CONEM 2016
CONGRESSO NACIONAL DE ENGENHARIA MECÂNICA
21 - 25 AGOSTO DE 2016
FORTALEZA - CEARÁ

SIMULATION OF CURIOSITY AND EXO MARS ROVER ON AGRICULTURE TERRAIN

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Abstract. *Currently, one of the biggest challenges of agriculture and engineering is to improve agricultural productivity, A possible solution is the creation of soil databases or maps to apply precision agriculture techniques, with the aim to produce more in the same space using less agricultural supplies. This practice can be developed with help of robots type rovers applied to: agricultural data collect, mapping, scouting and supplies application; however the rover needs to move and adapt to terrain to obtain a real appropriate map of soil, and the correct application of supplies, in this context, this work presents the simulation of two types of rovers, applied to precision agriculture. The models were developed in the software SolidWorks based on the Curiosity and Exo Mars Rovers, developed by NASA and ESA, respectively. The paper presents the comparison, between the Curiosity and Exo Mars models, and its ability to real terrain adaptation using the parameters of torque, energy consumption and lateral deviation*

Keywords: *Mobile Robotics, Rover, Precision Agriculture, Simulation, Mechatronics*

1. INTRODUCTION

According to IBGE (Brazilian Institute of Geographic and Statistics) The Brazilian agriculture is growing and currently corresponds to approximately to 23 percent of PIB of the country, to the present year the expected growing will be of 2.4 percent respect to 2014 (CEPEA, 2014) turning the country as one of the principals agricultural suppliers into the world. The principal challenge of the productors nowadays is the improve of productivity using the same land and less supplies, then it is obligatory that current methods of food production become more efficient. For this reason, it is important to make use of new techniques and technologies to support agriculture production. Some of the new technologies to be applied in agriculture production are provided by mobile robotics. They are used to automate repetitive tasks and/or apply techniques of precision agriculture, assisting specific needs of each plant in the crop. These new technologies present considerably important challenges. The agricultural environment, for instance, has spatial and temporal variability, It consists of an unstructured environment, in which is important the development of outdoor mobile robotics platforms. Some previous researchs were developed as presented by Moreira *et al.* (2014) the article presented a comparisson between the rovers Crab and Schrimp. The present research presents the models and simulations of two types of rovers used to spatial exploration the MSL (Mars Science Laboratory) commonly named of Curiosity developed by NASA (National Aeronautics and Space Administration) and the ExoMars developed by ESA (European Space Agency) they were choosen because they are the most recents and advanced passive suspension models. this kind of suspensions have less energy consumption and it is an important characteristic to modern agriculture. The models were studied and were simulated in agricultural environment. The results obtained present its energy consumption; torque and lateral slip comparative study.

2. METHODOLOGY

The methodology used was based on the methodology proposed by (Faber Archila and Becker, 2013). It starts with passive suspension systems study and work environment and application study, followed by kinematic and dynamic parameters, the CAD (Computer Aided Design) and CAE (Computer Aided Engineering) models with its respective simulations, and results, which allows the comparison between rovers Curiosity and Exomars, in the simulations we used the topography of a perennial crop field. the block diagram that describes the methodology is presented at Figure.1

