DESIGN AND ANALYSIS OF TERRAIN ADAPTIVE ROBOTIC SUSPENSION ROVER

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Abstract - *In this paper, the proposed concept is to replace the existing rocker bogie suspension system which is currently the most favored design for every space exploration and research with a new conceptual design. Our project involves a bio-inspired link which will be used in the place of rocker bogie suspension link. The main motive of this project initiation is to understand mechanical design and advantages of our proposed suspension system in order to find suitability to implement it in space rovers or space vehicles to enhance their efficiency and also to cut down the maintenance related expenses of conventional rover suspension systems.*

***Key Words*:** exploration, efficiency, mission, rocker-bogie, bio-inspired link, Suspension.

1. INTRODUCTION

To design an effective suspension mechanism with minimum design and control complexity for a space rover is the focus of the research here. Past research on wheeled all-terrain vehicles has led to the development of two types of suspension mechanisms: active and passive. Passive suspension rovers adapt passively to the underlying environment by the virtue of contact forces and hence do not require any actuators for controlling the internal configuration of the vehicle thus significantly reducing the control architecture. When sophistication increases the number of joints and links also increases significantly increasing the overall complexity and weight of the system. In general joints are heavy parts and can easily lead to trouble in space environments.

In our work we aim to find a mechanism where the elements of active suspension mechanism are utilized. We first analyze a six wheeled passive suspension rover and try to replicate the same motion with a similar 4-wheeled active suspension design. The control strategy proposed for the deduced four wheeled rover is simple and require the knowledge of only the angular velocity of the back leg of the rover. The complexity of the design is greatly reduced in terms of the number of joints and links comprising the system without compromising with the traversibilty of the rover. The novelties of the work include bio inspired suspension mechanisms and a simplified control methodology for the 4-wheeled active suspension mechanism.

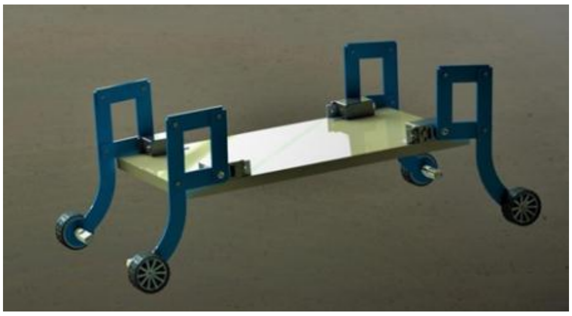

Fig-1: A 3D image of the conceptual rover

1.1 WHAT IS A ROVER?

A mobile rover is an autonomous vehicle capable of traversing a terrain with natural or artificial obstacles. Its chassis is equipped with wheels, tracks or legs and possibly a manipulator setup mounted on the chassis for handling of work pieces, tools or special devices. Various preplanned space operations are executed based on a pre-programmed navigation strategy taking into account the current status of the current environment. The idea of sending a mobile robot to the surface of another planet is to allow earth bound scientist's access to specific areas of interest without enduring the harsh environments of space. The robot carries instruments to various terrestrial formations for in-situ experimentation. The goal of the rover is to move between areas of interest quickly and safely. In order to better represent the planet of interest the rover must be able to travel tens of kilometers.

1.2 ROCKER BOGIE SUSPENSION- AN OVERVIEW

The rocker bogie suspension system, designed especially for space exploration vehicles have deep history embedded in its development. The phrase "rocker" describes the larger links present each side of the suspension system that are used to balance the bogie as these are connected to each other and to the vehicle chassis through a differential. In accordance with the motion to maintain the center of gravity of the entire vehicle, when one rocker moves up-word, the other goes down. The chassis plays a vital role in maintaining the average pitch angle by allowing both the rockers to move as per the requirement. On the basis of the design, one end of a rocker arm is fitted with a drive wheel and the other end is pivoted to a bogie which provides required motion and degree of freedom.

