

回転表面波機構を用いた 防塵防水型レスキューロボットの開発

Development of RS-Wave Mechanism



Shigeo Hirose

Tokyo Institute of Technology

2013.11

Outline

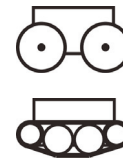
- Background
- Introduction of RS-Wave Mechanism
- Design of RS-Wave Vehicle
- Experiment
- Conclusion

Background

- Wheels and crawlers are widely used on mobile robots

✗ : Infinite rotation → tangle and get stuck easily

✗ : Only single propelling surface.



RS-Wave Mechanism

- A new propulsion mechanism
- ✓ **Generate wavy motion from the whole surface by a single motor**
- ✓ Water and dust protected

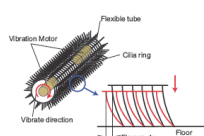
3

Former Studies of the Vehicles with Propulsive Surface

Active Scope Camera (Tohoku Univ.)



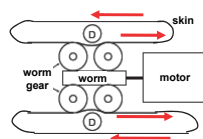
Ciliary vibration mechanism



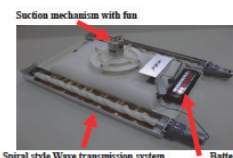
Skin Drive Robot (CMU)



Toroidal Propulsion



Wall Climbing Robot (Chuo Univ.)



Pedal Wave (Snail)



4

Former Studies of the Vehicles with Propulsive Surface

Earthworm Robot

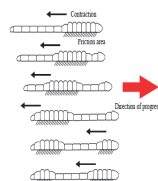
(Chuo Univ.)



(CWRU)



Peristaltic Motion
(earthworm)



Slim Slime Robot

(Tokyo Tech., Ohno, Hirose, 2000)



- Pneumatically driven robot
- Long and thin body
- Multiple locomotion: creep motion, pedal wave, pivot turn...

5

Rotary Surface Wave (RS-Wave) Mechanism



- ✓ **Circular shape**
All the cylindrical surface generate propulsive motion.
- ✓ **Covered by watertight coating entirely**
- ✓ **Only single actuator**

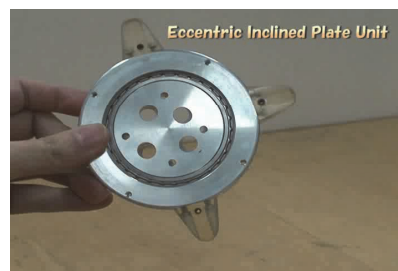
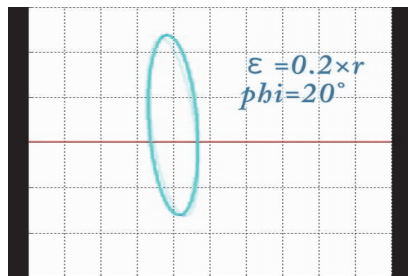
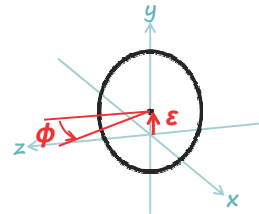
6

RS-Wave Mechanism

- Propulsive motion produced by the rotation of **Eccentric Inclined Plates**

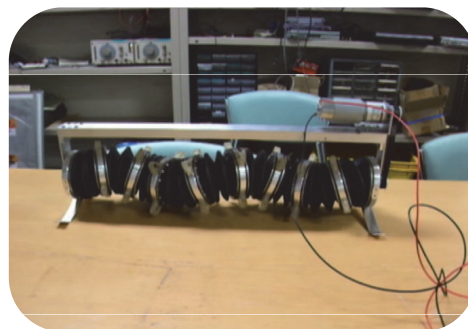
ε : eccentric distance

ϕ : incline angle



7

Prototype



○ Smooth and steady

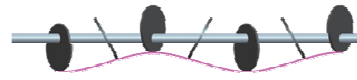
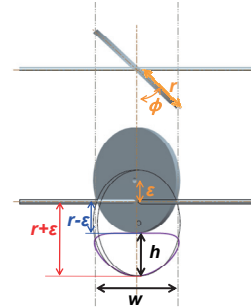
✗ Moving direction

Dimensions	479.3 × 135.3 × 200.9 (mm)
Weight	3.25 kg
Motor	Mabuchi, DC 13.1W, Gear ratio 71:1

8

Design Factors

1. Eccentric distance ε
 2. Incline angle ϕ
- } Size of trajectory
- Larger ε and ϕ
- Bigger stride, higher speed
 - ✗ Require more power
3. Phase shift between adjacent plates
- Wave length
 - Contact points
 - Torsion applied to bellows

