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DEVELOPMENT OF FIELD ROBOT
(Steering mechanism and crawler tilting mechanism)

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ABSTRACT

In many fields, all terrain vehicles are highly demanded with high performance and efficient energy consumption. Some vehicles run on four or six tires, and some vehicles run rubber tracks, called crawlers. In this paper, we will focus on crawlers and their applications. First, we will describe the vehicle's features, and its characteristics. A unique four-wheel-steering Z link mechanism is applied. Crawlers with a tilting mechanism are applied that enables the vehicle to run over steps and obstacles.

KEY WORDS

Four wheel steering, steering mechanism, crawler tilting mechanism

INTRODUCTION

We developed a multi purpose robot that could be applied in many fields, such as construction areas, agricultural areas, and hazardous areas for example landmine fields. Eventually, for every task there is a specific robot or machine, limited with particular features. This field robot has a wide field.

Background

In hazardous areas, man could be injured severely or could loose his life on the field. Therefore, wireless or remote controlling system is necessary to prevent such accidents. Some of these areas are difficult to reach and to proceed with the task. Therefore a new multi purpose field robot has been proposed.

Objective

The main purpose of this research is to develop an efficient and smart steering mechanism. That mechanism gives the robot a flexible structure to run through narrow areas. And undergo any kind of tasks at places with limited amount of space. The development of the tilting mechanism is one of the objectives of this project. Titling mechanism is a mechanism that enables the crawlers to incline or decline depending on the ground features. Obstacles such as stones, tree logs or even steps would not stop, or delay the robot from proceeding. Finally, develop a wireless network to control the whole field robot including the steering and tilting mechanism.

FIELD ROBOT FEATURES

Field Robot characteristics outline

The robot is powered by a diesel engine. The engine runs a two axial piston pumps. One of these piston pumps is a hydro static transmission called (HST). The HST drives four hydraulic motors installed to each crawler. On the other hand, the other piston pump drives the steering cylinders and the titling mechanism. The crawlers could steer 90 degree to the right and 30 degree to the left. Front crawlers are attached to the body by a shaft that it enables the 2 crawlers swing. The whole system (PLCs, servo valves and HST) is controlled by a PC and a controller.

Figure 1 Field robot image

Table 1 Field robot specification

Dimensional Size	2.6/1.5/1.8 m
Wheel Base	1.980 m
tread	1.341 m
Weight	1600 kg
(Power Source)Engine	Ishikawajima Shibaura N843L-SH5(Diesel, 1.7 cc)
Drive	4 Wheel Drive
Transmission	HydroStatic Transmission
Steering	Front/rear independent steering
Steering angle	Right 90, left 30 degree
Undercarriage	Rubber tracks (crawlers)
Suspension	None (Swinging mechanism)
MAX SPEED	3.3 km/h

STEERING MECHANISM

In this robot a Z link steering mechanism is installed. That mechanism enables the four crawlers to rotate 90 degrees to the right and 30 degrees to the left. Thus steering range is 120 degrees. To rotate the crawlers with a hydraulic cylinder a Z link mechanism comes in handy as shown in the following figure.

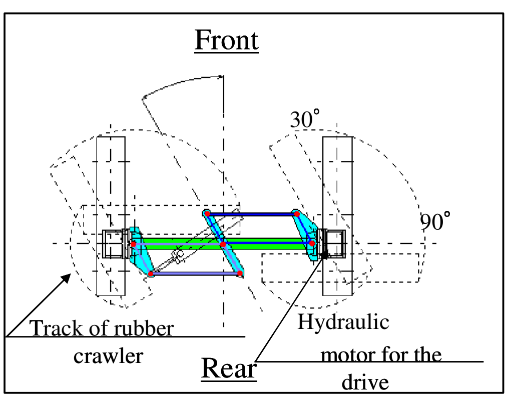

Figure 2 Steering mechanism

Four wheel steering enables the robot to steer its wheels to any direction as shown in the lower figure.

