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Study of Robot with the Ability to Detect Land Mines Using Pneumatic Bilateral Servo System

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ABSTRACT

In this research, we selected Pneumatic Bilateral Servo System (PBSS) consisting of master and slave cylinders as an actuator system for the land mine apparatus. Usually the master side operates the slave side in PBSS. But we realized in our system that position and power controls are made by comparing and feeding back physical information between the master and the slave. It also makes possible that the slave operates the master on the basis of this information. For the above reasons, PBSS is suited to be the actuator for the land mines apparatus. In this research, we work on the following tasks based on PBSS as the basic system.(1) Construction of pneumatically-controlled bilateral servo system(2) This system becomes harmless on the environment and human. (3) Making this system can sense and be controlled by minute pressure change by the 100-gram weight.

Keywords

bilateral servo system, land mine, demining, direct probe measuring

NOMENCLATURE

Fin : Total load force on slave cylinder
f : Total viscosity conficient
M_{sp} : Total mass of rod and piston
L : Load force
x : Displacement of piston
ASr : Sectional area of slave cylinder in rod side
AS_b : Sectional area of slave cylinder in bottom side
P_r : Pressure of rod side
P_b : Pressure of bottom side
Fr : Force of pressured Pr slave piston
Fb : Force of pressured Pb slave piston
p : Initial pressure in a cylinder
n : Ratio of specific heat

INTRODUCTION

Background

Now, land mines, 70 million from 60 million, are laid underground in 88 countries. Those were laid underground or dissemination. Every year, about 100,000 land mines are removed, and about 60 people die with land mines. It will take 600 years to 700 years to remove all land mines at present speed.

Land mines are removed by deminers using metal detectors, mine prodders, mine dogs, etc. When using a prodder, a deminer repeats stabbing it to the ground at a slant carefully.

There are many land mines at any area. Treading or touching land mines, people become limb amputation, or blindness, loss of hearing, or death. Actually, about 26,000 people are sacrificed and injured by land mines each year. It means that one person per 20 minutes dies. Most of land mines are plastic antipersonnel land mines it is very difficult to detect those. Therefore, exact land mine detection by deminers is needed.

In this paper, we describe our land mine detection system with pneumatic bilateral servo actuators. The goal of this research is to establish the method of mine detection and cleaning by our robot with high safety, assuredness and expedition.

Present Situation of Land mine Detection and Positioning of This Research

Recently, many research organizations are studying about prevention from damage by land mines.

Sato et al.[(1)(2)(3)] are researching the underground search radar that distributes short pulse microwaves from the transmitting antenna toward the ground and detects microwaves reflected by objects. Many parts of landmines are made from plastic and wood. This radar can detect metal and nonmetal objects.

Shimoi et al.[(3)(7)] are researching the infrared camera system to measure temperature distribution of the ground. The ideal photography condition is that the temperature difference becomes largest at the sunrise and the twilight. The device detects the position of land mines, measuring the temperature difference between landmines underground and the surface. This device has characteristics to be able to measure widely from a remote place and to visualize easily the temperature distribution but is too expensive.

Hirose et al.[(4)(5)(7)] are researching the contact-type probe system. This system recognizes materials of a land mine, for example plastic and steel, analyzing sound of collision between the sensor probes and a land mine when setting the probe in the ground. The probe consists of the direct operated impact driving function and the shock and vibration sensors. The former sends shockwave towards the probe, controlling the compressed air by solenoid valve. The latter detects the shockwave. It is possible to recognize shape of a land mine, detecting shockwave by these probes arranged in parallel.

Nonami et al.[(6)(7)] are researching the high sensitive magnetic mine detector to detect metals, recognizing slight magnetic field. The characteristics are the compact size and the high sensitivity, and less subject to the disturbance from earth magnetism and commercial alternator. Now, the land mine detection robot COMET walking by 6 legs with detector.

In this research, applying the pneumatic bilateral servo actuator, we aspire for the realization of high reliable land mine detection technology.

In our case, it searches by setting probe in the ground and detects land mines directly. The system analyzes materials by heating an object by the heater in the probe head, and understands shape of an object by the detection sensor arranged in a matrix. The structure is simpler than other detection system and the cost for the realization and the maintenance fee are cheap.

We will mount this system on the Gorilla type 4 leg walking robot with PBSS actuators, and can realize the land mine detection and demining anywhere.

