Preface

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Biographical notes: Lin Li is a Senior Analysis and Simulation Engineer of Liebherr Mining Equipment Co. He received his BSc and MSc from Jiangsu University (China), and PhD from Virginia Tech (USA). His areas of research interests include vehicle dynamics, suspension and tyre modelling and testing, ride comfort, handling, terrain model, vehicle-terrain-soil interaction. He is an associate editor of SAE *Journal of Commercial Vehicles.*

Xiong Zhang is a senior engineer in Computer Modelling and Simulation of Systems Engineering, Engineering Design and Development, General Dynamics Land Systems – Canada (GDLS-C). He graduated from Northern Jiaotong University at Beijing, China in 1983 and obtained his MSc in 1989 from the China Academy of Railway Sciences. He was at the University of Leeds, UK, for two years before he moved to Canada in 1997. He received his PhD in 2001, from Concordia University, Montreal. He has expertise in vehicle dynamics, tyre modelling, suspension design, shock and vibration analysis, and test data interpretation. His research interests include off-road vehicle mobility and applications of advanced technologies in modelling soft-soil tyre interface for ground vehicle systems. He is a licensed member of the Professional Engineer Ontario, Canada.

Dongpu Cao, PhD, is a Lecturer at the Department of Engineering, Lancaster University, UK. He obtained his PhD at Concordia University, Canada. His research interests include vehicle dynamics and control, electric and hybrid vehicles, driver-vehicle dynamics, advanced suspensions, vehicle system design, optimisation and integration. He has contributed more than 40 peer-reviewed journal/conference papers and one patent to the research areas.

When we were preparing this special issue ‘Off-road Vehicle Dynamics’, NASA’s latest and greatest Mars Rover, Curiosity, landed successfully on Mars, and started her journey of exploring the mysterious red planet, just as her predecessors Spirit and Opportunity did. As engineers and researchers working on off-road vehicle dynamics, we were surprised that these big ‘toys’ could travel pretty long distances on the type of surface and soil that we have almost zero knowledge about, especially that Opportunity has driven over 21 miles as of August 2012, which makes us expect that Curiosity could make longer trips. Although their average speed is extremely slow (0.02mph), the structure of tyres is totally different from regular ones, and other differences, such as those in driving system, dimension, and weight, are not comparable with those prevailing on Earth, we are very optimistic about the planetary exploration from the dynamics perspective. We can’t wait to see Mars-version World Rally Championship, tractors plough the fields and plant crops, excavators dig dirt and minerals, and ATVs jump in and out of craters, just as my four-year old can’t wait to have her own baby girl!

We have plenty of reasons to be excited. Unlike highway or so-called on-road vehicles, there are lots of (maybe too many) challenges for off-road vehicle designers. For example, highway and local roads are well built and maintained; there are hundreds and thousands of regulations, rules, and guidelines that constrain and direct on-road vehicles’ design, development, and usage; most of the parts, even the whole on-road vehicle, can be tested and certified by one way or another, which make it non-mysterious to us. In contrast, off-road vehicles leave us numerous obstacles to overcome. First of all, as the name explains itself, off-road or rough road travel is already hard enough to make us scratch our heads. The surface that off-road vehicles travel on could be very different every day in terms of wavelength and amplitude (roughness may not apply due to the micro scale). The surface changes due to weather, humidity, wind, and the loads from vehicles make measuring, characterising, and predicting the road surface profile very difficult. Secondly, needless to say, variations in types of soil/snow/ice/vegetation also make the prediction of off-road vehicles’ mobility extremely difficult, mainly due to the challenges in determining the characteristics of soil as well as the tyre-terrain interaction, especially under repetitive loads. Furthermore, off-road tyre properties are much more complicated than those of their on-road peers because the tyres have to fight the abominable operating environment and survive. Meanwhile, extracting tyre properties for dynamics study is no easier than manufacturing the tyre itself, particularly for those big tyres with diameters be up to 12 feet and a mass of up to 5 metric tons. Naturally, one could easily conclude that achieving the same level of ride comfort, handling, stability, and controllability as on-road vehicles for off-road vehicles becomes mission impossible.

In the past six decades, a lot of pioneers devoted their lives to off-road vehicle dynamics and have made significant progress. Their breakthrough work not only has substantial impact on understanding soil properties, terrain-tyre-vehicle interaction, tractive performance, etc., but also encourages others to join the efforts and contribute to this area.

