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DEVELOPMENT OF TESTING MACHINE USING PARALLEL MECHANISM

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ABSTRACT

The bench test machine of single shaft is used to develop the motorcycle frame now. It is not expressible for the simple apparatus though combined load is added to the frame while the motorcycle is actually running. Parts of the motorcycle might break down some time. This is very dangerous and efficient test method is desired. But application of conventional test method of single or multiple actuators is difficult, because test object is relatively small and fragile. In this situation, we developed new method of load test using parallel mechanism. Advantage of this method is possibility to generate any assigned force or moment vector at desired small point. That is, combined skew force or three-axis moment test becomes possible by only software change. We actually designed practical parallel mechanism actuating system for motorcycle. End-effector force and moment vector are converted to cylinder pressure command by Jacobian matrix method.

KEY WORDS

PARALLEL MECHANISM, POSITION CONTROL, LOAD CONTROL, HYBRD CONTROL, JACOBIAN MATRIX, FRAME OF MOTORCYCLE

NOMENCLATURE

i : 1~6
Fi: Position of joint installation on the platform
Gi: Position of joint installation on the base
E: Offset of rotation center
H: Height of neutral point
ti: Thrust of the actuator
fi: Power and moment of platform
J: Jacobian
f: End effector's power and moment
t: Thrust of actuator

INTRODUCTION

The bench evaluation examination of the single shaft testing machine is used for the development of the motorcycle frame now. However, present evaluation method is too simple to simulate actual complicated phenomena of motorcycle running condition. So the result of damage and the test that occurred because of the actual operation examination was not completely corresponding. Therefore, in actual running test, unpredictable failure and rupture of welded parts are frequently observed. Main reason of this kind of problem is the adoption of aluminum to motorcycle. From the need of lightening, aluminum is widely applied, and this tendency is assumed to continue in a future, too. Therefore, the body becomes the low limit design of the safety factor. Consequently,

evaluation test by present single axis machine could not satisfy required performance. Possible testing machine to evaluate complex load near actual running will improve the simulation function. So reduction in cost by improvement of development speed will be anticipated by this method. Purpose of our study is to develop new parallel mechanism machine possible to make actual load by complex actuating.
In the following, design and control method of this machine will be described.

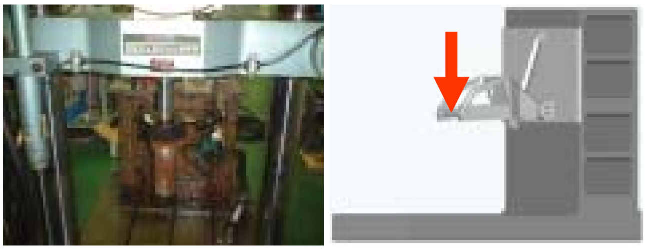

Fig.1Existing bench test machine

PARALLEL MECHANISM

Definition of Parallel Mechanism

Parallel mechanism is defined as mechanism having plural of power transmission paths between base and mechanical interface. This mechanism is divided in four types, namely, stretch, direct, rotational and wire type. In this study, Stewart platform parallel mechanism of stretch type is selected.

A system that has 12 universal joints and 6 cylinders to hold upper plate (platform) and lower plate (fix base), and generates six phases of free movement by changing the length of cylinders. Refer to Fig.2.

Inverse Kinematics of Parallel Mechanism

In parallel mechanism, command signal of each actuator is easily obtained by inverse kinematics. Inverse kinematics is determination of each on link length from the position of end-effector, and the position of each actuator is defined as the Fig, 2. That amount of displacement becomes command signal.

Linearized Small Scale Motion Dynamics of Parallel Mechanism and Statics

Relationship between platform and actuator displacement under Linearized small scale condition, is solved. But, Jacobian matrix thus found, is a inverse Jacobian matrix, because this is inverse kinematics case. From the principle of virtual work, considering actuator and platform dong small scale motion at their equilibrium state;

$$\boldsymbol{J}^{\mathrm{T}}\boldsymbol{f} = \boldsymbol{t}$$

is obtained. From this equation, each actuator's output is shown clearly by the force, moment applied by platform.

