Multibody System Dynamics Simulation for Automotive Cyber-Physical Test Benches

Jon García-Urbieta*†, Diego J. Palomar*, Marta Marijuan*, Borja Rodríguez†, Francisco González†

* GKN Automotive Zumaia
Sagarbidea 2, 20750 Zumaia, Spain
{jon.garcia, diego.palomar, marta.marijuan}
@gknautomotive.com

† Laboratorio de Ingeniería Mecánica,
Industrial Campus Ferrol,
CITENI, University of A Coruña
Mendizábal s/n, 15403 Ferrol, Spain
{borja.rfrade, f.gonzalez}@udc.es

Abstract

Novel automotive components and technologies require extensive testing campaigns before they can be released to the market. Road vehicles are complex systems with a large number of components that interact with each other and with their environment during operation. Thus, the validation of new technical solutions has traditionally relied upon system-level prototype experimentation, i.e., full-vehicle circuit or road tests, to ensure proper behaviour in the widest possible range of operation scenarios. System-level tests, however, are resource- and time-consuming, and rely upon the availability of operational vehicle prototypes. Model-based system testing (MBST) is an alternative option for component assessment by means of the combination of physical experimentation and virtual environments [1]. Cyber-physical test benches are a particular application in MBST, in which physical components under test are interfaced to a simulation that recreates their operating conditions [2] in a Hardware-in-the-Loop (HiL) or System-in-the-Loop (SiTL) setup. Figure 1 shows the schematic of a cyber-physical bench for e-powertrain motors, where the device under test (DUT) is interfaced to a full-vehicle simulation. The tested motor is actuated by an identical component that receives the commands of the virtual environment through a real-time co-simulation interface. The scheme illustrates the possibility of using digital twins to gain additional information about the system operation [3].

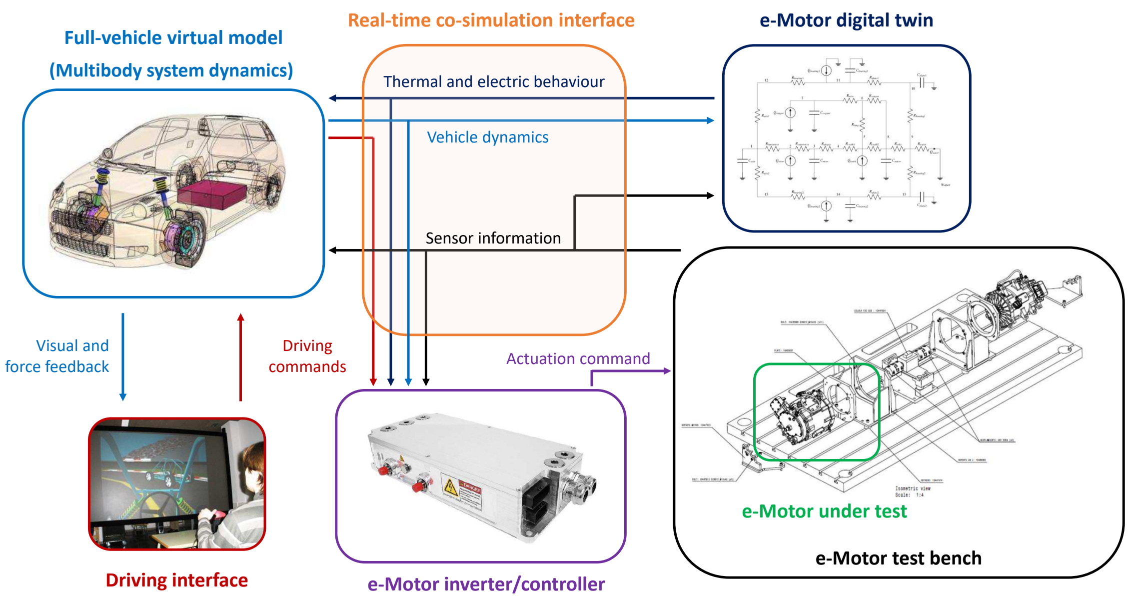

Figure 1: Schematic of a cyber-physical test bench for e-powertrain motors.

