Quadruped walking with parallel link legs

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Abstract: We are proposing an underwater robot for the work. In this study, we designed the robot, which has body of rectangular plane and 4 legs at each corner. The leg is consisted with parallel mechanism of 2or3 cylinders, and the end of each cylinder is attached on the robot body with free rotational joint and the end of both piston rods are connected with pin joint. 2 cylinder leg's motion is restricted in forward or backward direction but 3 cylinder leg can move any direction. We are studying the control scheme of walking for this robot, which is putting mind especially on smooth and steady movement without rolling, pitching, yawing or heaving motion and keeping the body horizontally. We confirmed the validity of control scheme with simulation and experiments.

Keywords: Underwater working robot, walking, parallel link

I. INTRODUCTION

In late years, importance of the marine technical use increases widely in the world. As deep sea is very severe environment for human, we usually use an underwater robot instead of human. In many years, the underwater robot was used for exploration, so the mainstream of research and development to the robot was for exploration. And the resources in the sea floor, such as petroleum or mines, were cleared from the results of exploration. Now, it is thought that the underwater working robot which has special functions such as maintenance, management or setting on sea floor of observation machinery is necessary. We thought that it was desirable to give robots the function changing their form suitably for work environment and work kinds to get high work performance, and suggested the mechanism design of the robot and the conformity method to environment and the work kinds. In this paper, we refer to the moving mechanism and control of the robot. As well known, robot faces to big reactive force when it is working and it should move stably, carrying heavy goods. We thought a quadruped walking robot which has parallel mechanism for the leg structure is adequate, and confirmed the basic performances keeping prescribed posture and smooth movement by using the experiment and simulation, and expanded the walking condition to uneven terrain surface and to soft surface like mud or sand.

II. LEG STRUCTURE

１． Correspondence to Underwater Work

Depending on a difference of working environment, the structure and control method for underwater robot has big difference to a land robot at the points such as buoyancy, load mass, waterproofing, the power supply etc. Therefore, we proposed the concept that under water robot equipping multi-arms and legs should change the role adequately for stability of posture and effectiveness of work, and showed the judging algorithm in AROB13th (2008). In this study, we show the detail of quadruped moving mechanism and walking control as the most fundamental system to realize the concept.

２． Parallel mechanism

When the robot works in the water, the load to each joint becomes small because the main body weight decreases with buoyancy. But it has a reactive force depending on a work motion and resistance force to the body with fluid. For this reason the posture control becomes difficult to underwater work robot. And leg has important role for stable work. Giving high power to leg comes to size up and weight up of the robot under using conventional serial mechanism. Therefore we decided to adopt the parallel mechanism as shown in Fig. 1, which is keeping objective enough functions for work, and preventing upsizing and weight up of leg.

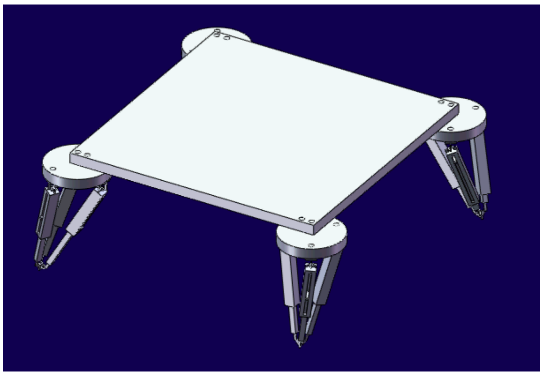

Fig.1. Underwater working robot (parallel link)

The parallel mechanism is constructed with parallely arranged links, base plate and end plate. Themovable space is smaller than serial link mechanism with mechanical restriction, but it can move more quickly and precisely, because it can move any direction with one action and the position error does not pile up. It also has higher rigidity because it can distribute the load to each link. Considering those characteristics, we can get a stronger and more active leg when we apply parallel mechanism to the leg. Moreover, it will bring the improvement of ability such as payload, smoothness of walking or acceptability to the change of situation such as posture in work environment or reactive force with a working motion.

