Multibody model for enhancing the dynamic behavior of an agricultural tractor

Matteo Magliani[1], Alberto Martini[1,2]

[1]DIN - Dept. of Industrial Engineering
University of Bologna
V.le del Risorgimento 2 - 40136 Bologna, Italy
matteo.magliani2@unibo.it

[2]CIRI - Advanced Mechanics and Materials
University of Bologna
V.le del Risorgimento 2 - 40136 Bologna, Italy
alberto.martini6@unibo.it

EXTENDED ABSTRACT

1 Introduction

Numerical simulations have become an essential tool to support the design process of complex mechanical systems, also thanks to higher computational resources typically available to manufacturers. In a software environment, it is possible to model real operating conditions for predicting reliably the behavior of the system, hence reducing the amount of field tests required. This leads to higher data availability since the early design stage and thus to higher optimization opportunities. In the automotive industry, multibody models are among the most used tools to investigate vehicle dynamics and assess the performance in different working conditions. Numerous works dealing with agricultural vehicles can be also found [1, 2].

This study aims at developing a multibody model of the front axle suspension of an agricultural tractor, that must be coupled with a model of its hydraulic actuation system. The activity has been carried out in collaboration with the company CNH Industrial (Amsterdam, NL), and focused on a medium-range tractor, namely the New Holland T7 LWB CVT (Fig. 1). Its front axle suspension is characterized by a proprietary architecture (referred to as *Terraglide*™) hydraulically actuated. The final goal is implementing a model that can run in real-time, to possibly enable an optimization of the system dynamic response [3].

2 Materials and methods

The developed numerical tool consists of a multibody model of the complete tractor and a hydraulic model of the front axle suspension, integrated in Simulink (Mathworks, Natick, MA, USA) environment. The multibody model has been created with the software Simcenter 3D (Siemens, Plano, TX, US), and it is composed by 11 rigid bodies connected by different kinds of ideal and force constraints. The final model has 18 total degrees of freedom (DOF), with 3 DOF associated with the front axle suspension subsystem. Tire-ground interactions have been currently defined by means of a simplified tire model that the adopted commercial software can handle. The hydraulic model of the suspension has been built with Amesim (Siemens, Plano, TX, US). The hydraulic system consists in a single suspension cylinder, valves, accumulators and a hydraulic pump.

Simulink is used as interface and control system for co-simulation. The system is driven by the input signals commanding the valves of the hydraulic cylinder, coming from experimental measurements on the field. The hydraulic system provides an output force, which is imposed as input to the hydraulic cylinder of the front axle suspension in the multibody dynamic model. Then, the latter gives as outputs the velocity and displacement of the suspension cylinder, which are fed back as inputs, creating a closed loop system (Fig. 1).

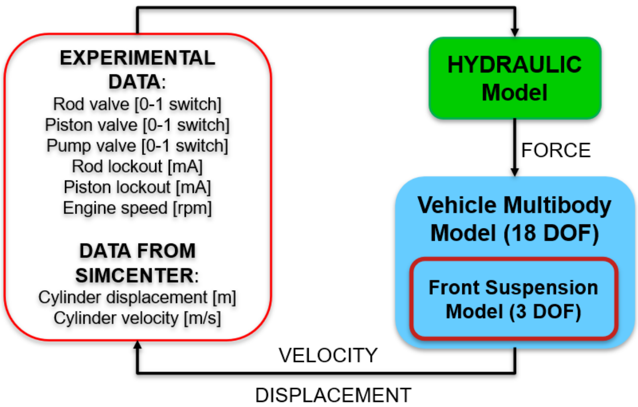

Figure 1: New Holland tractor subject of the analysis (left) and co-simulation scheme (right)

The implemented model has been preliminarily validated by performing an experimental test referred to as leveling maneuver (Fig. 2). The tractor begins the maneuver with the suspension at its equilibrium position. Then, the suspension cylinder is brought to the inferior end of its stroke (fully compressed cylinder). This position is maintained for a certain time. Then the cylinder is fully extended, again keeping the position, and finally returning to the initial equilibrium position. In such test, in addition to the cylinder controlling signals normally available, the distance between the two attachment points of the suspension was also measured, through a position transducer.