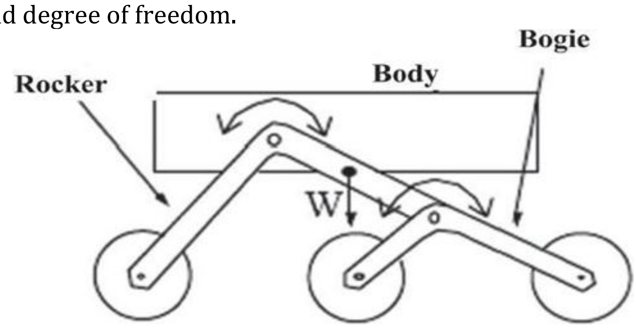

Fig-2: 2D Line diagram of Rocker-bogie suspension system and its motile joints

2. BIO-INSPIRED LINK DESIGN

Our project involves a bio inspired link which will be used in the place of rocker bogie suspension, where it is inspired from the human body. Human body is the most advanced control system in the world the design is inspired from the joints of human limbs under controlled actions like self-balancing of our posture while riding a bicycle under uneven terrain and etc.

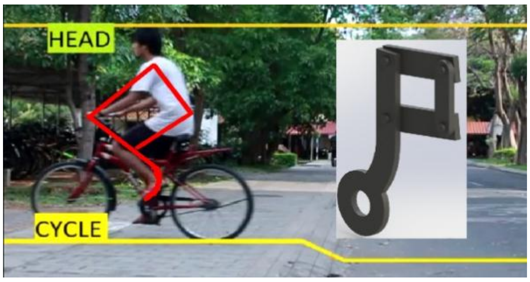

Fig-3: Cycling profile compared to the link

The movement of the link under uneven terrain is illustrated as below:

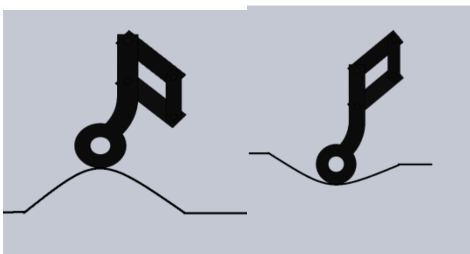

Fig-4 (a) & (b)

The above a & b designs show the displacement of the link when it approaches a bump and a ditch respectively

2.1 DESIGN CHALLENGES

- Minimal weight and size
- Reliable long term operation of all critical systems
- Ability to survive and operate in abrasive and dusty environment
- Safe utility in extreme radiation and thermal conditions
- Efficient power utilization and transmission
- Ability to maneuver in majority of terrains on Mars
- Modular systems that can be utilized across other missions

2.2 3-D DESIGN OF THE ROVER

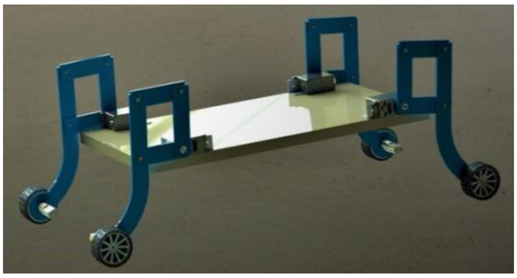

Fig-5: Rover without fixed column

The above design is the fully rendered image of the rover without any fixed points or extra stability. It has its one end of the j link fixed to the servo inducing high tension on the servo motor. Thus due to the lack of a supporting point the entire weight of the rover lies in the servos causing failure or lowered results while operation.