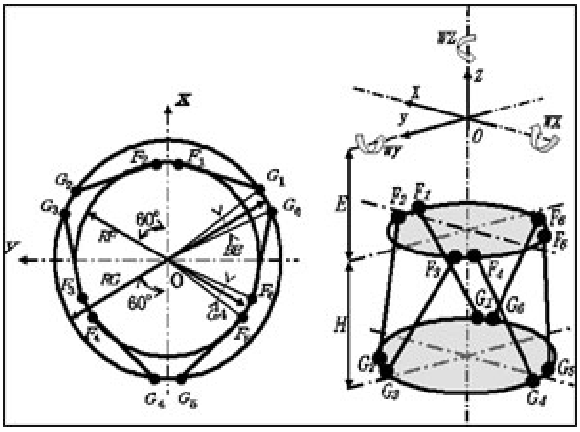

Fig.2 Coordinate definition of parallel mechanism

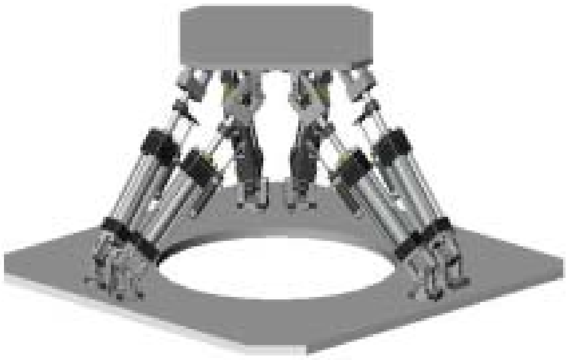

Fig. 3 Parallel mechanism

THE FLOW OF SYSTEM AND MACHINE SPECIFICATION

Specification of Parallel Mechanism

Parallel mechanism was newly designed for this study. Design conditions are as follows;

- Each output force X, Y, Z direction is 10kN, respectively.
- Wide workspace is not necessary.
- Size of this equipment should be same as present machine.
- From the above condition, new parallel mechanism was designed. The main specifications are shown in Table 1 and 2.

Table.1 Size of Parallel Mechanism

DIAMETER OF PLATFORM	φ350mm
DIAMETER OF BASE	φ880mm
JOINT INSTALLATION ANGLE OF PLATFORM	37deg
JOINT INSTALLATION ANGLE OF BASE	14deg
CYLINDER STROKE	100mm
HEIGHT OF NEUTRAL POSITION	452mm
SETTING ANGLE OF CYLINDER	49deg
TOTAL LENGTH OF CYLINDER	466mm

Table.2 Work Space and Output Power

	Work Space	Output Power
SURGE	+73mm -84mm	10kN above
SWAY	+75mm -75mm	10kN above
HEAVE	+65mm -70mm	10kN above
ROLL	+24deg -24deg	
PITCH	+30deg -22deg	
YAW	+25deg -25deg	

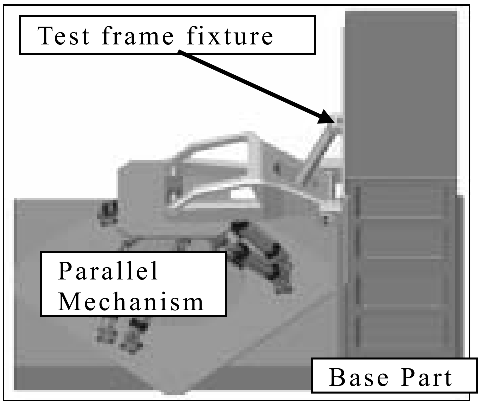

Fig.4 Image Figure of the test system

The testing machine consists of base part, parallel mechanism, and the test frame fixture. Image figure of the test system is shown in Fig.4.

