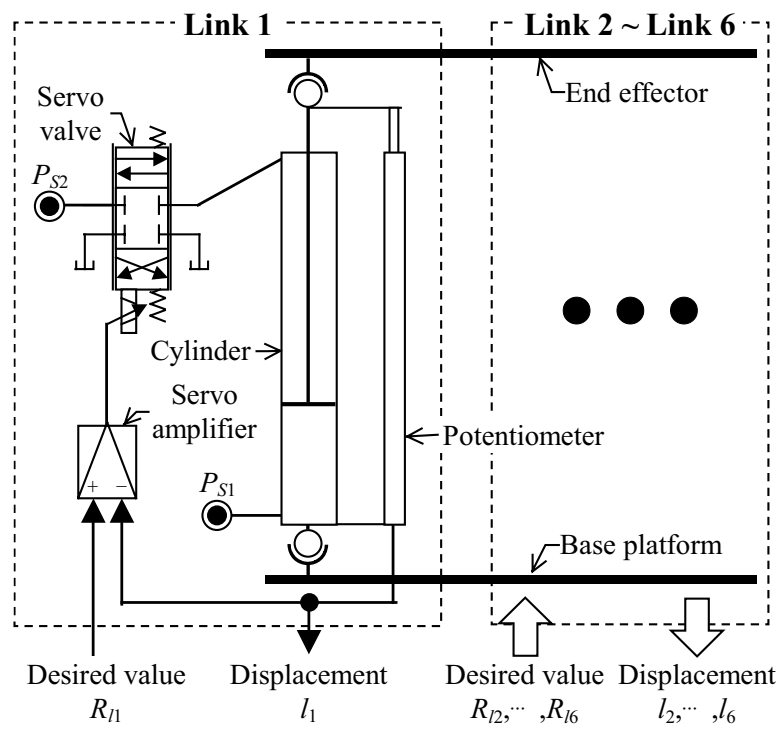


Figure 2 Structure of experimental device

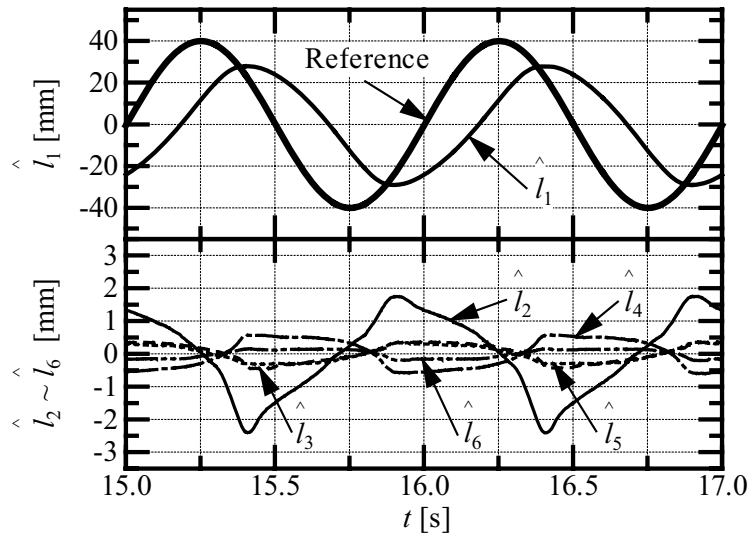


Figure 3 Time response of each link when sinusoidal wave signal is inputted to link1

Table 1 Parameter values

Cross-sectional area of cylinder in push side	$A_1=3.14 \times 10^{-4} \text{m}^2$
Cross-sectional area of cylinder in pull side	$A_2=1.37 \times 10^{-4} \text{m}^2$
Minimum link length	$L_{min} = 0.282 \text{ m}$
Maximum link length	$L_{max} = 0.377 \text{ m}$
Load mass	$M = 0, 20, 40, 60 \text{ kg}$
Supply pressure to cylinder in push side	$P_{s1} = 2.1 \text{ MPa}$
Supply pressure to servo valve	$P_{s2} = 7.3 \text{ MPa}$

Experimental Result

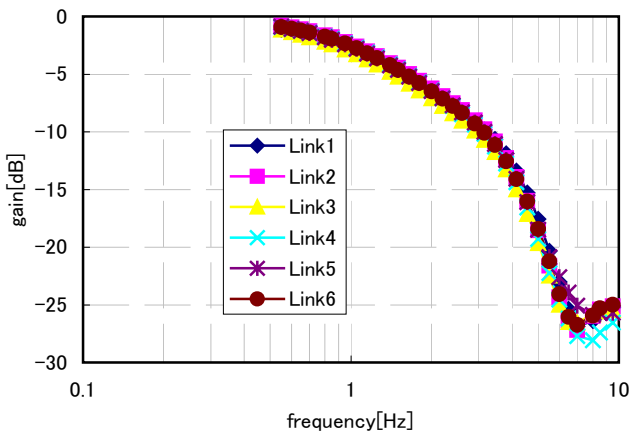


Figure 4 Differences among frequency responses of each link

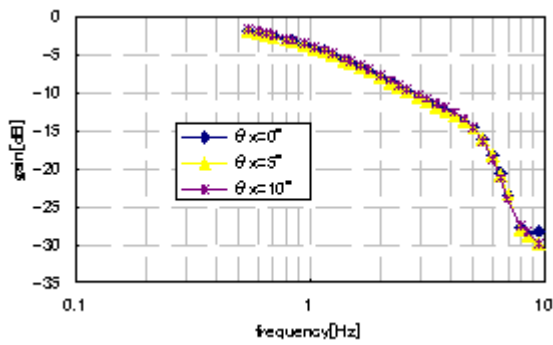


Figure 5 Effect of inclination

Figure 3 shows wave form when the desired value of 1Hz sine wave is inputted into link 1, and the movement of each link is shown. The desired values of the other links are constant (stop signal).

