

# Design of Spider Mechanism for Extraterrestrial Rover

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**ABSTRACT:** This paper relates to a mechanism that involves enabling the arms of a rover to traverse up steps / rocks and still be able to take the shocks of uneven or rough terrain. The primary use of the mechanism discussed in this paper is to allow extraterrestrial rovers to climb high stepped terrain and have a suspension system in place to provide restoring force for the arms to come down and provide traction for the wheels over the ground. Such a mechanism allows the rover to travel uncharted and unexplored terrain.

**KEYWORDS:** Spider mechanism, Stepped terrain, Rover suspension, Rover arm.

## I. INTRODUCTION

The design of this mechanism is to allow a rover to traverse rough and rocky terrain which at present is not possible for conventional vehicles. The most common mechanism that is found in mars rover is the rocker bogie mechanism, the principal advantage of the mechanism is that all the wheels of the rover are in contact with the ground at all times, this property allows it to travel any terrain. The traction that a rocker bogie mechanism provides is equal and comparable to our mechanism.

## II. BACKGROUND

The spider-leg mechanism ensures that a vehicle can traverse over a considerable height greater than the chassis height which could be as much as thrice the diameter of the wheels. Additionally, as the mechanisms are actuator-powered, the slope of the rover can be adjusted in such a way that it does not topple for a wide range of inclination and allows the rover to traverse over highly rugged terrain. It provides a large amount of traction with the ground even on terrains where there is a negative slope or vertical drop of around 1m using a spring-damper suspension mechanism.

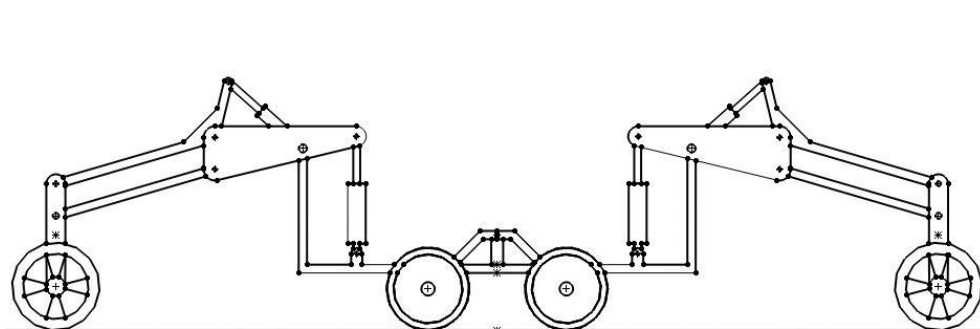


Fig 1: Side view of spider mechanism on a rover

Fig 1 illustrates how the spider legs help to support the vehicle when all the wheels are in ground. Please note that the entire linkage is pivoted at the centre of the mechanism. Initially this linkage is actuated when the rover encounters uneven terrain. The springs are mainly involved in traction control and supporting the weight of the vehicle.