Figure 3 wheel steering applied

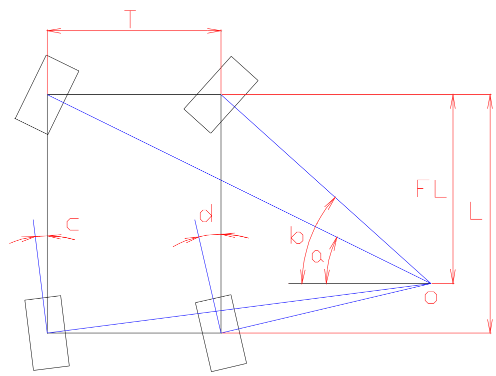

Figure 4 Minimum turning radius model

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other robots, designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii [1]. According to Ackermann steering geometry the following equations were derived.
This equation shows the minimum radius:

$$R = \frac{\frac{FL}{\sin a} + \sqrt{FL^2 + \left(\frac{FL}{\tan b} + Tf\right)^2}}{2} \quad (1)$$

However, pulling force:

$$FL = \frac{L}{\tan\frac{(a+b)}{2} + \tan\frac{(c+d)}{2}} \times \tan\frac{(a+b)}{2} \quad (2)$$

L: Distance between front and rear axis [m]
FL: Calculated axis distance[m]
T: Crawlers axis center[m]
a: Front outer wheel angle [rad]
b: Front inner wheel angle [rad]
c: Rear outer wheel angle [rad]
d: Rear inner wheel angle [rad]

That shows that a robot with 4 wheel steering mechanism could turn in smaller radius, compare to conventional vehicles steering mechanism

Servo control
Steering cylinders were actuated by proportional valve. As a result, bad response was observed, and skilled operator is necessary to perform the steering. Therefore, the proportional valves were replaced with servo valves to gain high positioning efficiency and sharp response. Each crawler weigh about 500 kgf defined as *Fw* and *Fm* is defined as the momentum torque acting on the kingpin, which is located between the steering cylinder and the crawler.

$$F_m L_1 = F_w L_2 \quad (3)$$

$$P_l = \frac{F_m}{A} \quad (4)$$

$$V_1 = Q_{70}\sqrt{\frac{A_1 P_S - F_m - A_2 P_T}{35(A_1^{\ 3} + A_2^{\ 3})}}[cm/s] \quad (5)$$

L_1: Space between cylinder & kingpin [mm]
L_2: Space between kingpin & crawler [mm]
P_S: Rated Pressure [kgf/cm^2]
P_t: Hose pressure loss [kgf/cm^2]
A_1: Cylinder head cross-sectional area [cm^2]
A_2: Cylinder rod cross-sectional area [cm^2]
V_1: Cylinder extending speed [cm/s]
V_2: Cylinder contracting speed [cm/s]
The equations above allow the selection of valves and potentiometers.

Steering control result
After replacing the proportional valves with servo valves, steering performance was improved in many stages. According to the command, response is faster and more accurate. Wireless control is more reliable, since the steering is controlled with servo controllers.

TILTING MECHANISM

Four rubber tracks known as crawlers are installed instead of the tires. Crawlers have bigger area contacting the ground, give it a strong grip and prevent it from slipping.

Rubber track
During work, normal vehicles use hydraulic assistant legs to increase the stability of the vehicle. While crawlers gives offers bigger stability to the vehicle, because of the tracks has big area that increases the ground resistance and prevent the vehicle from slipping. However, when the robot runs back ward with obstacles behind, the crawlers rise up and the robot looses its balance. Such action starts to turn into problems. Therefore a new crawler titling mechanism was introduces to the field robot. This titling mechanism prevents the crawlers to rise up while running backwards. And it assists the crawlers to rise when there are steps or obstacles ahead. A hydraulic cylinder was installed on the crawlers, to lift it up 30 degrees and lower it 30 degrees. As shown in the figure, the mechanism enables the crawler to run up 300 mm high step.