In this study, we decided to use a parallel mechanism as shown Fig. 2. This leg is consisted with 3(three) sliders and the end of piston are connected with universal joints.

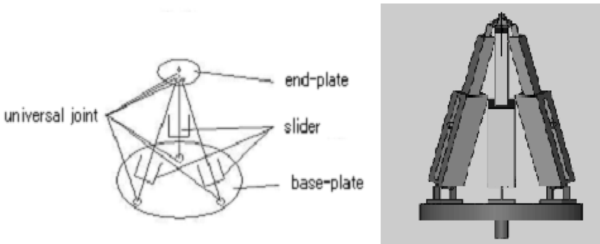

Fig.2. Leg of parallel mechanism

When we constitute one leg with three cylinders, we can define the movable range on the flat plane walking with the slide length of the slider and distance between the attached position of the slider to baseplate. In this study, when quadruped robot walks, we move the leg not to interfere each other. Then we designed the robot that has square shape body and at each corner leg mechanism consisted with circular plate and three (3) sliders attached. The sliders are attached to the plate at the top of right-angled isosceles triangle as shown in Fig. 3.

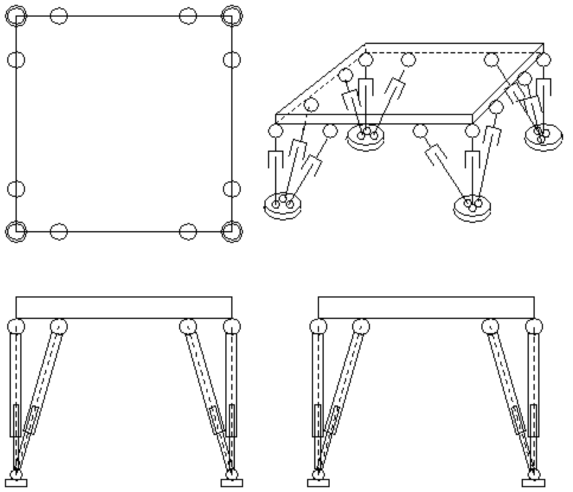

Fig.3. Joint design

One of the reasons of this design is that this arrangement is able to draw a large trajectory of foot and it guarantees the stability of body with putting the center of gravity of the robot into inside of the figure which landing foots draw. Second is that the side view as shown in Fig. 3 is same, so it can easily switchover control mode when it changes the walk direction on the work. In addition, as shown later in this paper, when we consider that the robot walks forward, backward or side direction mainly, only two sliders are used in Fig. 3 design and all sliders are used in Fig. 2 design. So, we are thinking that Fig. 3 type is advantageous from the view point of control or reliability than Fig. 2 type. As walking, we will hereinafter describe in detail.

III. WALKING

1. Concept

In this study, we assumed constant speed walking with keeping horizontal posture of body plane on a horizontal flat ground as a basic walk. These conditions are basic motion for the robot when he carries everything and not realized yet.

We will describe here the advantage of this walking.

- The main body of robot is stable
- The accuracy of work is improved because sensor or actuator is released from vibration or noise with stable robot motion.
- The influence on load deteriorates and accidents such as collapse, damage or fall of carrying material effectively prevent.

- In case of remote control, it becomes easy with reducing additional subtraction speed or vibration of the main body.
- The control system is designed for working part and moving part independently.

2. Walking Pattern

We will expand this walk to undulating land, a slant place, a step in future as well as level ground. When we compare the operation range of the robot with 3 slider type and 2 slider type, only side or oblique walk is impossible for 2 slider type and those walk are not so often appear in actual walk, and control become easy to 2 slider type. Therefore we are thinking that 2 slider type robot is more practical than 3 slider type.

