

MDO-based Platform Development for Attributes Inegration and Application on Vehicle Body Design

Lei Shi, Ji Yang, Zhaomin Zhang, and Zhan Zhang
Great Wall Motor Company Limited

ABSTRACT

Multidisciplinary Design Optimization (MDO) has been widely used in the automotive industry to balance overall weight and stringent vehicle attributes, such as safety, NVH, durability, etc. To improve product quality and shorten product development cycle, a comprehensive MDO-based platform for vehicle attribute integration is developed in this paper. Some key issues in the platform development are addressed: Parameter model synchronization, Metamodel predictive capabilities, and Pre/post processing, etc. In addition, a strategy for body design is proposed to achieve weight targets while meeting other vehicle attributes. Lastly, the proposed methodology is demonstrated by a real world example for vehicle body design.

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INTRODUCTION

Multidisciplinary design optimization (MDO) is one of the key enablers or lightweighting technologies other than materials for achieving vehicle weight target while meeting other vehicle attributes. It has become a common practice for vehicle attribute integration and weight reduction [1,2,3], as computing resources are powerful and computational mechanics theory are matured. A large number of studies currently is devoted to addressing MDO related issues such as large-scale and complex design problem [4,5,6], high-nonlinear responses of vehicle performance [7], and optimization strategy or algorithms [8,9] etc., which have limited its extensive application in automotive industry.

MDO is a trivial and tedious task. It has its benefits but those benefits are overridden with the following drawbacks. First, the major proportion of the parameterization time is consumed in defining different class of design variables, e.g., shape, thickness, material, spot weld design variables etc., on full vehicle finite element (FE) models. Usually, those FE models consisting of large amount connections, materials and proprieties etc., are very complex and needed to be repeated for different disciplines. Second, once the parametric model is defined completely on one disciplinary FE model (e.g., Safety model), there should not be re-defined for other disciplinary FE model (e.g., NVH model), as recreating the same parameters for other disciplinary model resulted in a time consuming in one MDO task. Third, an automated process for preparing FE model and extraction of results from various disciplinary simulation runs is required for an efficient MDO application. Most importantly, it is well known that it is almost impossible to conduct Safety or NVH design optimization using a high-fidelity finite element simulation directly, as it is often computationally expensive. One alternative is to use the design of experiment (DOE) and metamodel

to construct the approximation on the exploratory design space and perform optimization task. However, the accuracy of metamodel prediction is still a challenging task for high non-linear responses, especially for crashworthiness design in automobile industry [10]. There is no definite and clear way to decide what metamodel is the best for all the vehicle attributes approximation.

To sum up, the integration of parametric CAE and metamodel based optimization methodology has become more and more commonplace. A large amount of industrial studies had successfully verified the feasibility of MDO on vehicle programs. However, it was still time intensive and hurdled by core techniques mentioned above. In this paper, a comprehensive MDO-based platform for vehicle attribute integration is developed to expedite the entire process by offering faster turnaround time. Three key issues, i.e., parameter model synchronization, metamodel predictive capabilities, and pre/post processing, are addressed in [Section 2](#). A strategy for body design is also proposed in [Section 3](#) and demonstrated by a realistic example in the end.

MDO-BASED PLATFORM DEVELOPMENT FOR ATTRIBUTES INTEGRATION

Formal MDO is intended for the synthesis of multidisciplinary engineering systems, e.g., automobile system, aircraft system or weapons system, whose designs are governed by multiple disciplines, e.g., cost, manufacturing and engineering etc., often with multiple, conflicting objectives. MDO process should provide a flexible environment that would support: (1) easily access to remote analysis tools and bring together multiple analysis tools into an integrated system analysis while hiding the details of data management, (2) high performance computing for a large amount of CAE runs in large scale design problem, (3) advanced metamodel techniques for better

prediction of high non-linear responses for vehicle design, and (4) parameter model synchronization techniques for seamlessly integrating all the attributes together to achieve “One model driven design” design concept.

Framework of MDO-based Platform

The key elements of a MDO-based platform consist of MDO integrator, HPC Clusters, parameter model synchronization, etc., as shown in Figure 1. MDO integrator can easily access remote analysis tools, bring together multiple analysis tools into an integrated system analysis, perform optimization, monitor the optimization process, and visualize the optimization task to facilitate decision making. In this paper, the integrator is developed by integrating in-house codes, spreadsheets, databases under environment of commercial code, i.e., modeFrontier. HPC clusters with a large number of processors are built up to enable multiple levels of parallelism resulting in higher throughput and faster solution turnaround time. Several CAE solvers such as Nastran for NVH static and dynamic analysis, Ls-dyna for impact analysis, Abaqus for non-linear analysis, Star-CCM+ for fluent analysis are implemented.