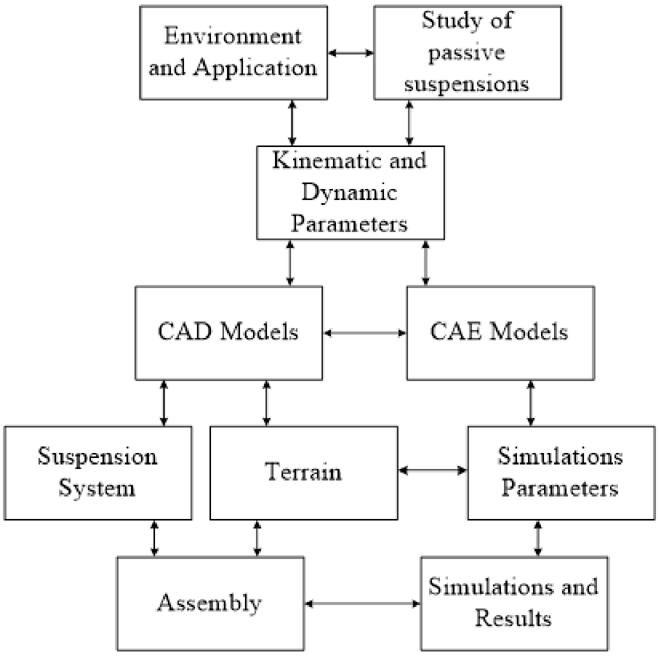

Figura 1: Methodology block Diagram, (Authors)

3. CAD MODELS

The CAD models were developed using the software Solid works. Two CAD (Computer Aided Design) models were developed. The first one is based on the Curiosity rover (NASA rover that landed in Mars on November 26th, 2011). The second one is based on the Exo-Mars, ESA rover that is planed to go to Mars in 2018. The Exo-Mars was designed as a result of analyses and evolution of seven concepts of previous rovers. They are: RLC Concept C, D and E (originally by RCL - Transmash Russia), CRAB (ETHZ Swiss Federal Institute of Technology in Zurich - EPFL *Ecole polytechnique federale de Lausanne*), 3-Bogie and V Bogie proposed by Astrium, and Rocker Bogie (NASA at JPL Jet Propulsion Laboratory). 3-bogie concept was considered the preferred arrangement. The rover has six drive wheels and six steering and tactile wheels. (Patel *et al.*, 2010)

3.1 Curiosity

The Mars Science Laboratory MSL nicknamed of curiosity was patented in 2010 US D673482 S (Rivellini, 2005) is a rover with six drive wheels, four steering wheels and Rocker bogie suspension mechanism, as they predecessors MERs (Mars Explorer Rovers). Curiosity's weight is approximately 900 kg. The rover is powered by a radioisotope thermoelectric generator (RTG) that produces approximately 110W of continuous electrical power. Rechargeable li-ion batteries provide approximately 1600Whr of usable energy storage each day. The energy budget allows the rover to be awake about six hours of each Martian day and it sleeps the rest of the time to recharge batteries. (The Martian solar day, or sol, is 39 minutes longer than an Earth day). An active thermal control system includes a continuously-operating pumped fluid loop to control temperature of the hardware inside the rover while the Martian ambient temperature fluctuates between approximately -80C and 0C every sol. Warm-up heaters are required on exterior actuators and cameras to ensure they are above a minimum operational temperature of approximately -50C before use. The rover communication system includes a low data-rate direct-to/from-Earth XBand transceiver as well as a high data-rate UHF-band transceiver for communication with Mars orbiters for data relay with Earth. See Figure.2.

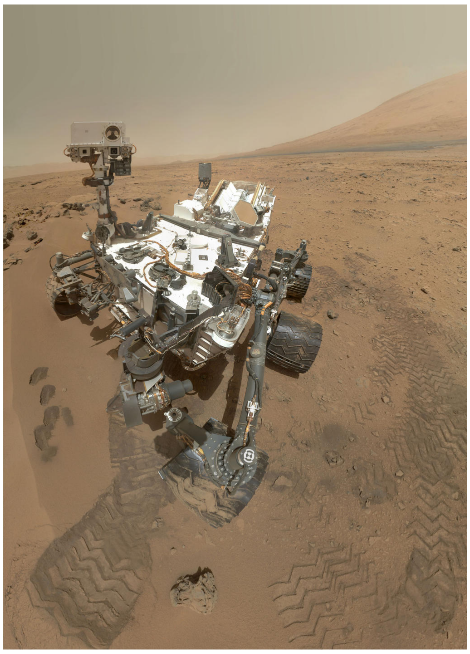

Figura 2: Self-Portrait by Curiosity Rover Arm Camera, (NASA)

The Curiosity rover was scaled and the scaled parameter found was 3.714 it was calculated using the wheel diameter of the Figure.2 and transform to 130 mm correspondent to wheel diameter parameter chosen to these simulations. Tab.1.