This special issue, as part of the efforts, collects the following outstanding research articles to either address some of the problems mentioned above or improve existing experimental and analytical technologies.

'A fatigue formula and a new measure of the roughness of a terrain profile', by Sun et al., proposes a creative method to characterise the terrain profile numerically, based on the fact that the profile oscillation accumulates fatigue and damage to the vehicle and passengers. This method borrows the concept of rainflow from fatigue theory and proves it to be better than RMS and IRI in evaluating the terrain profile. Unlike the previous research using fatigue formula for surface assessment, this method relies purely on physical measurement without including any vehicle model.

'A general model for inferring terrain surface roughness as a root-mean-square to predict vehicle off-road ride quality', by Durst et al., also tries to improve the evaluation of terrain profile, putting effort into overcoming the drawback of RMS, i.e., requiring accurate measurement. In this paper, the effects of data resolution on the RMS model are studied, and a continuous model for RMS as a function of fractural dimension (FD) and power spectral density DC offset is introduced.

'Simulation and experimental validation of a modified terramechanics model for small-wheeled vehicles', by Meirion-Gareth and Spenko, develops a novel diameter-dependent pressure-sinkage model for off-road vehicles' mobility prediction with small diameters, i.e., unmanned ground vehicles. The model was validated by experimental results with improved accuracy, and might be valid for large diameter wheels too.

Different from the previous paper, which studied the tractive performance in the longitudinal direction, 'Effects of steering dynamics upon tyre lateral forces on deformable surfaces', by Pytka, focuses on tyre lateral force measurement and analysis on deformable terrain. Controlled tests were performed on three types of terrain using a light SUV: loess, sandy soil, and wet snow. The relationship between peak lateral force and soil type, the relationship between tyre lateral force and steering rate, and the relationship between tyre lateral force and steering excitation frequencies are discussed.

'The relationship between vehicle yaw acceleration response and steering velocity for steering control', by Thoresson et al., shows that the relationship between vehicle yaw acceleration and steering rate for various vehicle speeds appears very similar to the side force vs. slip angle characteristics of the tyres (Magic Formula). Based on this discovery, a novel single point steering driver model was created and implemented in a highly non-linear vehicle model. A gain factor modelled with the Magic Formula was used to adjust the response with respect to different vehicle speed and yaw acceleration.

There are other interesting topics covered by this special issue, such as 'Gas damper: potential vehicle performance studied on a full-car model', by Prada et al. The paper addresses the influence of the use of a gas damper on vehicle performance, with results supporting the potential of the gas damper in comparison with that of a hydraulic suspension for off-road vehicles under deterministic inputs.

The paper 'Profiling of rough terrain', by Becker and Els, concentrates on the means of obtaining rough terrain profiles as the inputs for modelling vehicle-terrain systems, a more accurate and cost-effective approach than those offered by commercial inertial profile-meters. Petersen and McPhee, the authors of "A study of volumetric contact modelling approaches in rigid tyre simulation for planetary rover application', propose an efficient approach to modelling the dynamic interaction process at the rigid tyre/soil interface for a planetary rover, allowing the determination of closed-form analytical expressions for tyre contact forces, with consideration of the effect from ongoing compaction of soil and resultant plastic deformations. The results from these two papers are validated by experimental data, showing the readiness of the technology for practical applications in the fields. In addition, the paper 'Mathematical models for farm tractor rollover prediction', by Previati et al., presents a comprehensive investigation into rollover issues related to farm tractors on a sloped surface, with factors affecting the rollover mechanism fully analysed from a static stability perspective. Given that the potential loss of the lateral stability of a dump semi-trailer in operation is related to its rigidity, the paper 'Analysis of the torsional rigidity of a dump semi-trailer under unfavourable load conditions', by Valladares et al., focuses on decreasing the rollover risk of a tipped semi-trailer undergoing an unloading process, with the effect of the related structural elements and geometric factors analysed using FEA.

The special issue concludes with 'Snowmobile model for ride dynamic analysis', by Hébert et al., which might be fun to read especially for snow sports enthusiasts. This paper developed a multi-body dynamics model of a snowmobile including the driver. Snow ground and trail surface were measured and implemented in the model. The actual driver's response was recorded as well and compared with the model outputs. Using RMS of the vertical acceleration on the seat surface as a criterion, a parametric study was performed and the design was greatly improved based on analytical analysis.

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