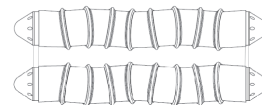


9

RS-Wave Mechanism with Built-in Actuator



Parallel Connection

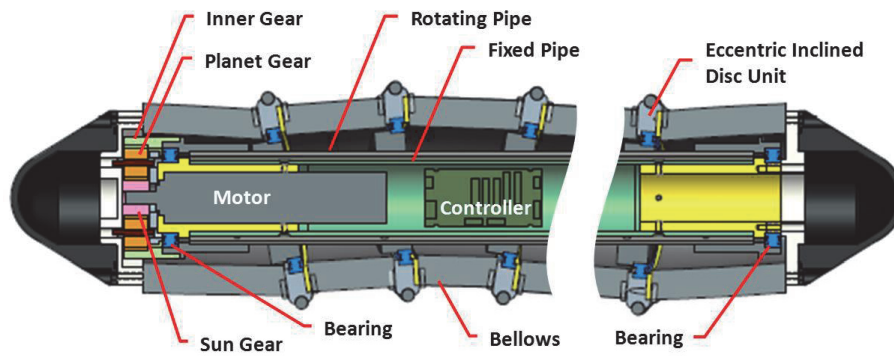


Series Connection



10

Structure

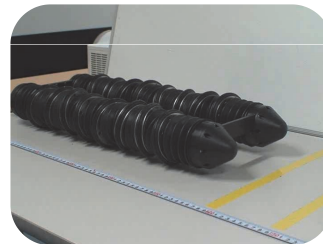


11

RS-Wave Vehicle

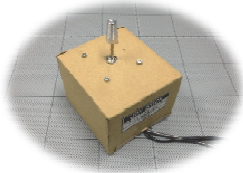


Dimensions: 592.5×243 ×88 (mm)
Speed: 84 mm/s
Weight: 6.8 kg



12

Motion of RS-Wave Vehicle



Direction Control

	Forward	Backward	Right Rotation	Left Rotation
Motor 1 (R)	CW	CCW	CCW	CW
Motor 2 (L)	CCW	CW	CCW	CW



Forward/backward



Turning

13

Motion of RS-Wave Vehicle



Slope climbing (15°)

Climbing angle is limited by

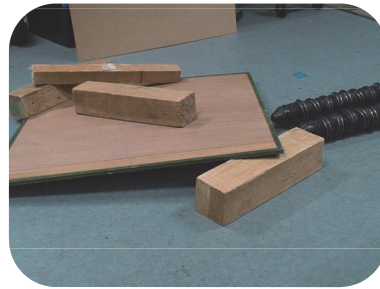
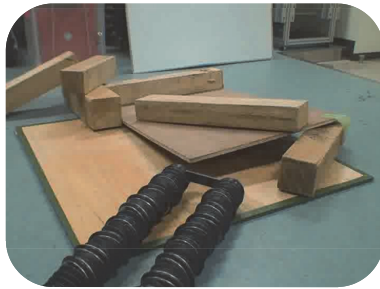
1. Rigid body



2. Lack of friction

14

Motion of RS-Wave Vehicle



It can enter / escape from narrow space easily.

15

Motion of RS-Wave Vehicle

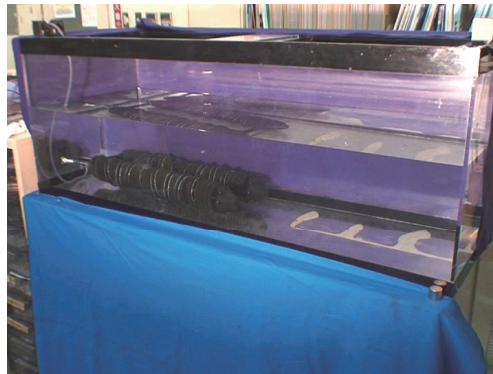


keep moving after flipped over

16

Motion of RS-Wave Vehicle

Underwater



17




Experimental Result

- Max. speed **84 mm/s**
- Max. angle of ramp climbing **15°**
- Max. height of step climbing **25 mm**
- Large Propulsive Surface ☐
- Underwater ☐



18

Propulsion Mechanism Comparison

	Wheel / Crawler 	Leg 	RS-Wave 
• Required Actuators	△	×	○
• Efficiency	○	△	△
• Water/Dust Protection	△	△	○
• All-surface Propulsion	×	×	○
• Terrain Adaption	△	○	×
○: Good △: Fair ×: Poor			

19

Conclusion

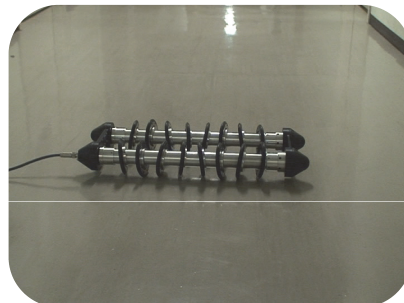
- A novel propulsion mechanism, “RS-Wave mechanism,” was introduced.
- A mobile robot with RS-Wave mechanism was made, and several motion experiments were presented.
- Future works:
 - Improve the mobility and efficiency of RS-Wave mechanism.

20

Thanks for your attention!

Motion of RS-Wave Vehicle

No bellows



Slide to sideways easily

Motion of RS-Wave Vehicle

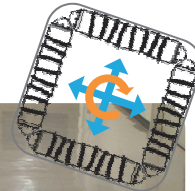
No bellows



Forward



Rotation



Omni-directional Vehicle