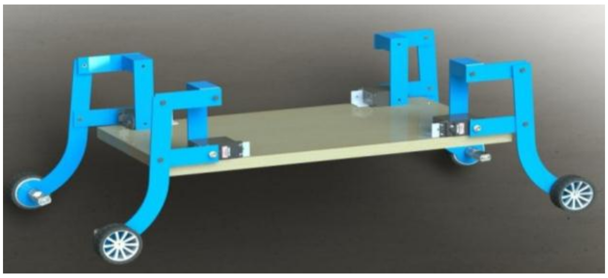

Fig-6: Rover with fixed column

In order to overcome the above drawback, we removed the freely placed four bar link and replaced it with a rigid four bar linkage supported by a rectangular L shaped column for even distribution of load and stress . This rigid columns also provide greater stability, load bearing capacity and ease at link movement compared to the freely hanging four bar link. Thus the addition of the fixed points improved the efficiency of the rover.

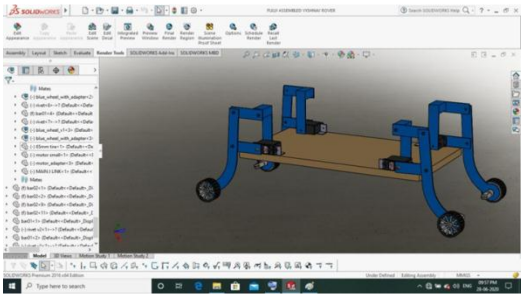

Fig-7: Solid works design model of the rover

With the improved design stated in the previous title, the rover is capable of traversing all steep obstacles. However due to the no availability of six wheeled locomotion, the rover may struggle to regain its stability while climbing obstacles. The main drawback associated with improved design is that, when the obstacle to be maneuvered is narrow, there are some chances that the base of the rover may get wrecked or run aground by the obstacle which results in loss of traction or mobility.

In order to overcome this drawback, we designed a pair of hinge limbs which are provided at the center of the base of the rover such that whenever the rover gets stranded or wrecked by obstacles these limbs actuate out of their positions and release the body of the rover stranded by the obstacle. These limbs may also be programmed in such a way that it prevents the rover from toppling at exo-planetary surfaces. Therefore the rover combines the capability of maneuvering over obstacles like a six-wheeled rover and the mobility of the four wheeled rover through the implementation of these hinge limbs.
The design is as follows:

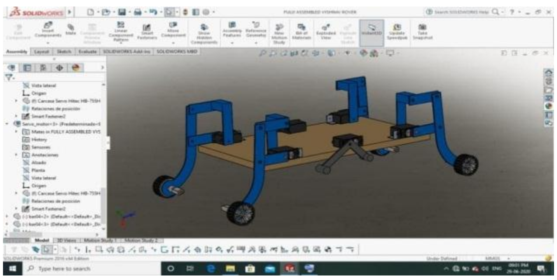

Fig-8: Rover with hinge limbs

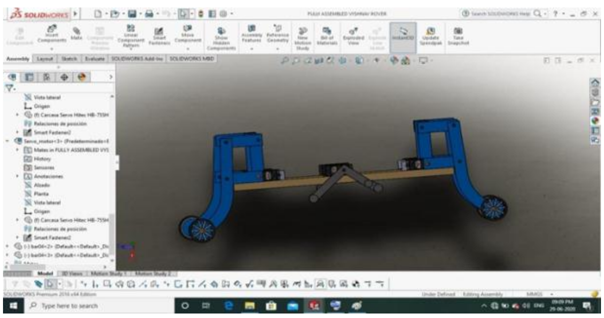

Fig-9: Side view of the rover

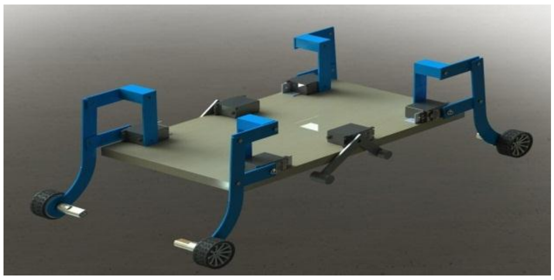

Fig-10: 3D rendered image

3. WORKING PRINCIPLE

The working of this rover is similar to that of rocker bogie suspension, In rocker-bogie mechanism there are two types of arms, they are rocker arm and bogie arm. The rocker arm moves independently over the surface which helps to climb over the inclined surfaces. The bogie arm is connected to rocker arm through the hinges. The rocker-bogie setup can be operated by using high torque dc motors connected to the wheels of the system. Rocker-bogie mechanism has six wheeled structure which has more control over other wheel drives but here we use 4 wheeled structure. By using higher torque dc motors we can able to move the rover over inclined surfaces. The forward and backward motion of the vehicle can be controlled by using power control to the battery supply. Servo motors are used to rotate the rover about 360 degrees. These can be controlled wirelessly by setting microcontroller unit to the system, the microcontroller controls the action of the rover as per the input it receives. It also controls the direction of the motion of vehicle by controlling the servomotor.

4. ANALYSIS OF THE J-LINK

The finite element analysis is a very important tool for those involved in engineering design; it is now used routinely to solve problems in the following areas.

- Structural analysis
- Thermal analysis
- Vibrations and Dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations

We carried out structural analysis for the rover design especially for its bio inspired link. The following are the analysis of the proposed link for suitable materials. The most suitable material for the space rover is Aluminium and Titanium. However Titanium is not cost efficient, in order to overcome this, we chose a material with similar properties called acrylic for inland explorations under earth conditions. Titanium or Aluminium can be used for space explorations.

The analysis is as follows:

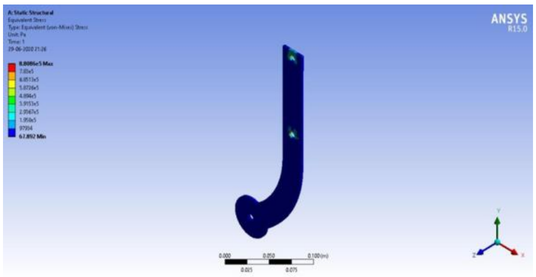

Fig -11: Equivalent strain (Aluminium)

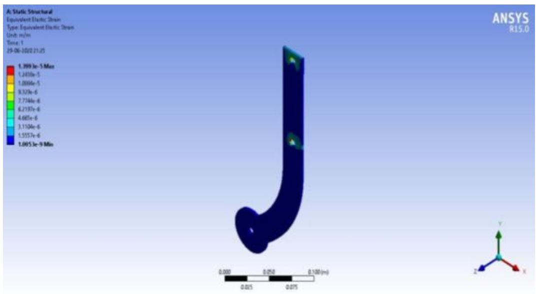

Fig -12: Equivalent stress (Aluminium)

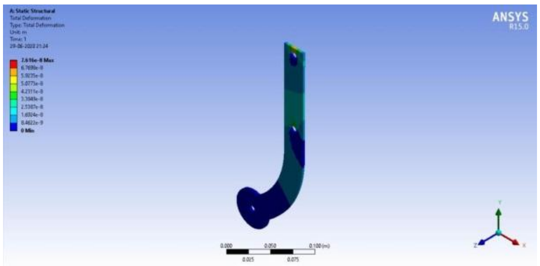

Fig -13: Total Deformation (Aluminium)

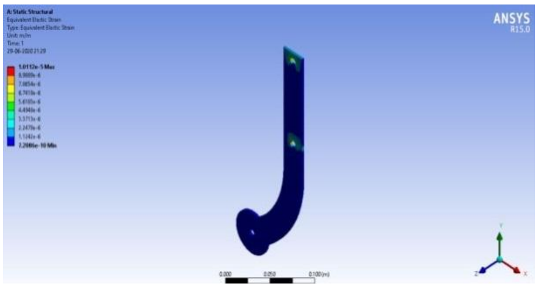

Fig -14: Equivalent strain (Acrylic)