Cyber-physical test benches enable component assessment in realistic conditions already in the early stages of product development, at a reduced cost and with precise knowledge of the operation point of the system. Identical test manoeuvres can be repeated consistently in a controlled and safe way. On the other hand, cyber-physical tests impose stringent requirements on the virtual environment, the co-simulation interface, and the sensing and actuation framework, which must guarantee real-time performance while maximizing the fidelity of the experiment to real-world conditions.

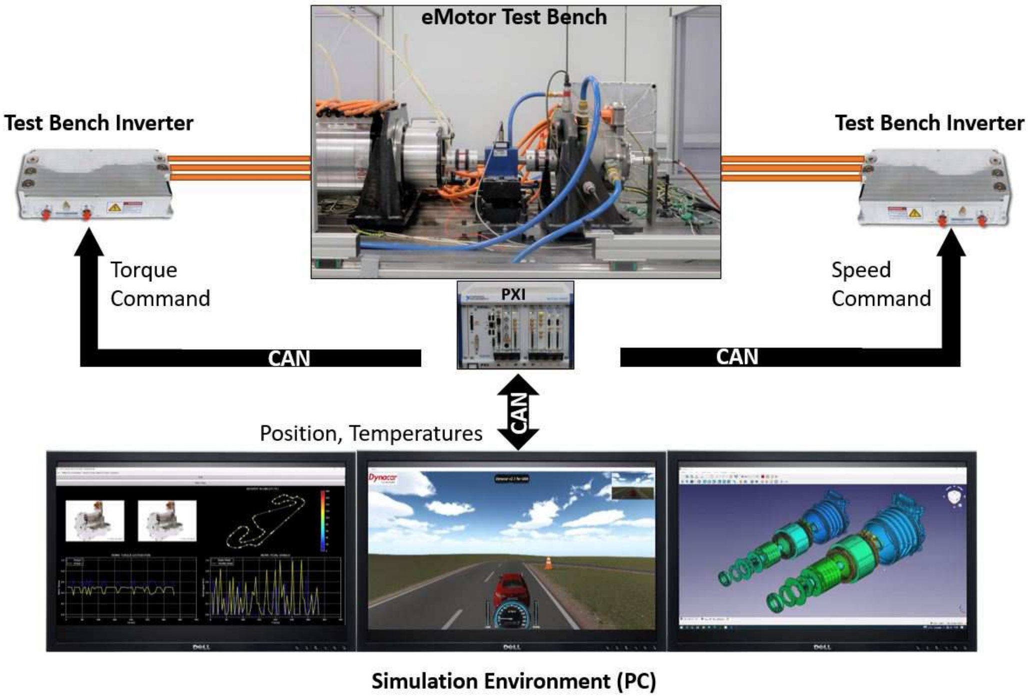

Figure 2: Current cyber-physical bench in a back-to-back configuration and information flow scheme.

This work describes a cyber-physical test bench for automotive-grade electrical motors assembled at GKN Automotive Zumaia, following the configuration shown in Fig. 1. The bench aims to describe accurately the electronic and thermal effects in e-Motors of road vehicles during standardized driving cycles and manoeuvres. The vehicle dynamics is described by a high-fidelity, real-time capable MBS dynamics software implementation. The physical part of the bench includes two e-Motors in a back-to-back configuration, with a torque cell between them, and two inverters, controlled in speed and torque mode, respectively. The e-Motor on the right side of Fig. 2 is the DUT while the one on the left operates as a slave unit that transmits the loads calculated by the simulation. The communication is performed via CAN by means of a PXI bus, both for command delivery and test bench data acquisition. Accelerometers, current sensors, and thermocouples gather data to monitor system performance and to enable NVH and thermal studies. A digital twin of the DUT, intended to provide further insight into its operation point, is currently being developed. The bench aims to be a hub for electromagnetic and thermal model calibration. Results from SiTL tests in a virtual circuit have already been used to establish preliminary comparisons between data from physical sensors and the predictions of computational representations, e.g., lumped-parameter thermal networks included in the simulation environment.

Acknowledgments

This work was supported by the Ministry of Economy of Spain through the Ramón y Cajal contract No. RYC-2016-20222, and by the Galician Government under grants ED431B2016/031 and ED431F2021/04.

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