3 Results and discussion

The first results provided by the validated model show that a quite satisfactory accuracy could be achieved. The comparison between the suspension cylinder displacements of the real vehicle and the simulated ones is reported in Fig. 2 (the actual displacement values are omitted due to NDA). The model is able to replicate in quite a precise way the behavior of the tractor suspension during the test. The superior and inferior ends of the stroke of the suspension are closely matched. During the transients, the model behavior is acceptable as well.

As for the computational requirements, the simulation time appeared not completely suitable for real-time applications, notwithstanding some modelling simplifications. Real-Time Compliance has been evaluated by comparing the computational time required for the simulation (t_c) and the real (i.e. physical) duration of the simulated event (t_r):

$$\frac{t_c}{t_r} = \begin{cases} \geq 1: not\ real - time\ compliant \\ < 1: real - time\ compliant \end{cases} \quad (1)$$

During the leveling maneuver, the model required a computational time almost double compared to the real duration of the simulated event. If a more challenging force input is directly imposed to the suspension cylinder, such as a sinusoidal wave simulating the tractor travelling along a rough surface, the performance in terms of Real-Time Compliance may even worsen. Therefore, while the preliminary results are promising in terms of accuracy and reliability, further investigations are required to achieve Real-Time Compliance for all the possible operating conditions of the tractor.

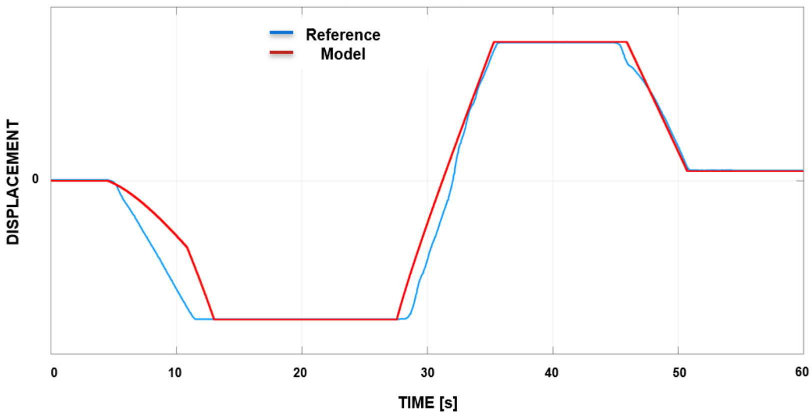

Figure 2: Comparison between experimental (Reference) and simulation results for a leveling maneuver

4 Conclusions and further developments

A numerical model of the front axle suspension of an agricultural tractor has been developed. The model, based on the co-simulation of a multibody model of the complete vehicle and a hydraulic model of the suspension actuation, proved quite effective. Different strategies for further improving the performance of the model in terms of accuracy, as well as for achieving Real-Time Compliance, are being evaluated and tested.

Additional measurements on the field are ongoing, in order to verify and further refine the model for different, more challenging, operating conditions. The definition, development and validation of possible methods to improve the computational performance of the implemented numerical tools are under investigation as well.

Acknowledgments

CNH Industrial, in particular Riccardo Molinari, are gratefully acknowledged for cooperation and support through this activity.

References

[1] F. Mocera, A. Nicolini. Multibody simulation of a small size farming tracked vehicle. Procedural Structural Integrity, 8, 2018.

[2] D. Rubinstein, R. Hitron. A detailed multi-body model for dynamic simulation of off-road tracked vehicles. Journal of Terramechanics, 163-173, 2004.

[3] S. Jaiswal, P. Korkealaakso, R. Aman, J. Sopanen, A. Mikkola. Deformable Terrain Model for the Real-Time Multibody Simulation of a Tractor with a Hydraulically Driven Front-Loader. IEEE Access, 7, 2019.