Tabela 1: Scaled Parameters (NASA) Curiosity

		WHEEL		
WHEEL DIAMETER	35	130		
PROPORTION	3.71428571			
		BOGIE		
HEIGHT1	37.5	139.285714	140	109.756098
ANGLE1	84.1			
LENGTH1	45.53	169.111429	170	133.258537
LENGTH2	39.45	146.528571	147	115463415
ANGLE	157.5			
HEIGTH2	14	52		40.9756098
		ROCKER		
LENGTH1	62.43	231.882857	232	182.721951
ANGLE1	149			
LENGTH2	67.47	250.602857	251	197.473171
ANGLE2	102			
HEIGTH1	40	148.571429	149	117073171
VERTICAL SUPPORT	16	59.4285714		46.8292683

The final model to the Mars Science Laboratory Fig.3 was published by Welch *et al.* (2013) and by the Jet Propulsion Laboratory at NASA. Figure.3(a) the CAD model developed is presented in the Figure.3 (b). It uses the rocker bogie suspension, the differential mechanism and the proportions that were given in the Tab.1

(a) MSL (NASA - JPL) (b) CAD model

Figura 3: MSL (NASA-JPL) and CAD model

3.2 Exo-Mars

The rover ExoMars, developed by ESA (European Space Agency), was designed as a result of analyses and evolution of seven concepts of previous rovers. They are: RLC Concept C, D and E (originally by RCL - Transmash Russia), CRAB (ETHZ - EPFL), 3-Bogie and V Bogie proposed by Astrium, and Rocker Bogie (NASA – JPL). 3-bogie concept was considered the preferred arrangement. The rover has six drive wheels, six steering and tactile wheels. See Figure.4. This design does not use the differential system used by rocker bogie that decreases the weight, which means that stability is better. ExoMars offered better step climbing performance. The rover has tactile wheels that improve the contact with the soil and the traction. (Patel *et al.*, 2010)

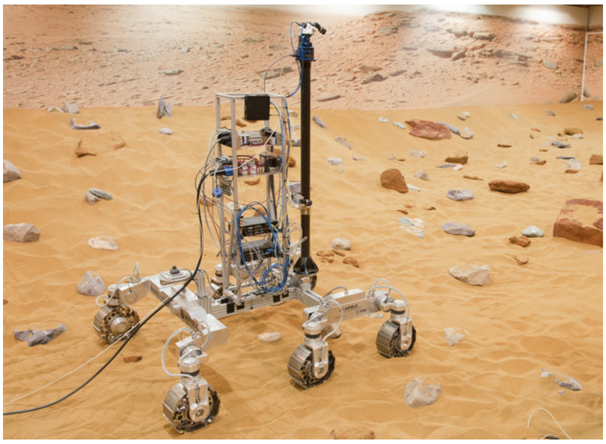

Figura 4: ExoMars Rover, (ESA)

The ExoMars uses the three bogies concept, two bogies are in the lateral and the other bogie is in the rear of the rover, the proportions are according the model Curiosity using the same wheel diameter and dimensions, the CAD model uses the three bogie concept and is presented at the Figure.5, the body of the CAD model was made to achieve the same mass of curiosity CAD model.

(a) ExoMars (ESA)

(b) CAD model

Figura 5: ExoMars (ESA) and CAD model

3.3 SIMULATIONS AND RESULTS

Were made two type of simulations the first one we use an step terrain. Figure.6, to compare the climb ability and a second one simulation using real terrain modeled and obtained of Maringa field (Citrosuco). In the first simulation we obtained the maximum step to climb and the maximum to go down, the results are presented in the Tab. 2.