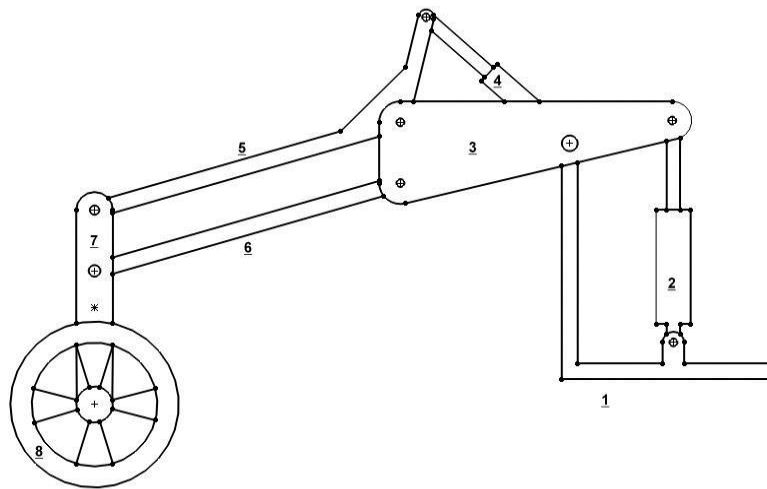


Fig 2: Spider-Leg Mechanism

The parts of the spider mechanism are

1. Chassis
2. Linear Actuator
3. Link 1
4. Shock Absorber
5. Link 2
6. Link 3
7. Link 4
8. Wheel

Fig 2 clearly depicts the spider-leg mechanism, which is a combination of the four bar linkage, spring-damper and the linear actuator; this setup provides assistance for the rover to traverse over small hindrances. One link of the mechanism is hinged to the chassis and one end of this link is pinned to the actuator and the other end to a four bar linkage.

### III. KINEMATIC ANALYSIS OF THE MECHANISM

The leg of the rover employs a linkage, which specifically is a planar linkage. For a planar linkage the degree of freedom can be calculated by Grubler's criterion.

$$F = 3*(N-1)-2*J$$

Where,

$$J = 1/2*(2*N_2+3*N_3)$$

N = total number of joints

N<sub>2</sub> = number of binary joints

N<sub>3</sub> = number of ternary joints

A spring in a linkage can be converted to a turning pair. This is because the action of a spring is to elongate or shorten as it becomes in tension or compression. A similar variation is obtained by two binary link joined by a turning pair. The linkage consists of four binary links (N<sub>2</sub>=4) and two ternary links (N<sub>3</sub>=2).

Hence the total number of links is six (N=6).

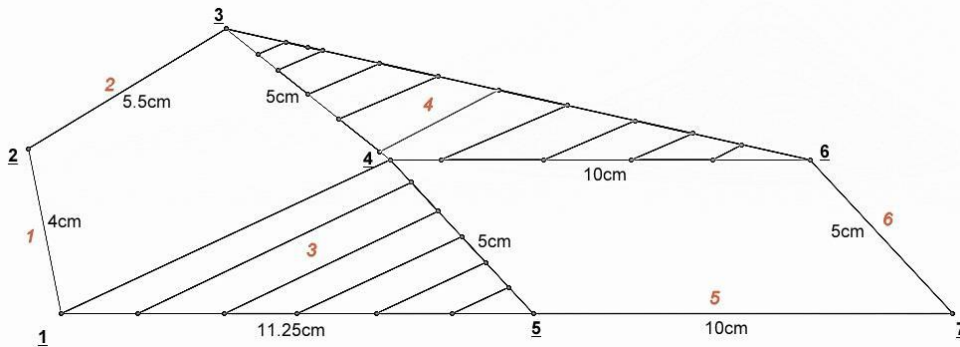


Fig 3: Equivalent Linkage Diagram

$$F = 3*(N-1)-2*J$$

$$\begin{aligned} 2*J &= 2*N_2 + 3*N_3 \\ &= 2*4 + 3*2 \\ &= 8 + 6 \\ &= 14 \end{aligned}$$

$$\begin{aligned} F &= 3*(6-1)-14 \\ &= 1 \end{aligned}$$

According to Grubler's criterion for a planar linkage when the degree of freedom is one, it is called a mechanism.

#### IV. FORMULATION OF VELOCITY POLYGON

The links move dependent of each other. Thus the velocities of each link have a relation to maintain. We experimentally deduce the velocity of a link to find out the absolute as well the relative velocities of the other links.

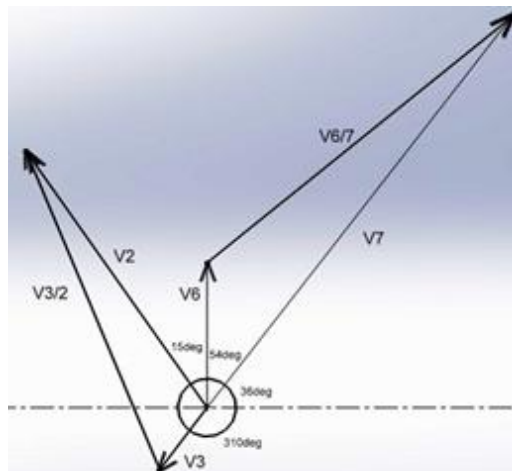


Fig 4: Velocity Polygon for Spider Leg Mechanism

For the rover, the initial velocity given was 7 cm/sec. This velocity was given at the wheel of the rover. We take an assumption that this will be the velocity with which the legs of the rover will traverse the terrain. From the velocity polygon it was understood that the velocity with which the spring displaces is about one tenth of the velocity with