THE BASIC EXPERIMENTAL EQUIPMENT OF MINE-DETECTING

Most of land mines are buried from 20 mm to 100 mm under the ground and are detonated with from 0.4kg from 1kg of the load. The experimental equipment is shown in figure 1. This equipment has 3 pneumatic bilateral servo actuators and the slave cylinder is moved along each axis.

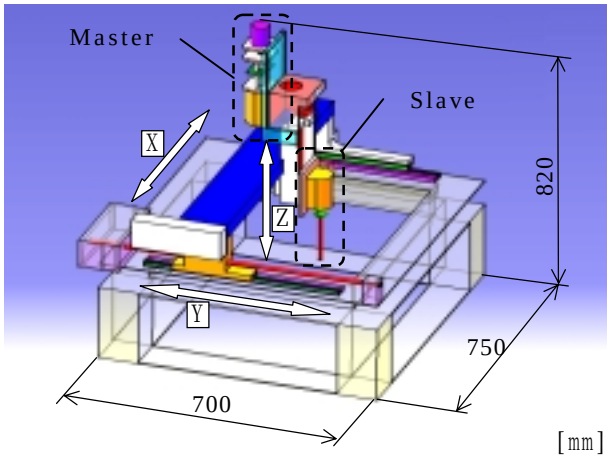


Figure 1 PBSA experimental equipment

In the experiment, the probe is repeatedly inserted into the ground for detecting imitations of land mines, moving in a reticular pattern. When the probe touches an object, it judges from the difference of pressure in PBSA that it is a landmine or not.

BILATERAL SERVO ACTUATOR SYSTEM

In size of most antipersonnel landmines the external diameter is over 80mm, the thickness is over 30 mm and the weight is more than 100 g less than 250g. Shape of antipersonnel land mines is a plastic ellipse or a wood cuboid.

In this research, the pneumatic bilateral servo actuator (PBSA) in figure 2 is used.

The PBSA consists of a master cylinder and a slave cylinder that are linked to each other by tubes and filled with compressed air. When the torque transmitted by the ball screw of the motor moves the piston of the master cylinder, the piston of the slave cylinder is moved by antagonistic effect. When the rod of the slave cylinder is moved by external force, the force is transmitted to the piston of the master cylinder by antagonistic effect.

The probe is connected to the rod of the slave cylinder and set in the demining machine. When the probe head touches to a landmine, pneumatic pressure in cylinders changes, and the force is detected as variation of pressure by the pressure sensor. At the time, displacements of the pistons are detected by potentiometers.

The advantage of PBSA is written as follows.

(1) It is possible to reduce in size and weight of a device because a PBSA driven by a small motor generates high torque.
(2) Pressure loaded to the probe is directly detected by sensors.
(3) Impact strength between the probe and a target is buffered by compressed air in cylinders and the air is low-pollution.

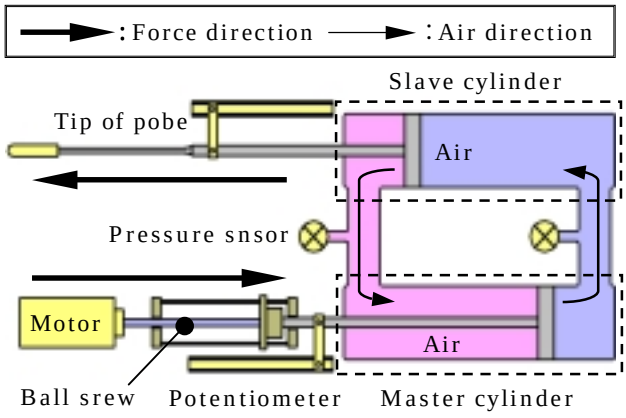


Figure 2 Schematic of the pneumatic bilateral servo actuator (PBSA)