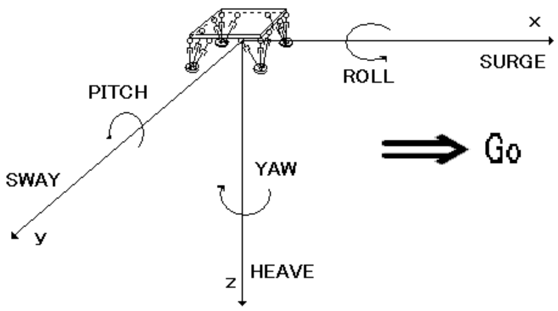

Fig.4. Body-fix

Here we show the walking pattern for straight walking with constant speed, keeping horizontal posture and constant height on a flat horizontal ground. The walking motion can separate following 3 modes.

- Walking start mode···
  ①Float and move front left leg ahead
  ②Another supporting legs move the body to go ahead
- Walking (cruise) mode···
  ①After landing front left leg, float front right leg and another legs move the body.
  ②After front right leg landing, float aft left leg and then aft right leg. Continue this sequence.
- Walking stop mode···
  ①Move supporting legs to get vertical condition when stop order given.
  ②Land the floating leg to get vertical condition。

The pattern is shown in Fig. 5.

To make walking control easy, we adopted pattern control that moves leg with predetermined pattern and change or correct the pattern if necessary. The algorithm of the walk pattern change is going to use action judgment algorithm based on suggestion as the IF-THEN method that was introduced in AROB13th (2008)[1]. About the motion of leg such as landing-backward moving-floating-forward moving, we set some basic patterns so that a walk of constant speed, horizontal posture and constant height can perform smoothly.

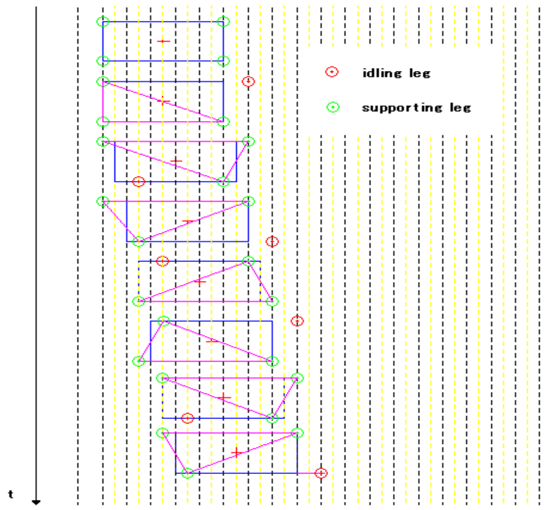

Fig.5. Example of walking pattern of 2 slider type

3. Walking Control

Walking motion of this robot includes many kinds such as Straight walk (forward or backward), Curving walk (right or left), Turning (right or left) and Climbing or descending slope or step. We must establish control algorithm for every walking. Here we introduce basic control system depending on pattern method

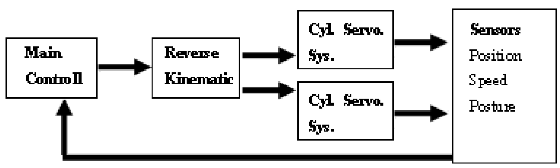

Fig. 6 Control System

IV. EXPERIMENT

Simulation

At first we confirmed the performance with simulation. Here we built 3-D model with Solid Works and gave each slider of each leg mentioned pattern of motion. As shown in Fig. 6, we could get expected results of constant speed, horizontal posture and constant height.