Difference among frequency response of each link

The difference among the characteristics in the drive system of each link was tested. Inputting the desired value of sine wave into one link, and constant value (stop signal) into other links, the frequency response of each link was measured. It turns out that each link has the almost same frequency response characteristics.

Effect of inclination

Inclination was given to the end effector and the frequency response of link 1 was measured. It turns out that there is almost no difference in frequency responses between $\theta_x = 0$ and 10 degrees.

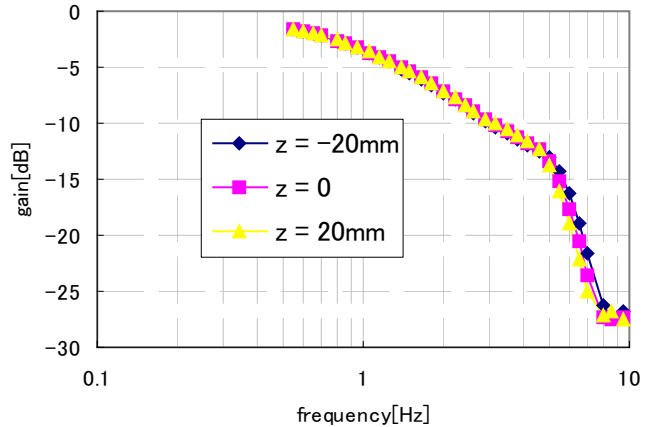


Figure 6 Effect of level z

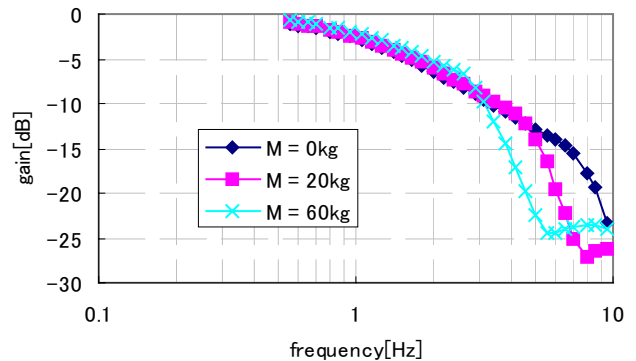


Figure 7 Effect of load mass M

Effect of level

The center position of the end effector oscillation was moved in vertical direction, and the frequency response of link1 was measured. Some difference appeared with the position.

Effect of load mass

The frequency responses were measured for various load mass. When mass is large, the gain fall is large at the frequency more than 3 Hz.

Effect of amplitude

The influence of the amplitude of reference signal was examined. The gain fall is remarkable on the frequency more than 3 Hz, when the amplitude is large.

Interference to each link from link 1

When the desired value is inputted into one link, the other links are moved by interference as shown in Figure 3.

When the desired value of the sine wave was inputted into link 1, and constant values (stop signal) were inputted into the other links, the vibration of each link was measured.

The Bode diagram is shown in Figure 9 by calculating the ratio of the amplitude of each link to the amplitude of link 1. On low frequency, there is little interference. When frequency becomes high, interference becomes large. Especially the interference to link 2 is large.

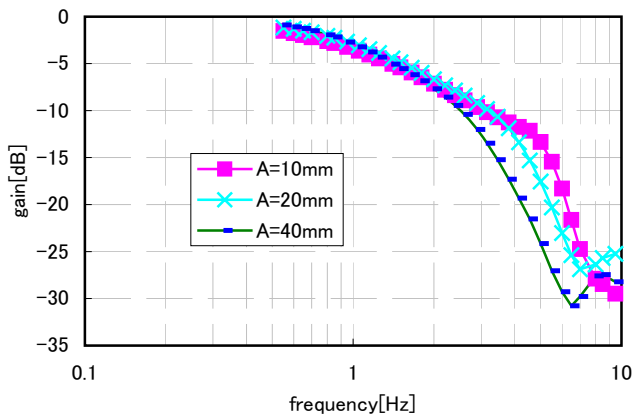


Figure 8 Effect of amplitude A

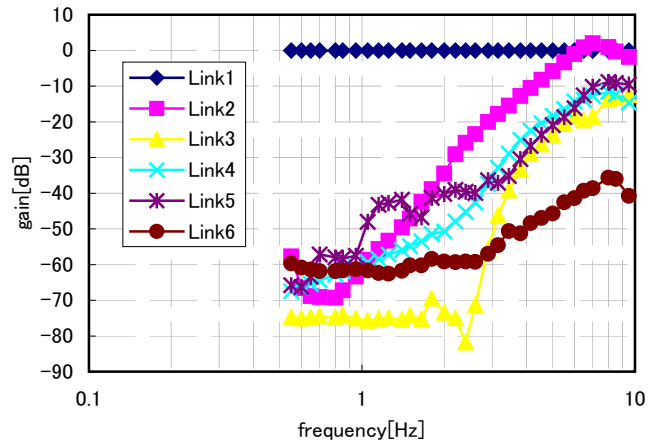


Figure 9 Interference to each link from link 1

Conclusion

The frequency response of each link of parallel link mechanism with 6 degrees-of-freedom using electro-hydraulic servo cylinders was investigated in detail.

The influences of the center position, posture of the end effector, load mass, and the amplitude on the frequency responses were investigated experimentally.

The frequency response hardly changes depending on the center position or the posture of the end effector.

When load mass or the amplitude is enlarged, the fall of the gain is remarkable on high frequency.

The interference between links was measured. The interference also becomes remarkable with the increase in frequency.

REFERENCE

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