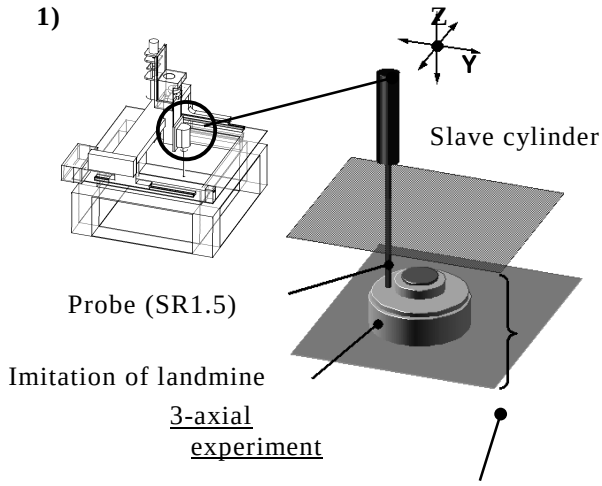


Figure 3 Detection of a land mine by PBSA

BASIC PRINCIPLE OF PBSA

A symmetric bilateral servo mechanism gives emphasis to positioning accuracy. But the demining by positioning control of the mechanism is impossible. To detect a land mine, it is important to detect the reactive force when a plodder, hits to a land mine. Therefore, force-reflecting bilateral

servo actuators are needed. It is especially needed to detect reaction force by a plodder.
The motion equations of force-reflecting PBSA in figure 4 are as follows.

$$m\ddot{x} + f\dot{x} = Fin \tag{1}$$

we obtain

$$\ddot{x} = \frac{Fin}{m} - \frac{f}{m}\dot{x} \tag{2}$$

where

$$m = M_{sp} + L \tag{3}$$

$$Fin = Fb - Fr = Pb \cdot ASb - \Pr \cdot ASr \tag{4}$$

The equation of adiabatic change of master and slave cylinder are expressed as follows.

$$Pr = p\left(\frac{Vr}{Vr + dVr}\right)^n \qquad P_b = p\left(\frac{V_b}{V_b + dV_b}\right)^n \tag{5}$$

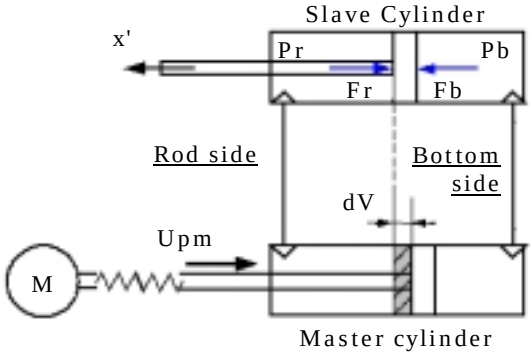


Figure 4 PBSA system

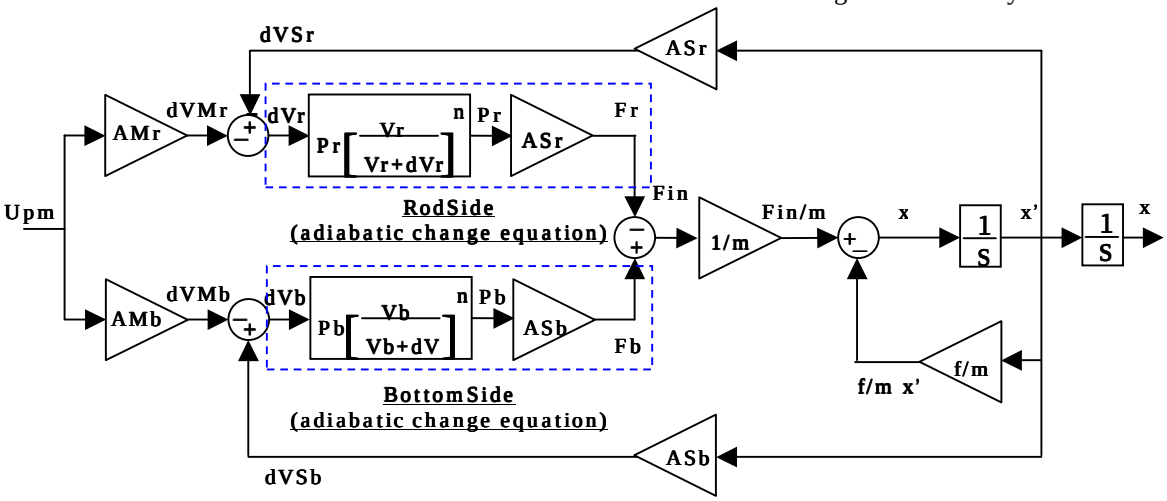
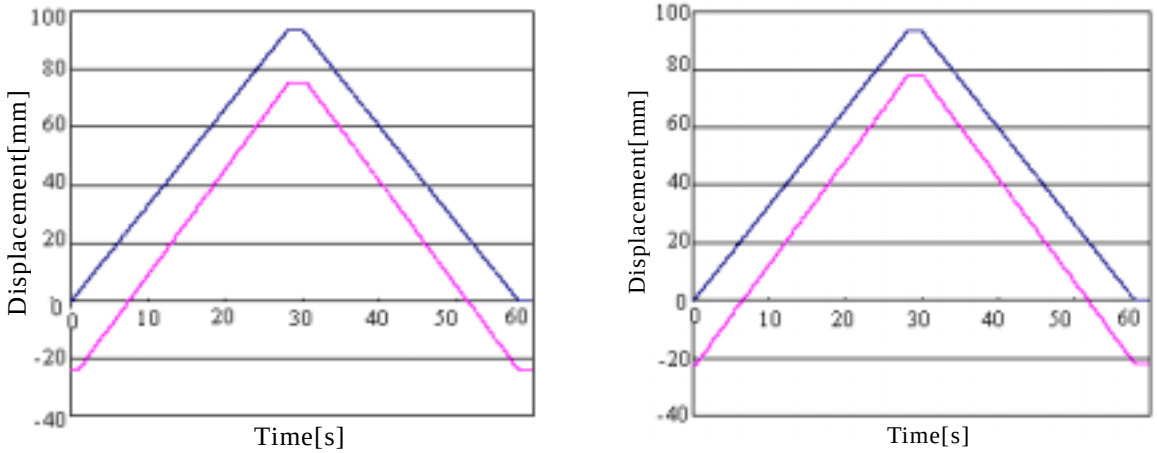


