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Development of a Spiral Propulsion Mechanism in Wetlands -Relation between Torque and Load

Qunpo LIU*, Yoshito HAYASAKA*, Naohiko HANAJIMA**, Kunio KAWAUCHI***, Mitsuhisa YAMASHITA**, Hiromitsu HIKITA** and Toshiharu KAZAMA**

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This paper addresses load properties of a spiral propulsion mechanism in wetlands. Recently, area of wetland has been decreasing due to farmland development and so on. The phenomenon is becoming one of the major environmental conservation concerns. The project of investigation of the current state and its degradation trend of the marshland has been started. The most significant challenges to the field surveys focus on the development of locomotion mechanism to carry measurement devices in wetland. One of the authors has proposed spiral propulsion mechanisms for movement in wetlands. Fundamental experiments have been performed in the bank of a river, where was covered with dried long-stem plants, and the traction properties of the spiral propulsion mechanism in wetlands is investigated. We have proposed a simple formula which describes the relation between torque, load and traction. The data of the experiment fit the formula well in range of less than a certain value of load.

Key words: Wetland, Spiral, Environment at investigation, Coil

1 INTRODUCTION

Environmental protection has been people's concerns for a long time. The problem of reduction of wetlands' area is becoming one of the most important environmental conservation concerns. In Kushiro mire, which is the largest wetland in Japan, the distribution areas of Alder forests or veitchii are increasing. The project of the nature restoration has been started. First of all, the investigation of the current state and its degradation trend of the marshland are critical to the project.

Many efforts are made for field surveys. We can obtain spatially wide data by remote-sensing system such as radar images or visible images from satellite. However, field survey is mandatory if we want to obtain more precise physical data, and lots of tools should be carried. It's very hard for people to walk around huge area in muddy soil of the wetlands with heavy tools. At the same time, vehicles are restricted to enter into wetlands. Therefore the most significant challenges for the field surveys focus on the development of locomotion mechanism to carry measurement devices.

New and exciting applications continue to be found for mobile robotic systems. One of the most important trends of the past decade has been the increased use of mobile robots in rough, unstructured terrain, such as underground mines, forests, disaster sites, and planetary surfaces. And recently many robotics researchers shift their focus from developing robots that operate in laboratory settings, to those that can successfully overcome the real-world challenges associated with rough terrain operation. New locomotion mechanism suitable for

*　Division of Mechanical Systems Engineering
**　College of Design and Manufacturing Technology
*** College of Environmental Technology

the wetlands, which suppress damages of the vegetation and do not sink in the mud, has been a high-priority goal in the robotics community.

In this paper, we describe a spiral propulsion mechanism and its experiments. It threads its way through vegetation by spinning itself. The spiral keeps its trajectory when spinning. Therefore it would not exert strong force on the vegetation. Since the spiral makes plural points of contact with ground and its load is distributed, it mustn't be easy to struck in the mud. We made a spiral as prototype and investigated relation between torque, load and traction.

2 MODEL OF THE SPIRAL PROPULSION MECHANISM AND FORCE ANALYSIS

The spiral propulsion mechanism is a mechanism that rotates the spiral shaped structure in the grasses, and converts the torque to the thrust force. Here the model of the spiral propulsion mechanism and force analysis are presented, as illustrated in Fig.1 and Fig.2.

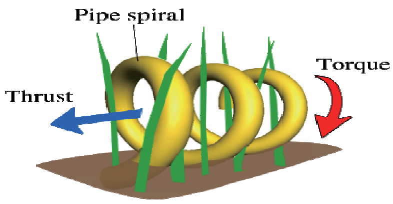

Fig.1 Diagram of a proposed spiral propulsion mechanism.

As shown in Fig.1, the spiral receives a reaction force from hard stem plants when the part of the spiral pushes on them. In the same way, it receives the reaction force from them if the spiral wades in mud and water. If both of the normal component and the reaction force balance to each other, the

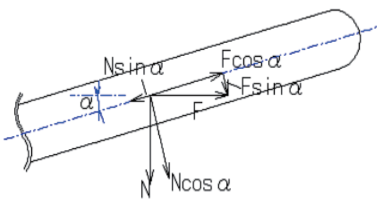

Fig.2 Relation of forces in locomotion

only tangent component will remain. Therefore the spiral revolves along a path formed with its own shape and moves along the center axis (as shown in Fig1.). Finally the translational movement produces thrust force, N (as shown in Fig2.). Therefore in rotating, the spiral receives frictional force from the plants and the mud, and.