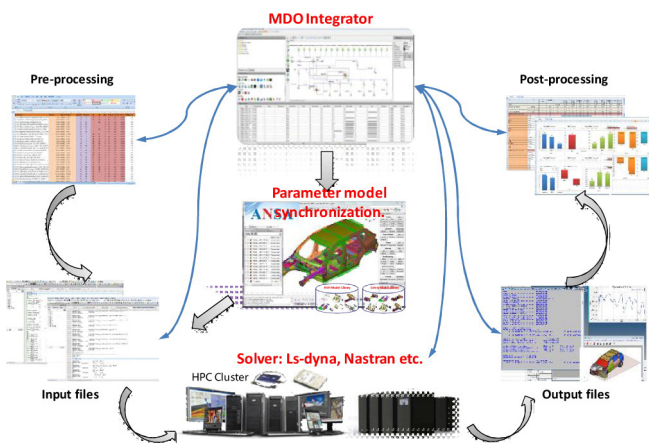


Figure 1. Framework of MDO-based Platform

The process not only take care of the efficiency of the optimization process, but also can handle optimal use of computing resources through the efficient parallelization of all necessary CAE runs. It can be smoothly completed in a fully automated way without any user interaction. This concerns both the parallelization of runs within a workflow as well as the parallelization of individual experiments. After that, all the post processing tasks will be done by calling the post scripts, and the results automatically pass to the text file or Excel file. It is note that distribution of available software license is not addressed in this process and required to investigate in future.

Parameter Model Synchronization

With the advancement of computer hardware and software, morphing technique allows users to quickly parameterize models and strengths finite element meshes when geometry of vehicle structure is changed. Various commercial codes, such as SFE and DepMorpher, are available for parameter model build-up. Most of them can deal with general parameter model in one discipline scenario. In this work, a state-of-the-art pre-processor for model synchronization, ANSA, is

used and further enhanced by in-house scripts. It has the potential to reduce design and engineering costs as existing meshes can be quickly morphed to hypothetical design consideration, without remeshing, for evaluation while preserving the model integrity and connectivity. Parameters setup in one disciplinary model such as NVH model can be automatically synchronized and applied to other model such as Safety model. The flowchart of parameter model synchronization is shown in Figure 2. The key of the model synchronization in ANSA environment is how to switch the different solver automatically. An in-house code implemented in ANSA is developed to address this issue. Thus, all attribute models can be generated at all-in-one time.

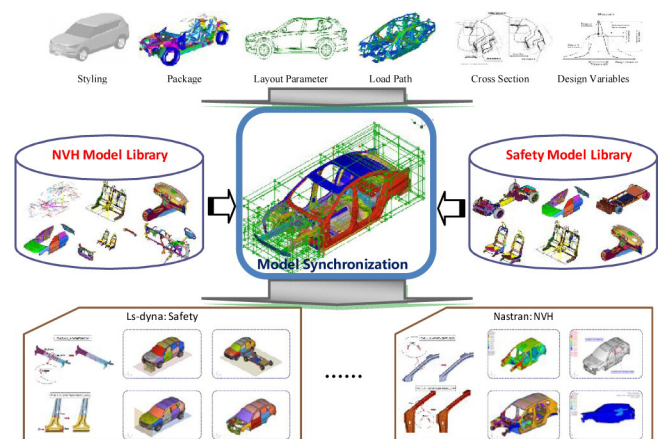


Figure 2. Flowchart of parameter model synchronization

Metamodel-Based Design Optimization

Metamodel-based design optimization has been widely used in the automobile industry to deal with large-scale design problem. The fundamental purpose of a metamodel is to provide a cheaper and/or a more convenient representation of an actual system. Substantial research has been done in past decades to improve the fidelity and the robustness of metamodels. However, one of the major deficiencies of using metamodel in design optimization is the poor accuracy it may often encounter [10]. In essence, the metamodel ignores the data uncertainty, which may result from high nonlinearity of the response of vehicle attributes, numerical simulation and uncertainties in simulation [11,12].

To address those issues, a metamodel technique based on model bias correction method, which has been well proven in previous published work [13], is used as the approximation tool in design optimization. The basic concept of model bias correction is that using model bias to capture the model error due to uncertainties in computer model [11, 13]. A general model bias correction is formulated as:

$$y^e(x) = y^m(x) + \delta(x) + \varepsilon \quad (1)$$

where $y^m(x)$ denotes the metamodel, $y^e(x)$ is the physical observations or the high-fidelity finite element model, $\delta(x)$ is the bias function or model discrepancy function and ε is the experimental error of the physical observation. Generally, ε is assumed as the Gaussian Process