Optimization of a Rolling/Walking Hybrid Locomotion

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BACKGROUND

Planetary Exploration

In the field of robotic locomotion there is a strong need to achieve a simple and energy efficient method of mobility across unstructured terrain. Three popular forms of locomotion are illustrated below.

Legged Locomotion
- Advantages: Great stability, large load distribution
- Disadvantages: More energy consuming, complicated controls

Wheeled Locomotion
- Advantages: Quick, energy efficient
- Disadvantages: Small obstacle clearance, predetermined path

Hybrid Locomotion
- Advantages: Combines both legged and wheeled locomotion
- Disadvantages: Previous designs are energy inefficient

Figure 1: Legged (left), Wheeled (center), and Hybrid locomotion (right).

PURPOSE

The objective of this research is to develop an optimized robotic hybrid drivetrain that would be beneficial to the state-of-the-art exploration and task performance in harsh and/or remote unmanned environments.

MATERIALS AND METHODS

MSC ADAMS Software:
- Multibody dynamics simulation software
- Simulates designs of planetary gear train mechanisms
- Evaluate performance of scale models
  - Energy efficiency
  - Obstacle traversal ability
  - Satisfaction of constraints

MODELS

Configuration 1
- Carrier rotation constrained by a stiff spring
- Torque rises if stalled against obstacle
- Carrier forced to rotate in same direction as wheel
- Similar to a rocker-bogey system

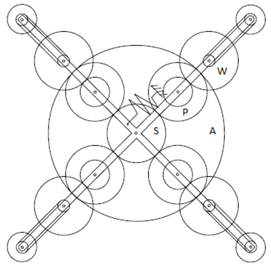

Figure 2: Configuration 1

Configuration 2
- Annulus used as the drive wheel
- Carrier rotation constrained by a stiff spring
- A second carrier used to overcome obstacles

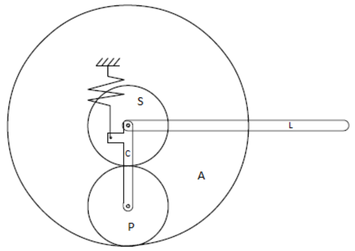

Figure 3: Configuration 2

Legend	
S	Sun Gear
P	Planet Gear
A	Annulus/Ring Gear
C	Carrier Link
L	Leg Link

GRAPHS

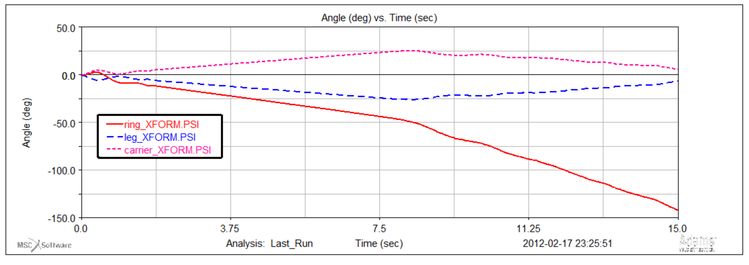

Figure 4: Angle (deg) vs. Time (sec), Ratio of 3:1

Figure 4 shows how the leg, carrier, and annulus gear move through the simulation. As the model climbs the obstacle, it attempts to keep an even balance between the leg and carrier link.

In Figure 5 slipping occurs after about seven seconds causing the sudden change in the graph's curves.

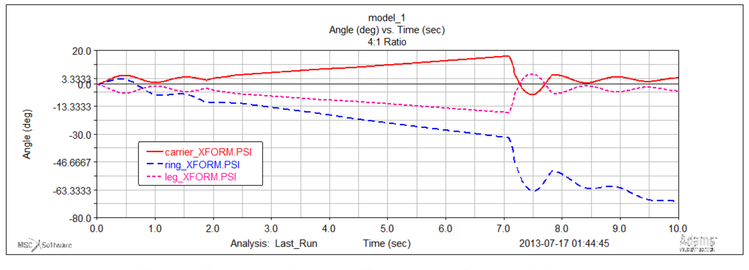

Figure 5: Angle (deg) vs. Time (sec), Ratio of 4:1

GRAPHS

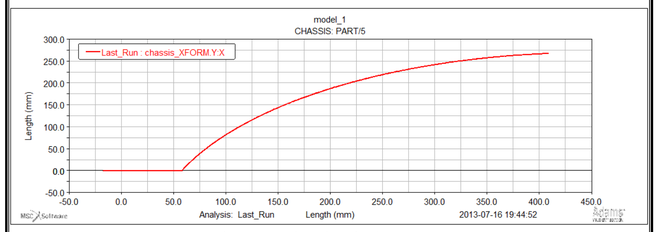

Figure 6: Chassis Displacement

Figure 6 illustrates how the chassis moves throughout space during the simulation. For each given ratio the displacement was similar, however, the 3:1 ratio had the smoothest movement.

RESULTS

Parameters
- Gear Ratio: 3:1, 4:1, 5.1
- Spring Stiffness: 27 N/mm
- Spring Damping: 0.67 N-s/mm

Configuration 1 proved to have greater obstacle clearance and terrain adaptation. Additionally, the model incorporates a true hybrid motion in that it exhibits both rolling and walking locomotion.

Configuration 2 demonstrated a greater torque output which allowed the leg link to climb over obstacles. With this model, the mobility of the locomotion is more of a rolling and climbing method.

Trials revealed a lower gear ratio proved more ideal as it did not slip from the obstacle during climbing. Spring stiffness and damping also affected climbing during the simulation.

POTENTIAL APPLICATIONS

- Unmanned planetary exploration
- Cargo transportation
- Robotic disaster response
- Military uses
- Personal mobility

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