

A predictive wheel-soil interaction model for planetary rovers validated in testbeds and against MER Mars rover performance data

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Successful designs of vehicles intended for operations on planetary objects outside the Earth demand, just as for terrestrial off-the-road vehicles, a careful assessment of the terrain relevant for the vehicle mission and predictions of the mobility performance to allow rational trade-off's to be made for the choice of the locomotion concept and sizing. Principal issues driving the chassis design for rovers are the stress-strain properties of the planetary surface soil, the distribution of rocks in the terrain representing potential obstacles to movement, and the gravity level on the celestial object in question. Thus far, planetary rovers have been successfully designed and operated for missions to the Earth's moon and to the planet Mars, including NASA's Mars Exploration Rovers (MER's) 'Spirit' and 'Opportunity' being in operation on Mars since their landings in January 2004.

Here we report on the development of a wheel-soil interaction model with application to wheel sizes and wheel loads relevant to current and near-term robotic planetary rovers, i.e. wheel diameters being between about 200 and 500 mm and vertical quasi-static wheel loads in operation of roughly 100 to 200 N. Such a model clearly is indispensable for sizings of future rovers to analyse the aspect of rover mobility concerned with motion across soils. This work is presently funded by the European Space Agency (ESA) as part of the 'Rover Chassis Evaluation Tools' (RCET) effort which has developed a set of S/W-implemented models for predictive mobility analysis of rovers in terms of movement on soils and across obstacles, coupled with dedicated testbeds to validate the wheel-soil models.

In this paper, we outline the details of the wheel-soil modelling performed within the RCET work and present comparisons of predictions of wheel performance (motion resistance, torque vs. slip and drawbar pull vs. slip) for specific test cases with the corresponding measurements performed in the RCET single wheel testbed and in the RCET system-level testbed, the latter permitting drawbar pull vs. slip measurements for complete rover development vehicles under controlled and homogeneous soil conditions. Required modifications of the wheel-soil model, in particular related to modelling the effect of wheel slip, are discussed. To strengthen the model valida-

tion base, we have run single wheel measurements using a spare MER Mars rover wheel and have performed comparisons with MER actual mobility performance data, available through one of us (LR) who is a member of the MER Athena science team. Corresponding results will be presented.

Keywords: rovers, wheel, soil, mobility, vehicle performance, RCET (Rover Chassis Evaluation Tools), MER (Mars Exploration Rover mission)