Figure 5 Crawler image

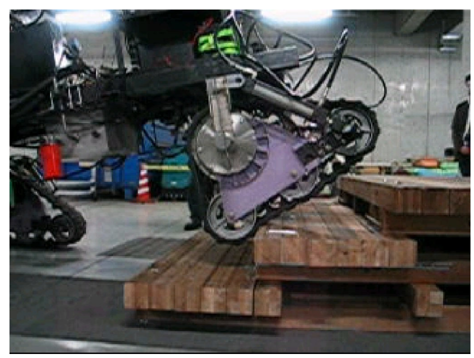

Figure 6 Crawler running over steps

Crawler tilting results
The experiment was to drive the robot up the stairs and back down. The stairs consist of 3 steps. Before running through the stairs the front crawlers are lift up. Then the robot is driven until the crawler starts running over the first time. At the same time the rear crawler tilting cylinder pushes the crawler downward to have a stronger grip of the ground. Technically front crawlers help to climb and the rear crawlers help to push the crawler forward. The experiment was held successfully. However for the crawlers were controlled manually, for safety reasons.

Wireless Control

In the field, sometimes man cannot accompany the robot for operations. Thus, a total wireless control system was proposed. *AD5430* controller is installed in the robot. The controller is controlled by a personal computer through a wireless LAN. Engine ignition, HST, crawler tilting and steering cylinders are controlled through the controller.

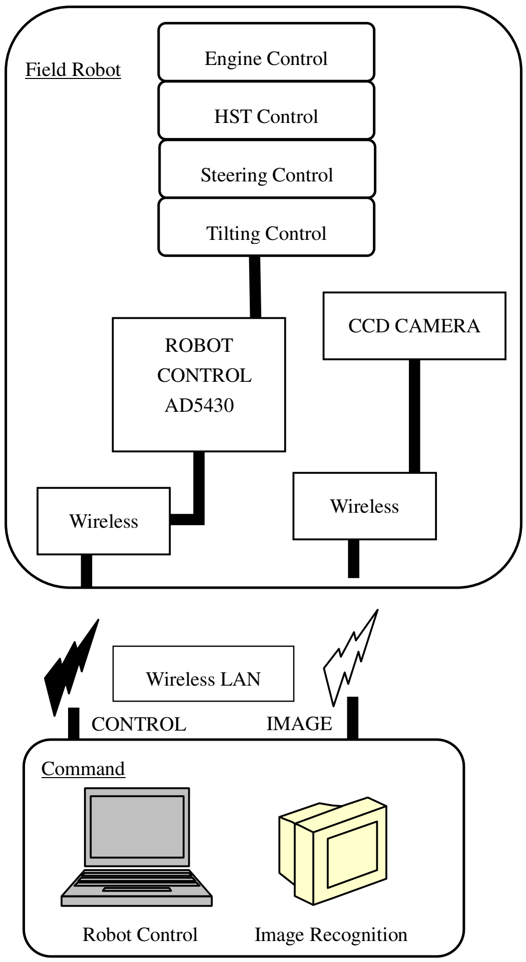

Figure 7 Wireless Control System

The Above figure shows that the controller AD 5430 gives commands PLC that turns on/off the engine, and to the stepping motor attached to the pump and feed back by rotary encoders installed to the crawlers. The steering cylinder is controlled and monitored since steering force differs in each running status. In addition to the crawling mechanism which eventually will be an automated system.

Running Experiments and results

The controller which controls the whole robot system is basically programs and system blocks created by MATLAB SIMULINK. And Virtual console is used to create a simple interface between the operator and the field robot, in which the operator can control all the actuators and monitor the speed and other data from sensors.

The running test of the robot took place on a 300 meters long track. The at the distance of the 300 meters away from the operator the data transmission was weakened and slower and at 350 meters it lost its connection completely. In case the robot runs out of range accidentally the robot will automatically shut down and wait for another confirmed command signal. The displacement error is about 1.3% that is caused by the rubber crawlers which expand and extract according to the road features.

Conclusion

In this research, we developed a robot with many features that support it during its running off-road. In case of narrow areas, or small spaces the robot can steer through it with the new steering mechanism. In the other hand, when the robot faces obstacle the crawler tilt device will be activated to support the robot. Further experiments are expected on the crawler tilting mechanism.

Applications

Figure 8 Robot applied in landmine field

Applying this robot in landmine fields, demands several equipments, such heavy shield to prevent any serious damage in case of explosive accidents. Other equipments are required too, for example landmine sensors and defecting robotic arms.

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