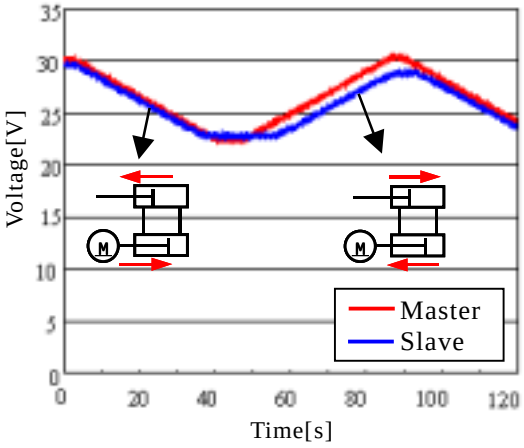
Figure 5 Block diagram of PBSA



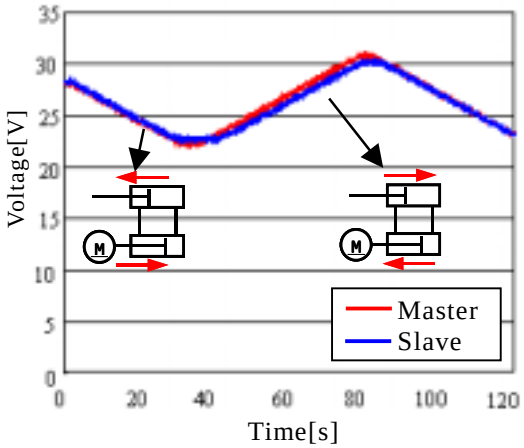
(a)Air pressur : 0.15[MPa]

(b)Air pressure : 0.35[MPa]

Figure 6 Response experiment (Simulation)



(a) Air pressure : 0.15[MPa]



(b)Air pressure : 0.35[MPa]

Figure 7 Response experiment (Experiment equipment)

Figure 5 shows the block diagram of the simulation.

Figure 6 (a) and (b) of simulation result when pressured by 0.15[MPa], 0.35[MPa] shows each response from input of master movement to output of slave piston. We can see response (a) is late a little.

Figure 7 shows the result of the experiment the response from master to slave motions. From figure 7 (a), we can confirm to be late response wave than (b). The time lag of right wave in (a) can be thought due to the difference cross-section area of piston and bottom side.

We developed the experimental equipment of PBSA

We confirmed that the higher the air pressure is, the higher the response is.