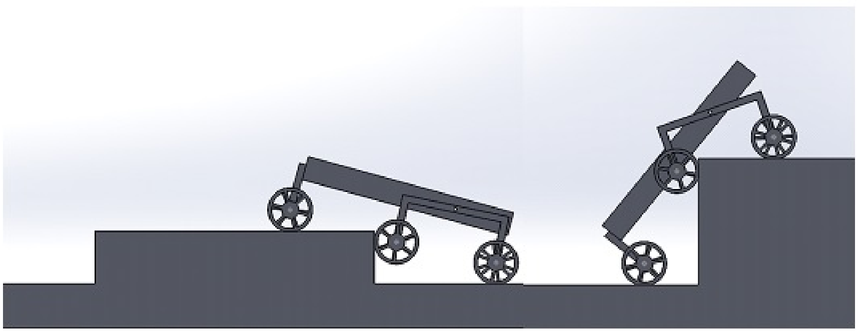

Figura 6: ExoMars climb test

Tabela 2: Simulations results for step test.

Parameters	***MSL***	***ExoMars***
Maximum step (Climb) [Wheel Diameters]	1.85	2.86
Maximum step (Get off) [Wheel Diameters]	1.05	1,19
Maximum torque [N-m]	1.399	1.964
Average torque [N-m]	0.141	0.194

According with results presented in Tab. 2 in the first phase the rovers were tested using the same obstacle size, the obstacle used has two step the first one has 1.05 times the wheel diameter and the second has 1.85 wheel diameter times, those dimensions are the warranty to the pass of the rovers configurations. Following we present the results to each rover type. Figure.7

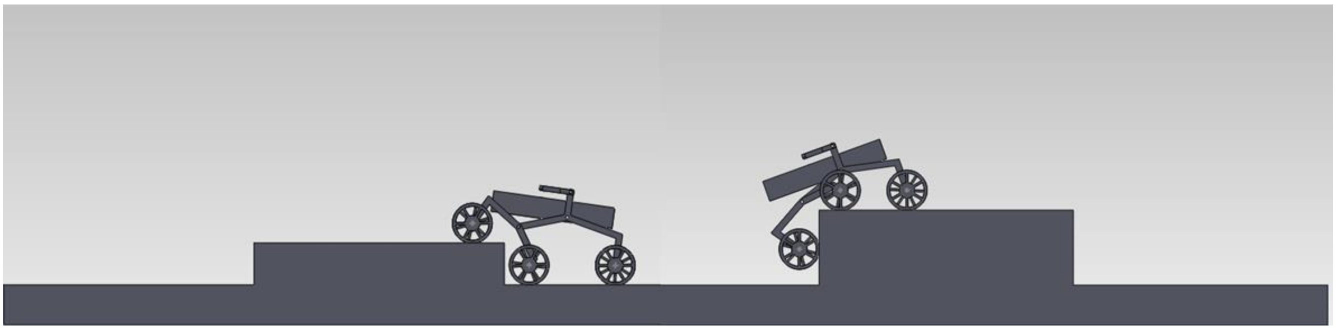

Figura 7: MSL test step

In the simulation using the step we obtained the torques to each rover's wheels one example is presented in the Figure.8. Where M1 are Front motors, M2 body Motors and M3 Rear Motors.

