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Abstract of Doctoral Thesis

Title：Experimental Study on Interaction Mechanics between an Active Lugged Wheel and Sandy Soil

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For planetary explorations and geological investigations, wheeled robots have been deployed to access sandy environments, which are widely distributed across terrestrial, lunar and Martian surface. On such soft terrains, wheels easily slip and become trapped, which may result in mission failure. The mobility of wheeled robots can be improved by attaching protrusions or convex patterns called lugs (i.e. grousers) to the surfaces of their wheels. However, these fixed lugged wheels inevitably generate unwanted fluctuations in the drawbar pull and vertical force as the individual lugs interact with the soil. Such oscillations would compromise the stability of the robot. In this study, we develop a wheeled mechanism, called Active Lugged Wheel (ALW), by integrating a set of actively actuated lugs into a traditional wheel. As the wheel rolls on soft terrains, inclination angle and protruded length of the lugs can be actively adjusted by controlling the position of the lug shaft. To highlight the advantages of tuning lug trajectory for improving performance of the ALW mechanism, the experimental study is firstly conducted to investigate the effect of lug motion on lug-soil interaction forces using a single lug, and then extended to investigate the effect on ALW-soil interaction forces. The idea of fluctuation reduction in drawbar pull by tuning the lug’s trajectory is also experimentally validated.

Based on results from the lug-soil and the ALW-soil interaction experiments, the lug inclination angle and protruded length are found to have significant effects on the ALW-soil interaction forces. From single lug experiments, we confirmed that soil reaction forces are independent of traveling speed as the speed is below 10 mm/s. As the lug horizontally moves in the soil, lug-soil interaction forces can be divided into transient state and steady state; the change of soil reaction force in the transient is mainly contributed from the ground swell owing to excavation of the lug, and soil reaction force is a quadratic function of lug sinkage length in both transient state and steady state. The similar results were also found in ALW-soil interaction measurements: the relationship of maximal soil reaction force and lug sinkage length satisfies the quadratic function. Furthermore, it is confirmed that the presence of the wheel rim enlarges the drawbar pull and vertical force than the single lug without the wheel. In addition, comparing with a conventional fixed lugged wheel, it is found that the wheel with an active lug has the advantage of being able to insert the lug into the soil earlier and depart from the soil later to generate larger soil reaction forces over a wider range.