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which the wheel moves up. Thus we obtain the velocities of the links from the velocity polygon as  $V_6=0.8\text{cm/sec}$ ,  $V_6/7=11.5\text{cm/sec}$ ,  $V_3=0.4\text{cm/sec}$ ,  $V_2=5.7\text{cm/sec}$  and  $V_3/2=6.3\text{cm/sec}$ .

**V. DYNAMIC ANALYSIS**

The computational tools for mechanical system simulations (MSS) are very useful in the field of computer aided engineering. With the development of MSS software, it has become possible to perform detailed investigations of the dynamics of complex mechanical systems. The various parameters of the newly developed mechanism have been found out using the help of ADAMS software. The parameters that were to be found out include velocity of each joint and link, acceleration of the links and joints, angular velocity, angular acceleration, force and torque acting on various parts and finally the deformations of the spring, deformation velocity and the forces that act on the spring. These are important in terms of the validating the new design.

The kinetic energy of the rigid body is given by,

$$T=1/2(mx^2+my^2+I\theta^2)$$

Where x,y is the location of the center of the mass in the fixed rectangular coordinate system and  $\theta$  is the orientation of the body in the plane measured from the horizontal x-axis.

The potential energy is given by,

$$V= mgy$$

The difference between the kinetic and potential energy gives the Lagrangian of the dynamic system. And Hence for a multi body dynamics the Lagrangian becomes,

$$L = \sum_{j=1}^N(T_j - V_j)$$

According to laws of Lagrangian dynamics, the motion of a multi body system is governed by,

$$\frac{d}{dt} \left( \frac{\partial L}{\partial \dot{q}} \right) - \frac{\partial L}{\partial q} + \phi_q^T \lambda = Q$$

The spider-leg mechanism was analysed in ADAMS for acceleration due to gravity of  $9.81\text{m/s}^2$ , with the weight of the members of each link. The graphs were obtained for each link.

