A STUDY OF A ROVER WHEEL FOR MARTIAN EXPLORATIONS, BASED ON A FLEXIBLE MULTIBODY APPROACH

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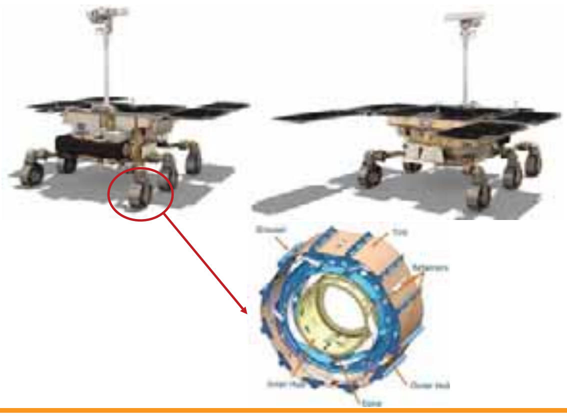


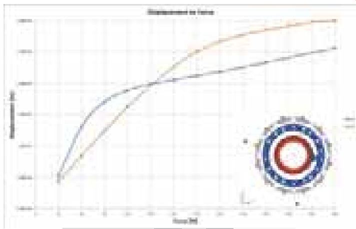
Introduction

Vehicles for planetary exploration have to operate in different environments, completely different from Earth. For this reason, the design process of the exploration unit has an important role and can affect the requirements of the entire mission for the different space agencies involved. These operations are very expensive and time consuming so that over the years, CAE methods have been developed to help engineers in the design stage. These methods are used to simulate several working conditions, evaluating the manoeuvres that these robots can perform safely once their mission is started. In this frame, a study was performed by *Politecnico di Torino* and *Thales Alenia Space Italia*. The goal was to find the most efficient implementation of the flexibility properties of a Rover for Martian explorations wheel, considering the ExoMars Rover as case study. When dealing with manoeuvres feasibility, the best compromise between the accuracy of the solution and the time required to obtain it should be found.

FE characterization of the wheel – Stiffness curves

A preliminary Finite Element Analysis, performed with Thales Alenia Space Italia's engineers, led to the nonlinear characterization of the wheel, obtaining a relationship between forces and displacements. These analyses were considered as a baseline reference for the validation of subsequent models created in the multibody environment. Two limit trend lines were identified to characterize the behavior of the wheel.

FE Model



Stiffness limit curve

MTB modelling techniques

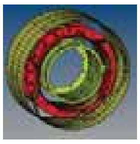
The aim of this study is to introduce flexibility properties of a component in a complex multibody model. Large deformation analyses can be efficiently solved using *Absolute Nodal Coordinate Formulation (ANCF)*, which have already been applied to a wide variety of nonlinear problems. This approach could be very time consuming from a computational point of view, due to the large complexity introduced in the model. For this reason, several alternative methods to introduce flexibility as a relative motion between bodies connected with compliant joints are explored.

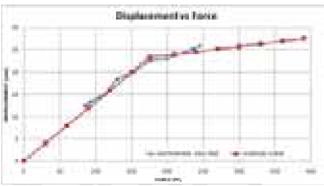
Strategies of implementation
- Flexible bodies
  - ANCF elements
- Rigid bodies and compliant joints
  - *Reduced mesh morphing model*
  - *Compliant revolute joints' wheel*

Flexible bodies

ANCF model of the wheel using NLFE (Altair MotionView):

The flexible parts of the wheel have been discretized through the use of Non-Linear Finite Elements (NLFE) bodies, a kind of flexible bodies available in Altair MotionView modeled according to the ANCF theory, using fully parameterized FE.

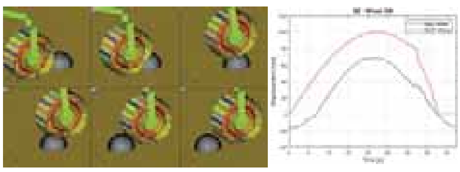




It is possible to notice that the absolute percentage error of the response was below 10% for almost all the considered cases

The limit curves obtained with the nonlinear static analyses performed in the FE environment were used to validate the NLFE model of the wheel. The validation procedure aimed to verify if, by modifying the force on each wheel, the deformation value obtained in the MTB simulation was consistent with the average one.

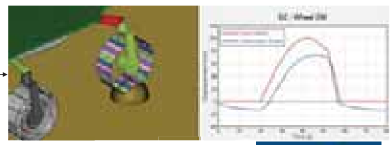
The NLFE wheel will be able to perform some maneuvers otherwise impossible with rigid wheels, such as overcoming some irregularly shaped obstacles.



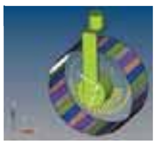
Vertical displacement of the wheel when the wheel overcomes a rock with 100mm of height. Results obtained with NLFE wheel were compared with those obtained with rigid wheels.

Rigid bodies and compliant joints

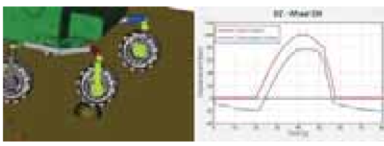
Reduced mesh morphing model of flexible wheel:
This approach is based on the construction of a set of cylindrical meshed sectors in the FE environment to model a deformable surface. These graphics are associated to massless rigid bodies and are connected with the center of the wheel with compliant joints in which their reference frame is oriented in order to express the stiffness of the wheel in radial, direction obtained during the nonlinear static analyses.



Vertical displacement of the wheel when the wheel overcomes a rock with 100mm of height. Results obtained with reduced mesh morphing model of flexible wheel were compared with those obtained with rigid wheels.



Compliant revolute joints' wheel:
This method is based on making compliant the joints located between the wheels and the wheel arms of the Rover. It is then sufficient to express the translational stiffness in vertical and forward directions to obtain the required deformable properties.



Vertical displacement of the wheel when the wheel overcomes a rock with 100mm of height. Results obtained with compliant revolute joints' wheel were compared with those obtained with rigid wheels.

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