PBSA CHARACTERISTIC EXPERIMENT

Loading characterization

A land mine explodes with force from 0.4kg to 1kg. Therefore, it is needed to detect slight change of load when the probe touches a land mine. We are experimenting the response to loads of our PBSA. Table 1 shows the condition. Figure 8 shows the change of positions of reaction force from slave piston. When each load in table 1 are applied to the rod of the slave cylinder. The position of piston and the pressure in cylinders changed over 50 g proportionally. We confirmed to be able to measure a slight load to the probe from the change of pressure in cylinders. And then we will experiment to know smallest measure limit of PBSA by changing load force smaller.

Table 1 The condition of the response experiment

Air pressure[Mpa]		0.2
Load[gf]		0, 30, 50, 70, 100, 120, 150, 170, 200
Measuring time[sec]		30
Sampling rat[Hz]		100
Measurement part	CH1	Position of the piston (Master cylinder)
	CH2	Position of the piston (Slave cylinder)
	CH3	Pressure (Bottom side)
	CH4	Pressure (Rod side)

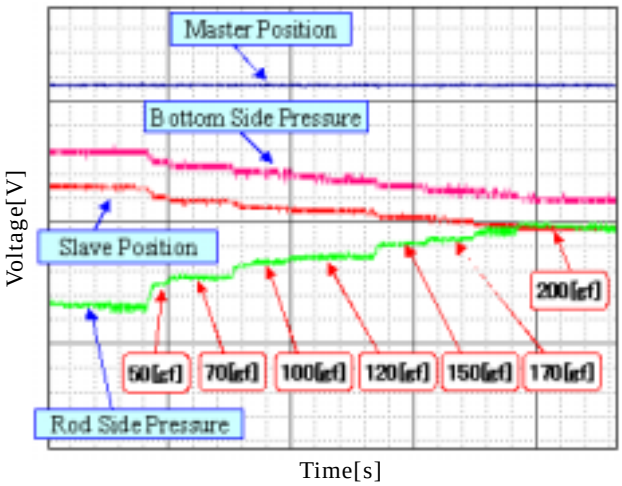


Figure 8 Loading characteristic experiment

Pressure sustainment

There are many land mines in an area. Therefore, our PBSA has to keep the air pressure in cylinders for a long time. Figure 9 shows the result of the measurement of the air pressure in cylinders. The initial pressure was 0.3 MPa. The pressure reduced after 15 minutes. After that, the pressure was kept

about 2 hoers. From this result, we confirmed that it is possible to use our PBSA for a demining for a long time.

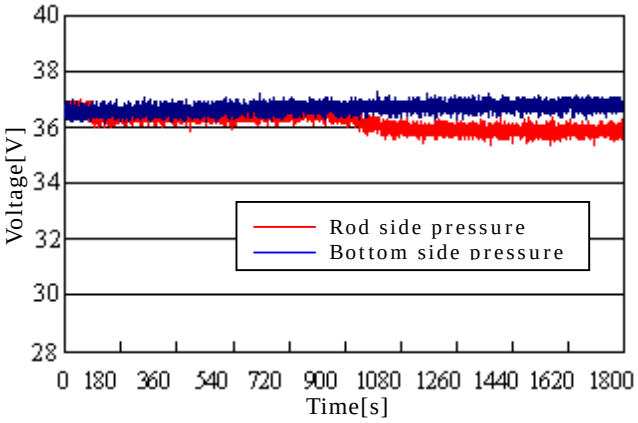


Figure9 Pressure sustainment experiment

CONCLUSION

We described the method to detect land mines, about 10 cm under the ground, by a prodder. The points are as follows.

(1) The vertical insertion of the probe for the mine detection into the ground at a constant speed and even interval. (In case of the mine detection by deminer, a deminer slides the prodder on an object under the ground and makes a distinction between a mine and other objects from the reaction force.)

(2) The pattern recognition of land mines from reaction force when inserting the probe in a reticular pattern.

(3) The experiment of load measurement by the force feedback control and by the positioning control.

(4) The detection of reaction force over 50 gf. And the quick start and stop by antagonistic effect by compressed air in the bottom and rod side cylinders.

(5) A slight pressure reduction in more than 2 hours. (It was possible to keep running the system without recruital of compressed air.)

In this paper, we described the basic experiment for the demining robot. We will develop the demining robot by application of our quadreputal walking robot “Gorilla”. The removal of plants at areas where land mines are buried in the ground is an issue.

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