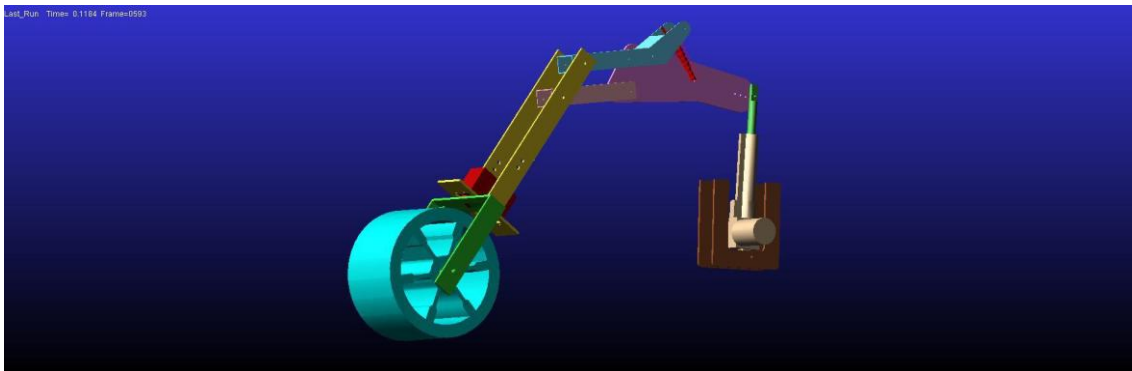


Fig 5: Simulation in ADAMS

Model graphs of rectangular link 1,

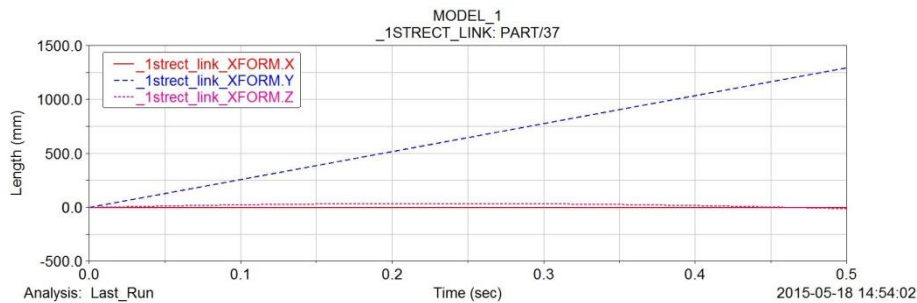


Fig 6: Length Vs Time graph of rectangular link 1

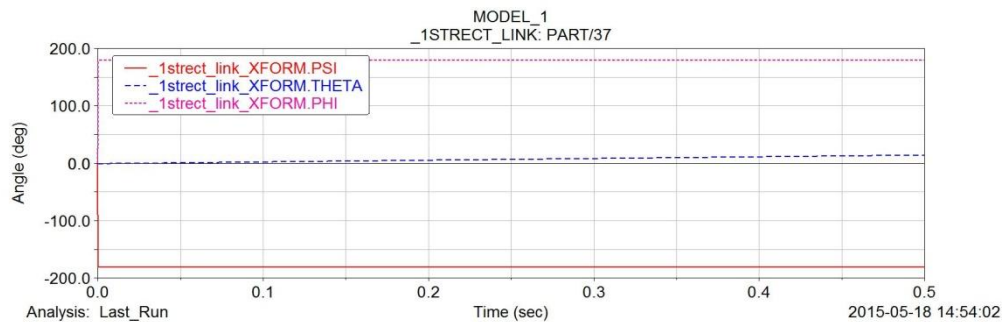


Fig 7: Angle Vs Time graph of rectangular link 1

## VI. CONCLUSION

An innovative spider mechanism has been implemented for which suitable kinematic linkage analysis and dynamic analysis were conducted to analyse that it is capable of traversing desired terrains. The fabrication of the prototype helped us experimentally validate and bring necessary changes to the design.

## REFERENCES

- [1] Mars Pathfinder: [www.mpf.jpl.nasa.gov](http://www.mpf.jpl.nasa.gov)
- [2] URC 2015:<http://urc.marssociety.org>
- [3] Hayati, S., et. al., "The Rocky 7 Rover: A Mars Sciencecraft Prototype", Proceedings of the 1997 IEEE International Conference on Robotics and Automation, pp. 2458-64, 1997.
- [4] Hervé Haco1, Steven Dubowsky1, Philippe Bidaud2, Department of Mechanical Engineering, Massachusetts Institute of Technology Cambridge, MA 02139, USA "Analysys and simulation of a rocker bogie mechanism exploration rover".
- [5] "Arbitrary Lagrangian-Eulerian methods" J. Donea, A. Huerta, J.-Ph. Ponthot and A. Rodriguez-Ferran2 LTAS, Thermo-Mécanique et Milieux Continus, Université de Liège, Campus du Sart-Tilman, B<sup>at</sup>. 52, Chemin des Chevreuils, 1, B-4000 Liège, Belgium.
- [6] 12th IFToMM World Congress, Besançon (France), June 18-21, 2007 Computing the mobility of mechanisms using displacement groups
- [7] K. Wolhart (2005), Mobility Formula Revisited, Paper CK2005 N07, Proceedings of CK2005, International Workshop on Computational Kinematics, Cassino May 2005.
- [8] J. Zhao, K. Zhou and Z. Feng (2004), A Theory of Degrees Of Freedom for Mechanisms, Mechanism and Machine Theory 39 (2004) 621-643.