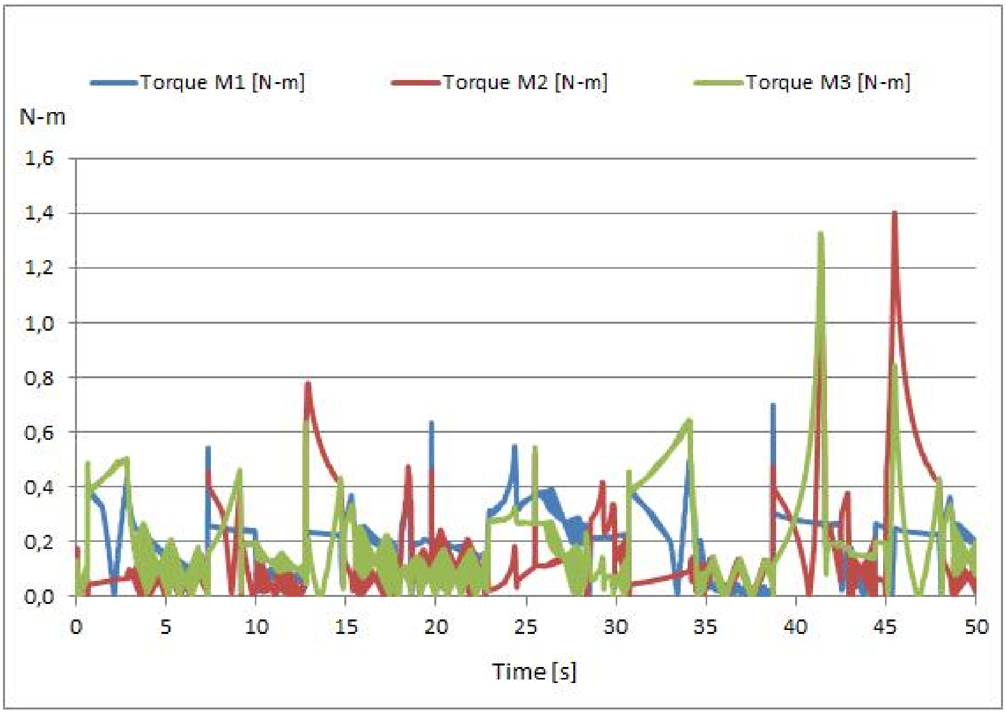

Figura 8: Torque to MSL in test step

The summarize results of the first simulation are presented in the Tab. 2. The table presents the Maximum step climbing, the maximum step to get off, the maximum torque to each rover and the torque average of the motors of each rover.

The second simulation uses real terrain data obtained in Citrosuco Brazil in the Maringa Farm, the terrain was modeled in Solidwork and used to simulations. The simulation evaluated the torque consumption and lateral deviation one example of results is presented in the Figure.9

