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APPLICATION OF ANALYTICAL TARGET CASCADING TO THE DESIGN OF A RAILWAY VEHICLE SUSPENSION SYSTEM

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ABSTRACT

Analytical target cascading (ATC) is a multilevel optimization methodology that stands as a tool to decompose large scale complex systems, and simultaneously, as a coordination process that ensures consistency between the decomposed parts of the system towards the optimal solution for the overall system.
This paper presents the research developed to review the ATC approach for large-scale complex systems and its application to the suspension design of a railway vehicle. This methodology has already been successfully implemented in the design of road vehicles and aircrafts, though as far as the author knowledge nothing has been done for the mechanical design of railway vehicles.
A simplified dynamic model of a railway vehicle implemented in MATLAB® is presented and ATC is employed to decompose and optimize the vehicle in terms of ride comfort when it travels at constant speed on tracks in bad conditions.
The preliminary numerical results showed that the partitioned solution substantially improved the ride comfort. Also, the optimized results obtained with the ATC strategy are discussed and compared with a non-partitioned optimization strategy (all-at-once).

Keywords: analytical target cascading, optimization, ride comfort, railway vehicle.

INTRODUCTION

Ride comfort related to vibrations is an important driver in the design process of railway vehicles. Some work has already been developed with respect to the optimization of comfort in terms of suspension parameters (springs and dampers) for railway vehicles (Kim et al, 2003; Younesiana et al, 2009). The principal quantity that is relevant to the vibration aspect of the ride comfort is the acceleration that the passenger is subject to during the motion of a railway vehicle, its evaluation and attenuation changes the overall running performance.
The approach taken for the optimization of comfort considers analytical target cascading (ATC) as the optimization architecture that coordinates the optimization process. ATC was initially proposed by Kim (2001) for product design and has been shown to be useful as a coordination method for decomposition-based optimal system design (Kim et al, 2002; Alison et al, 2006). ATC translates the overall design targets of a system to the terms of the decomposed multilevel elements. Initially, the complex system is partitioned into a set of subsystems that are hierarchically associated in levels. The desired design targets are defined at the top level and "cascaded down" to lower levels. Subsystems are formulated at each level so that the cascaded targets consistently match with the overall system targets.

The main advantage of ATC lies in the complexity reduction of large systems by separating problems or disciplines and assigning to each an analysis. Also, when used in early stages of

the product development, gives a first assessment of the target variables that prevents late design changes and increase the probability of achieving an overall optimized design.
Besides the fact that this methodology has not been implemented to the mechanical design of railway vehicles, the application is rather suitable, furthermore it has been frequently applied to design problems of the automotive industry (Kim et al, 2002; Kokkolaras et al 2004) and it has also been proved useful in multidisciplinary optimization of aircrafts (Alison et al, 2006).
As such, this paper presents the ATC formulation and its application in the optimization of a railway vehicle suspension concerning comfort. A dynamic model is used for simulating the railway vehicle and the suspension system when it travels at constant speed in a track in bad conditions. The objective performance parameters and constraints were defined and ATC was implemented as the optimization architecture.

RESULTS AND CONCLUSIONS

The dynamic model of the railway vehicle together with the proposed algorithm makes it possible to optimize all the suspension parameters (springs and dampers) even in the case of a complex dynamic system such as the one presented.

The preliminary results show the effectiveness of the proposed algorithm by improving ride comfort in about 20% while satisfying the constraints. The simulation of the whole system shows that the system performs well as defined and approaches the benchmark given by the all-at-once solution. This paper highlights needs and opportunities for future research work. The example problem here detailed is just a first step towards the design of a complete railway vehicle.

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