Title	弾性効果を利用した歩幅が等間隔でないリムレスホイールのステルス歩容生成と運動解析
Author(s)	川添，雅史
Citation	
Issue Date	2020-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/16390
Rights	
Description	Supervisor:浅野　文彦，先端科学技術研究科，修士（情報科学）

Generation of Stealth Walking Gait and Motion Analysis for Rimless Wheel with non-Equidistant Steps Using Elasticity

1810045 Kawazoe Masashi

It is essential for a walking robot to be able to walk stably on various road conditions regardless of whether it is on a paved or unpaved surface. Especially, stable gait generation on a road surface where the foot landing points are not equally spaced, such as a rocky site or a disaster site where fragments are scattered, has not been sufficiently studied due to theoretical complexity and difficulty. Furthermore, in order to make a walking robot correspond to such a road surface, it is necessary to realize walking in which the stride length is not equal. According to previous studies, passive walking of rimless wheels with non-equidistant steps has been performed, but not stealth walking. Furthermore, it has been shown that highly efficient stealth walking is possible by using elastic elements. In this study, we clarify the control theory of stealth gait generation for rimless wheels with non-equidistant steps using elastic elements in pursuit of high efficiency.

The purpose of this study is to improve the movement efficiency of rimless wheels with reaction wheels with non-equidistant steps on a horizontal plane. In order to improve the efficiency of movement, a walking form called stealth walking is adopted. This is a carefree walking form that has the feature that no collision occurs when the free leg touches the ground. Since no collision occurs between the swing leg and the ground, it can be said that there is no energy loss and it is very efficient. Furthermore, the walking speed is set to the maximum speed at which stealth walking is realized, and the connection between the reaction wheel and the rimless wheel via an elastic element contributes to efficient movement. Walking of a person with a disability on one leg can be regarded as walking in two cycles with different stride lengths. Therefore, walking with a model with non-equidistant steps can be regarded as a simplification of walking for a person with a disabled leg. Therefore, this model and its control method are applied to a rehabilitation robot that can be walked only by wearing a person with a disability on one leg. It may be possible to do so. Furthermore, because of the nature of stealth walking, collisions do not occur when the free leg touches the ground, so it is considered that the robot will be a user-friendly rehabilitation robot that can walk without putting a burden on the foot. In addition, the energy consumption is small due to the effect of the elastic element, and the running cost is low. From this, this study is considered to be a very useful study that is expected to be applied to rehabilitation robots.

First, a mathematical model of the rimless wheel used in this study is presented, and the equation of motion of the model is shown. Next, as a control method, DODC (Discrete-time Output Deadbeat Control) is applied to the control of this model, and control is performed in the shortest time. By doing so, it is possible to improve the robot's movement efficiency. Then, a numerical simulation is performed using the linearized model. The initial state is derived by performing approximate linearization. Furthermore, a numerical simulation with a nonlinear model is performed using this result. The initial state was searched using the bisection method. In the nonlinear model, there is a gap between the initial state and the terminal state. In this study, this gap was interpolated by introducing DSP (Double Support Phase).

An experimental machine that meets the specifications of this rimless wheel has been developed. This experimental machine can change the crotch angle arbitrarily and has a mainspring between the rimless wheel and the reaction wheel. Walking was performed by driving the reaction wheel with a motor. As a result, although only three steps were taken, the tendency of stealth walking could be confirmed.

The following results and findings were obtained as a result of verification on numerical simulations and demonstration experiments using experimental machines.

- A mathematical model was derived for a model with an elastic element between the rimless wheel and the reaction wheel and two different crotch angles.
- A highly efficient gait generation method was proposed by applying DODC to the control of this model and performing the control in the shortest time so that the minimum value of the vertical floor reaction force generated around the contact point of the support leg becomes zero.
- It was proved that the control inputs were the same because the gait of two cycles was under the constraint condition of $\alpha_1 + \alpha_2 = \pi/2$.
- By adding an elastic element between the rimless wheel and the reaction wheel, the walking movement efficiency could be improved, and the most efficient elastic coefficient was confirmed.
- The movement efficiency was changed by changing the crotch angle α_1 と α_2, and the most efficient crotch angle was confirmed.
- An experimental machine meeting the specifications of this model was developed.

- Experiments with an experimental machine confirmed the tendency of stealth walking.

In this study, we generated stealth gaits of a rimless wheel with two crotch angles. But this was done under the constraint of $\alpha_1 + \alpha_2 = \pi/2$. In the future, I would like to generate stealth gaits under this constraint-free condition. We also want to generate stealth gaits for rimless wheels with three or more crotch angles. Furthermore, I want to work on the development of an experimental machine that can always change the crotch angle even when walking. In addition, we believe that further verification of the actual machine for realizing stealth walking is necessary. In the future, by collecting the angular velocity and power consumption data of the experimental machine and measuring the change in power consumption due to the change in the elastic coefficient, we plan to confirm more objective stealth gait generation and compare the movement efficiency with the elastic coefficient. is there. In addition, we would like to conduct similar experiments with the crotch angle changed to an arbitrary angle.