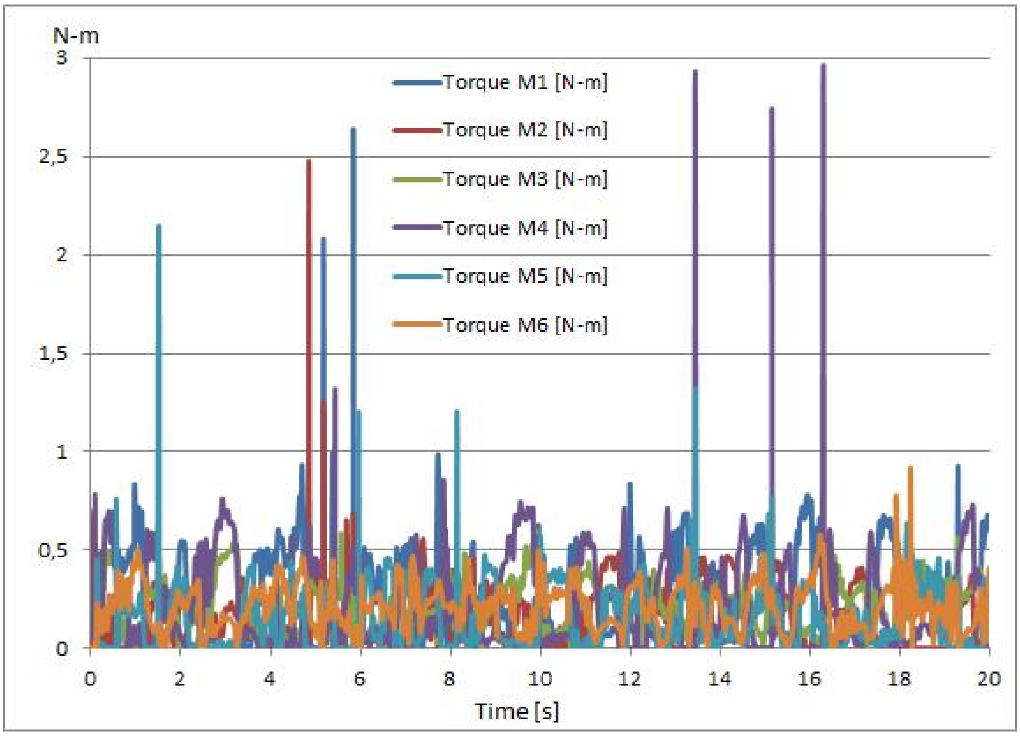

Figura 9: Torque obtained in the simulation to ExoMars

In the fig 10 we observe several peaks, these peaks, in some case, are the results of impact of wheels with the soil, it means that the wheels lose contact with the terrain and when the contact return the impact generate torque increasing one example is presented at Figure.10

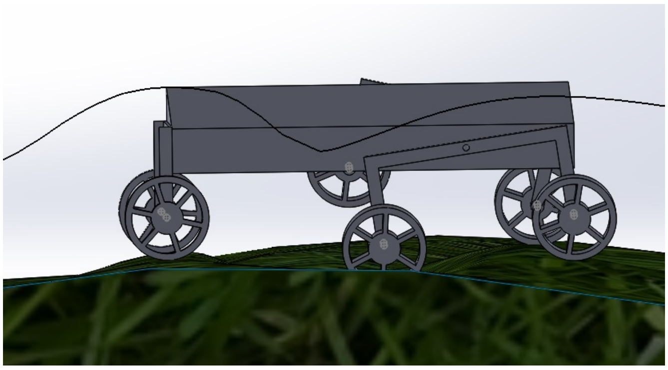

Figura 10: loss contact of the wheel in the simulation

Other obtained results correspond to lateral deviations that are measured as the proportion of deviation in the perpendicular direction of movement see Figure.11.

Figura 11: Lateral deviation

The summarize of results is presented in the Tab 3 the results corresponds to Maximum torque, higher average torque, total average torque, average power consumption and lateral deviation. MSL presented better values to Torques, however ExoMars presented less lateral deviation in about three percent respect to MSL.

Tabela 3: Simulations results for real soil

Parameters	***MSL***	***ExoMars***
Maximum torque [N-m]	2.836	2.96
Higher average torque [N-m]	0.262	0.244
Total average torque [N-m]	0.194	0.237
Average power consumption [Watts]	2.967	3.618
Lateral deviation (Y/X)*100	1488/19733 7.54%	915/19956 4.59%

4. CONCLUSIONS

Two simulations were developed: The first simulation uses the models of rovers MSL, ExoMars and a route controlled; the metrics used were the capability to overcome obstacles and torque values. The better performance was to ExoMars rover. The second simulation uses the models of MSL, ExoMars and a real soil, the metrics were: torque and lateral deviation, this simulation presents different routes to each rover using the same initial conditions. The better performance was to MSL. It is important to highlight that each rover has good characteristics according the metric used and it summarize was presented in tables 1 and 2. The results shown the consumption of two passive suspension systems in agricultural terrain and its capability to overcome obstacles, these characteristics are very important in agricultural terrain and future applications.

5. ACKNOWLEDGEMENTS

The authors express their acknowledgment to CNPq, FAPESP, EESC-USP, UIS, IFSP, and Citrosuco by support the research project and this Article.

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JPL, Jet Propulsion Laboratory. Available in: http://www.jpl.nasa.gov, visited: march 2015.

7. RESPONSIBILITY NOTICE

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