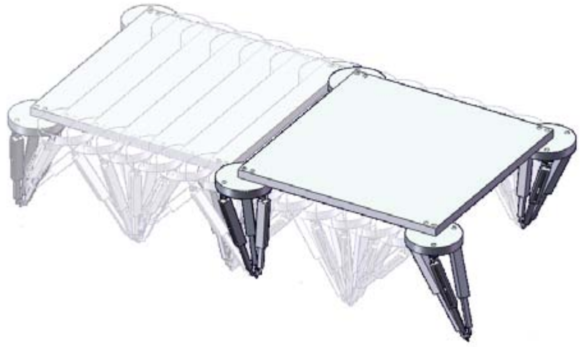

Fig. 7 Simulation Results

Experiment

2.1 Experiment System

In this experiment, we install a device for 1 that we constituted by two electric cylinders to show in Fig. 6 on a surface plate in form to do a joint as ankle on the top and build a system moving this by Matlab-Simulink and confirm a cylinder control system for walking. We show the specifications of the electric cylinder to use for this experiment in Table 1.

Table.1 Experiment system

Control system	: MatLab (simulink)
Electric cylinder	: YAMAHA YMS45
Cylinder stroke	: 20cm
Thrust force	: 2-6kg
Driver	: YAMAHA SR1-X

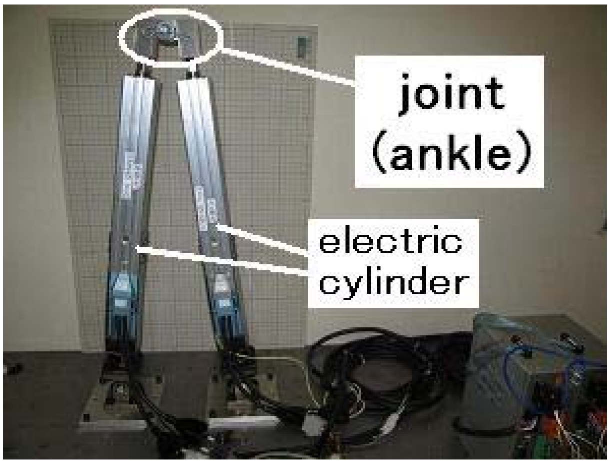

Fig.8 Experimental equipment

2.2 Control Method

In this system, we built the control system to realize the motion shown in Fig. 9. Each cylinder was controlled with the reference length decided from reverse kinematics depending on the trajectory and moving speed. This motion control program is shown in Fig. 10.

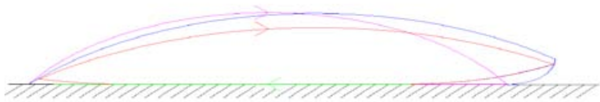

Fig.9 Example of trajectory pattern of foot

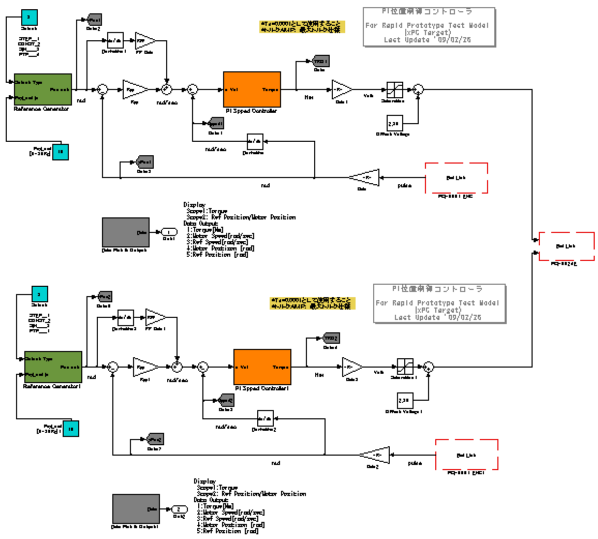

Fig.10 Control system

3. Experimental Results

We would like to report those results on the symposium as much as possible.

V. CONCLUSION

We proposed the walking robot having 4 legs with the parallel mechanism as underwater work use and examined the motion performance.

It showed enough possibility about the basic walking with simulation, and it is on the confirmation with experiment now.

Those results suggest us that this type of robot has a higher performance than conventional type and we would like to develop the system to higher level of applications.

REFERENCES

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