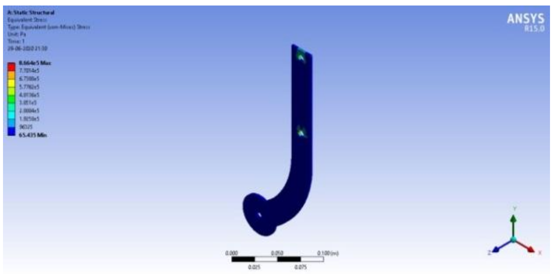

Fig -15: Equivalent stress (Acrylic)

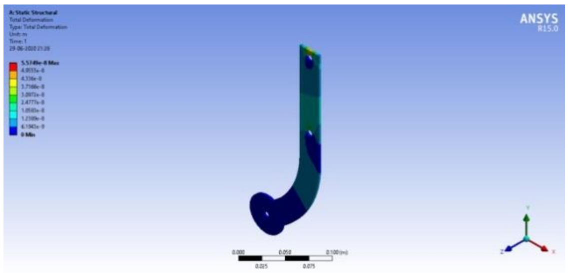

Fig -16: Total deformation (Acrylic)

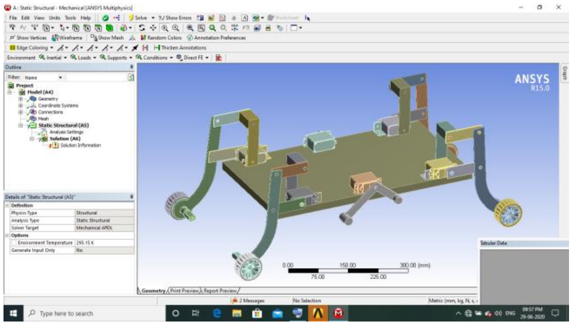

Fig -17: Structural Analysis of fully assembled rover

5. RESULTS AND DISCUSSION

The results for the Structural analysis of the J link for feasible materials are given below:

a) STRUCTURAL ANALYSIS – I

S.NO	TYPE	MAX (MPa)	MIN (MPa)
1	Total deformation (Acrylic)	$5.5749e^{-5}$ m	0
2	Equivalent elastic stress (Acrylic)	$8.664e^{5}$	65.435
3	Equivalent elastic strain (Acrylic)	$1.0112e^{-5}$	$7.2086e^{-10}$

b) STRUCTURAL ANALYSIS - II

S.NO	TYPE	MAX (MPa)	MIN (MPa)
1	Total deformation (Aluminium)	$7.616e^{-5}$ m	0
2	Equivalent elastic stress (Aluminium)	$8.8086e^{5}$	67.892
3	Equivalent elastic strain (Aluminium)	$1.3993e^{-5}$	$1.0053e^{-9}$

5.1 ADVANTAGES

- The proposed system is the most suitable for space exploration.
- All wheels of vehicles have more control over the terrain.

- It enables the rover to pass through the obstacles in the path.
- It can rotate and move through the various surfaces which have unparalleled surfaces.
- The weight of the vehicle is less due to the usage of lightweight material such as acrylic glass.

5.3 APPLICATION

- We can install some latest software in the rover and can be controlled by gadgets.
- By using latest technologies we can install camera in the rover and can be viewed and controlled over longer distance.
- It can be used for surveillance purpose.
- Due to its auto suspension system we can use it for various purposes like bomb detection and in defense.
- With a proper research, the links can be implemented in suspension system of automobile vehicles

6. CONCLUSIONS

This work describes constructing a rover by fully using a light weight material, acrylic and bio inspired link. Due to this light weight acrylic and the employment of bio inspired link, the mobility and speed of the rover is improved. This rover is controlled by RC kit, so that it can also be used for various purposes including surveillance, extraterritorial surfaces. This rover can also be developed further for future needs. The developed rover achieved climbing capacity for the slope of 30 degrees. It can have stable chassis with minimum degree pitch angle deviation. Therefore the rover combines the capability of maneuvering over obstacles like a six-wheeled rover and the mobility of the four wheeled rover through the implementation of these hinge limbs.

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