Seven parameters are required to define the configuration of the spiral propulsion mechanism in Fig.2. A torque T is applied at the central axis of the spiral in order to create rotation. The force F, which is generated by T on a small part of spiral, is resolved into its tangent and normal components (Fig.2). The spiral has radius of r and a mass of m. An angle of friction is denoted by β, and a lead angle α. A coefficient of friction which act between the spiral and ground, is indicated by μ. Gravitational acceleration is denoted by g.

Taking those parameters into consideration, force balance equation for the system in Fig.2 can be written as :

$$T/r = N\tan(\alpha+\beta)+\mu mg \qquad (1)$$

It aims to clarify the relation and the characteristic between torque, load and traction, which is necessary for the generation impellent of the spiral rotation. Issues related to thrust force traction N were discussed in references [1]. This article focused on the relationship between torque T and load.

3 EXPERIMENT AND DEVICES

Experiment has been performed in the bank of a river to confirm eq. (1), where was covered with dried long-stem plants. Density of the grasses was about 342 stems per square meter. Average length and mean radius are around 2.14[m] and 5.28[mm], respectively.

Fig. 3 Aluminium pipe spiral in wetlands

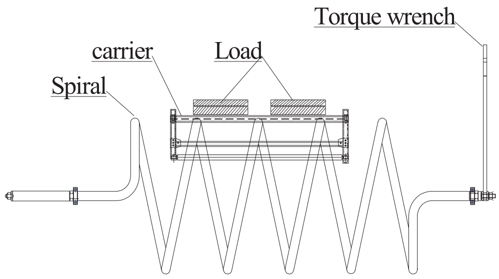

Fig. 4 Experimental system structure

Fig.3 and Fig. 4 show the experimental setup of the spiral propulsion mechanism. The spiral was made by curving the aluminum pipe of 32mm in the diameter and 2mm in the thickness. The outside diameter of the spiral was 500 mm, the rolling number, 4.5, the total length, 1000 mm, and the α, 0.138 rad.

So as not to bend the grass, the spiral was set up in the grass. A torque wrench was installed directly on this spiral axis. The torque to rotate the spiral was exerted and measured with the torque wrench. To change the load on the spiral, weights were put on a balanced carrier. The load was increased from 0 to 14 kg by 1.0 kg each, and then the force to rotate the spiral was exerted to the torque wrench. Immediately after the spiral began to rotate, the gage of the torque wrench was read as the torque T.

Fig.5 shows graphs of the load versus the torque. The graph marked by shadow represents experimental data and a straight-line linear regression model. It is observed that the graph fits eq. (1) well. From the linear regression model we obtained $\mu = 0.919$.

According to the experimental results the following conclusions can be drawn.

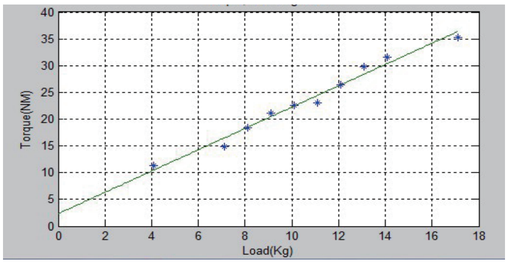

Fig. 5 Relation between Torque and Load

Firstly, value of μ, which is coefficient of friction between the spiral and ground, will depends on vegetation circumstances conditions. Therefore, the same torque will be converted into different thrust force N in the different vegetation circumstances.

Secondly, comparing with the coefficient of friction between clayey loam and an off-road tire, 0.45, μ = 0.919 is more than double. Relevant solutions should be put forward to reduce the losses caused by frictions for efficient locomotion.

Third, owing to special shape and uneven environment, spiral propulsion locomotion mechanism is very easy to rollover. The carrier, with suitable shape and location, should be designed to adjust the center of whole-system's gravity.

4 CONCLUSION

This paper introduces the background of the research work in field surveys. In view of bottle-necks and difficulties in this field at present, a countermeasure analysis was made and a spiral propulsion mechanism suitable for wetlands was described. Based on the essential relationship between the starting torque, the traction and load, experiment was performed and considered, and the relational expression was confirmed. The experiment result supported that the equation concerning the force balance between the torque, the thrust and the friction was suitable. Concerning the findings, interpretations and discussions are raised, and suggestions are put forward for the advance of the research work.

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