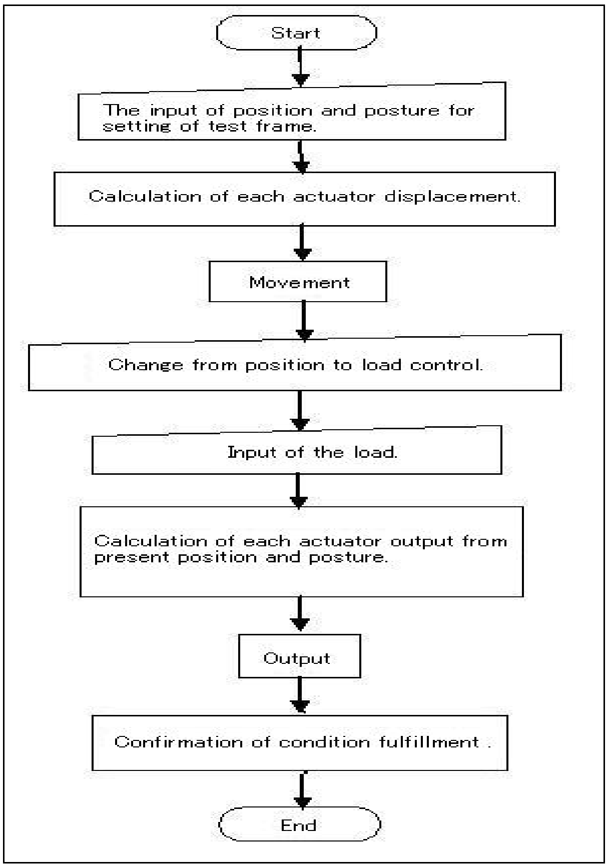

Fig.5 The flow of the system

Flow of the System

The flow of the system consists of two parts. The first is the work to connect test frame and the best machine by using position control of the parallel mechanism. The second is the work to generate force to each actuator by using load control algorithm. System flow is shown in Fig.5.

POSITION CONTROL AND LOAD CONTROL

Position Control

Position and posture of the platform are input to fix the test frame, and stroke of each actuator is calculated by using inverse kinematics. Command signal corresponding to this value is transmitted from personal computer to servo valve. Thus cylinder stroke is controlled. Actuator is detected by potentiometer. Position control loop is shown in Fig.6. Band with of this system is designed about 10Hz At present, software servo loop is constructed, which has 10ms sampling time.

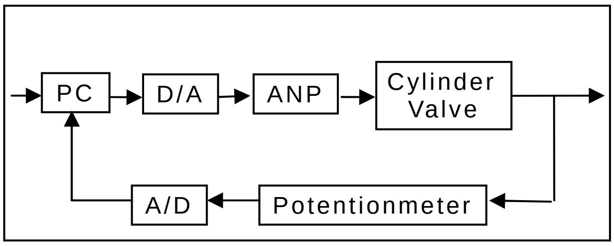

Fig.6 Position Control of Parallel Mechanism (1 axis)

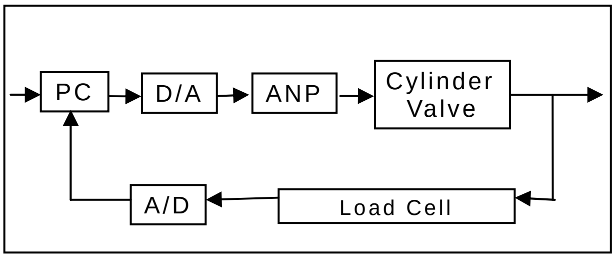

Fig.7 Load Control of Parallel Mechanism (1 axis)

Load Control

Load is inputted to the test sample from platform tip. Necessary force for each actuator is calculated from the position and posture of the test sample. Command signal is then given to servo system and thrust force is controlled. Thrust force is detected by the actuator in and out ports. Load control loop is shown is Fig.7. Band with of this system is assumed about 2Hz.

SIMULATION OF LOAD CONTROL

Resolved necessary thrust force for each actuator was calculated from command force to the test sample through parallel mechanism, this time. And, the arrangement of the actuator is shown in the Fig.8. It is possible to calculate for combined load as shown in Table.5. This value is outputted for each actuator.

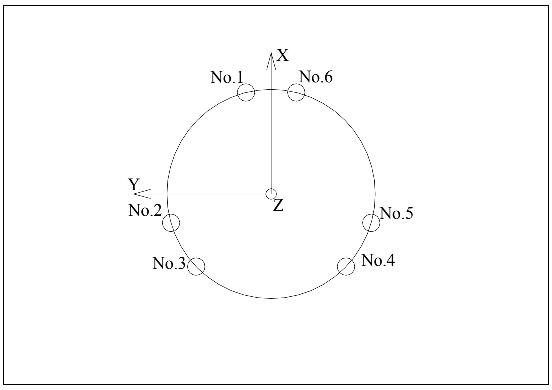

Fig.8 Arrangement chart of actuator

Table.3 In the Z direction, 10kN

No,1 Actuator	2.17kN
No,2 Actuator	2.17kN
No,3 Actuator	2.17kN
No,4 Actuator	2.17kN
No,5 Actuator	2.17kN
No,6 Actuator	2.17kN

