Identification of vehicle suspension parameters by design optimization

J.Y. Tey¹, R. Ramli³, C.W. Kitieng², S.Y. Cheong¹ and M.A.Z. Abidin¹

¹Advanced Computational and Applied Mechanics Research Group, Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia; ²Department of Computer Science, Faculty of Information and Communication Technology, Universiti Tunku Abdul Rahman, Jalan Universiti, Perak, Malaysia; ³School of Computer Science, The University of Nottingham Malaysia Campus, Malaysia; ⁴Proton Professor Office, Proton Holdings Bhd., Malaysia

(Received 7 June 2012; final version received 25 March 2013)

The design of a vehicle suspension system through simulation requires accurate representation of the design parameters. These parameters are usually difficult to measure or sometimes unavailable. This article proposes an efficient approach to identify the unknown parameters through optimization based on experimental results, where the covariance matrix adaptation-evolutionary strategy (CSA-Ev) is utilized to improve the simulation and experimental results against the kinematic and compliance tests. This speeds up the design and development cycle by recovering all the unknown data with respect to a set of kinematic measurements through a single optimization process. A case study employing a McPherson strut suspension system is modelled in a multi-body dynamic system. Three kinematic and compliance tests are examined, namely, vertical parallel wheel travel, opposite wheel travel and single wheel travel. The problem is formulated as a multi-objective optimization problem with 40 objectives and 49 design parameters. A hierarchical clustering method based on global sensitivity analysis is used to reduce the number of objectives to 30 by grouping correlated objectives together. Then, a dynamic summation of task value is used as pseudo-objective functions to reformulate the multi-objective optimization to a single-objective optimization problem. The optimized results show a significant improvement in the correlation between the simulated model and the experimental model. Once accurate representation of the vehicle suspension model is achieved, further analysis, such as ride-handling performances, can be implemented for further optimization.

Keywords: hierarchical clustering; global sensitivity analysis; design of experiments; kinematic and compliance analysis

1. Introduction

In the vehicle development process, experimenting with physical prototype remains an important task (Rani 2003). Often, these experiments are conducted by designers to obtain parameters for simulation and validation. However, the process of achieving accurate correlations between simulations and experiments is often difficult. According to Blindell (1997), this requires expensive set-ups of instruments and testing facilities. It is a time-consuming task that can take up to 21 person-days per axle to complete a vehicle characterization. Once the design parameters have been obtained, a fine-tuning process is necessary to simplify the model. This involves improving the correlation between the simulated model and the experimental model repeatedly. Conventionally,