Inverse dynamics for durability testing

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Introduction

A goal of the STW project INVERT (Robust Inversion of Nonlinear Dynamic Systems) is the improvement of drive file development in vehicle durability testing. Drive file development is the calculation of the actuator signals (or: drives) to a test-rig such that the measured responses of the mounted vehicle *equal* the target signals measured during a test-drive (fig.1).

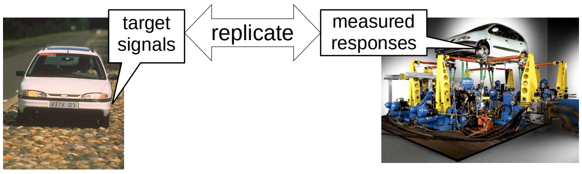

Figure 1 : Target signals replication on a test-rig

Objective

The objective is to develop a virtual benchmark problem. The benchmark is meant to compare the performance of existing methods with methods developed within INVERT.

Methods

The real nonlinear system $\mathbf{G}$ (vehicle + test-rig) is modeled as a linear frequency response function (FRF) $\hat{\mathbf{G}}$ using system identification (fig.2). During target simulation the correct drives are calculated iteratively (fig.2) where the drives $\mathbf{u}^j$ are updated with the inverse system model $\hat{\mathbf{G}}^{-1}$ times the error (targets - $\mathbf{y}^{j-1}$). To prevent overshoot due to the mismatch between $\mathbf{G}$ and $\hat{\mathbf{G}}$, only part of the error is corrected by using gains $\mathbf{Q}^j$, ($\mathbf{Q}^j =$ diagonal; $0 \leq q^j \leq 1$).

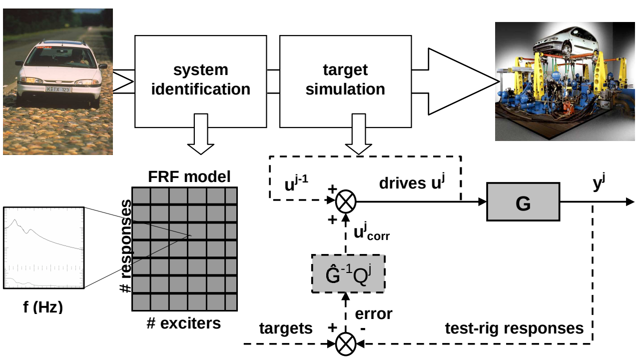

Figure 2 : Drive file development scheme [1]

This method is tested on a quarter car multi-body model (fig.3). The suspension includes a nonlinear spring/damper and a lateral nonlinear stiffness. The most problematic event for the method is the bump-stop when the spring is fully compressed (fig.3).

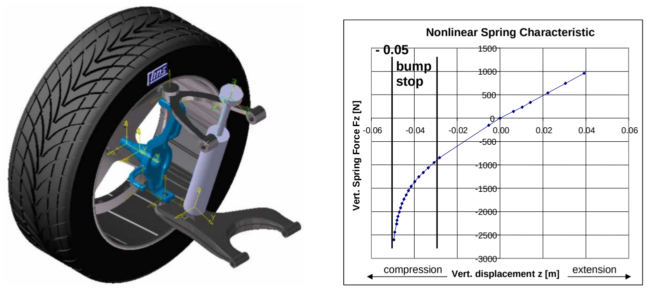

Figure 3 : Quarter car multi-body model (left) and suspension spring characteristic (right)

Results

For commercial state-of-the-art drive file development software, nineteen iteration steps and extensive user interaction were necessary to match target with responses and to overcome convergence problems at excitation peaks causing bump-stop events. Fig.4 shows the effect of such a peak on the convergence. The amount of iteration steps and user interaction is representative for real-life problems and therefore the developed problem is an excellent benchmark.

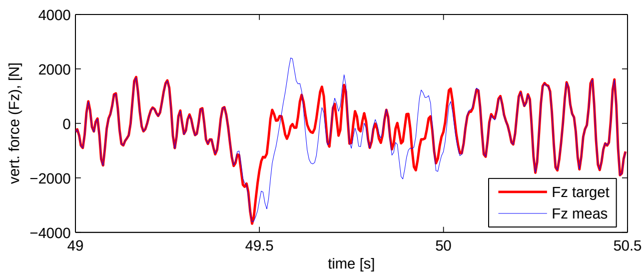

Figure 4 : Vertical target and test-rig wheel force

Further research

Develop novel inverse methods and compare their performance on the virtual benchmark problem.

Reference

1. De Cuyper, J.D.C. (2005) Robust tracking control on durability test rigs in the automotive industry, PhD Thesis (*draft*), KU Leuven/LMS, Belgium.