Table.4 In the Y direction, 10kN

No,1 Actuator	－4.63kN
No,2 Actuator	－3.6kN
No,3 Actuator	1.03kN
No,4 Actuator	－1.03kN
No,5 Actuator	3.6kN
No,6 Actuator	4.63kN

Table.5 In the Y and Z direction, 5kN

No,1 Actuator	－1.24kN
No,2 Actuator	－0.72kN
No,3 Actuator	1.6kN
No,4 Actuator	0.56kN
No,5 Actuator	2.88kN
No,6 Actuator	3.39kN

Fig.9 Overall view of the testing machine

COMPLIANCE CONTROL

In this research, the compliance control was used for the load control method.
The compliance control decides the direction where it wants to control the position or power, and the position and power in those directions are matched to the value of the target. First of all, the position and the power that should be controlled are measured. They are fed back, and the control technique that provides with the position control loop and the force control loop to match it to the set point is used. Therefore, the force control loop consists of taking

measurements of power and deflection with the target load in high rank of position control loops, and sending as the instruction to the position control. The installation part of the load cell is shown in Fig.10.

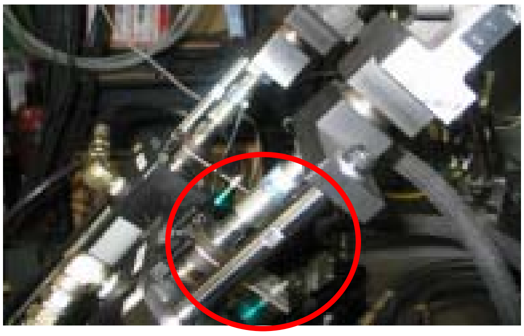

Fig.10 The installation part of the load cell

LOAD TEST IN DIRECTION OF HEAVE

The load only in the direction of heave is added to the motorcycle frame. The load is added from 0kN to 5kN in each 0.5kN.And the stability when 5kN is added is verified from 0kN.

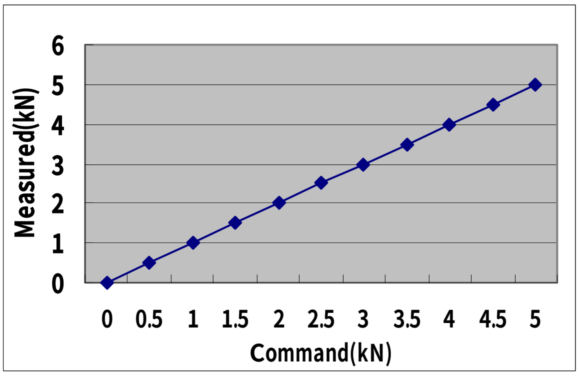

Fig.11 Comparison between measured data and command data

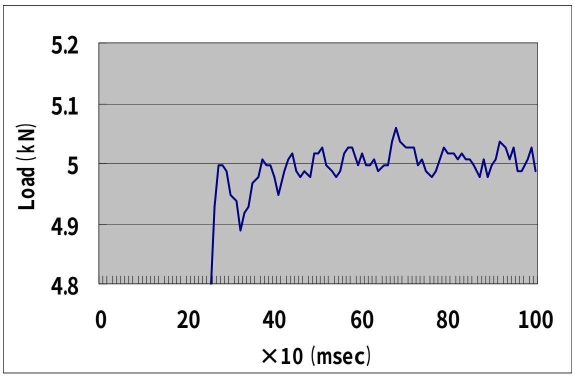

Fig.12 Stability of data

Experiment result

As for the comparison by the measurement and the command data, excellent data was obtained. The error margin was the maximum was 1%. The load was 5kN from 0kN and time when it reached was 250 milliseconds. And Stability was ±0.075kN.

CONCLUSION

In this thesis, the effectiveness of the use of the load control with the bench test machine that used the parallel mechanism was verified. It will examine it in all directions of six axis in the future. The actual running test by the bench test is scheduled to be simulated by using the data of actual running test in the future.

REFERENCE

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