Multi-Disciplinary Optimization of a Sedan Using Size and Shape Parameterization

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1 . Abstract

In vehicle development activity there are different disciplines with their own set of requirements that need to satisfied in order to get a successful product. Traditionally, the simulations were performed for different disciplines but at the time of optimization, Single Discipline Optimization (SDO) was usually performed and later confirmatory runs were done for the other disciplines. This process resulted in a time consuming loop of running several iterations with different disciplines and engaged people from these disciplines to make the optimized design meet the performance targets. Quite often these approaches led to tradeoffs made for design requirements or significant deviations from the optimized design obtained by running SDO.

Multidisciplinary Optimization (MDO) addresses this shortcoming and takes into account different disciplines for optimization, thus reducing the need to iteratively evolve the design for different disciplines. Though this process has its benefits but those benefits are overridden with the setup time required for MDO. The major proportion of the setup time is consumed in defining shape variables on full vehicle FE model that has all types of connections as the process needs to be repeated for different disciplines. As a result an alternate methodology is sometimes pursued to create concept models from the full vehicle FE models thereby reducing the complexities of a full vehicle FE model. This approach not introduces approximation in the entire process by idealizing the detailed FE model but also requires this definition of shape variables separately for each discipline.

In this paper, the MDO was performed on a full vehicle by considering Crash and NVH load cases. These two disciplines were considered to provide a process and to demonstrate its benefits. LS-DYNA® was used for crash simulations and Nastran was the solver used for NVH load cases. This process of MDO has been successfully applied to different vehicle programs including disciplines like durability, vehicle dynamics, occupant simulations, CFD etc. Due to IPR restrictions, the program specific work is not shared in this paper. The present process demonstrated on a sedan with different types of design variables defined for Crash and NVH load cases. The MDO is performed with the objective to reduce mass of the vehicle without any significant performance degradation. The approach presented here uses advance features of DEP's Meshworks and provides the processes through which MDO could be carried out without sacrificing the complexity of the full vehicle FE model. It expedites the entire process by offering faster turnaround time.

2. Methodology

The first decision that needs to be made at the time of planning for MDO is the type of different disciplines that need to be considered in the MDO. This usually gets determined by overall timing of vehicle program and at what stage of the vehicle program this process needs to be engaged. At this point the scope of the work needs to be identified in terms of type of design parameters that needs to be evaluated. Once the types of variables are finalized, we need to know the process enablers and their limitations for the MDO. This includes preprocessors needed to define the parameters and process automation scripts i.e. based on the legacy post-processing methodology used within the organization. Usually the type of variables that needs to be studied determines the tool set to be used. After finalizing on the types of variables and the tools to be used for the MDO, the variable ranges need to be decided that are usually controlled by the packaging and manufacturing requirements. At this point when all the above information is gathered thereby outlining an overall MDO strategy, process is kick started.

In the present work, the disciplines chosen for the MDO were Crash and NVH. The load cases associated to these disciplines were finalized.

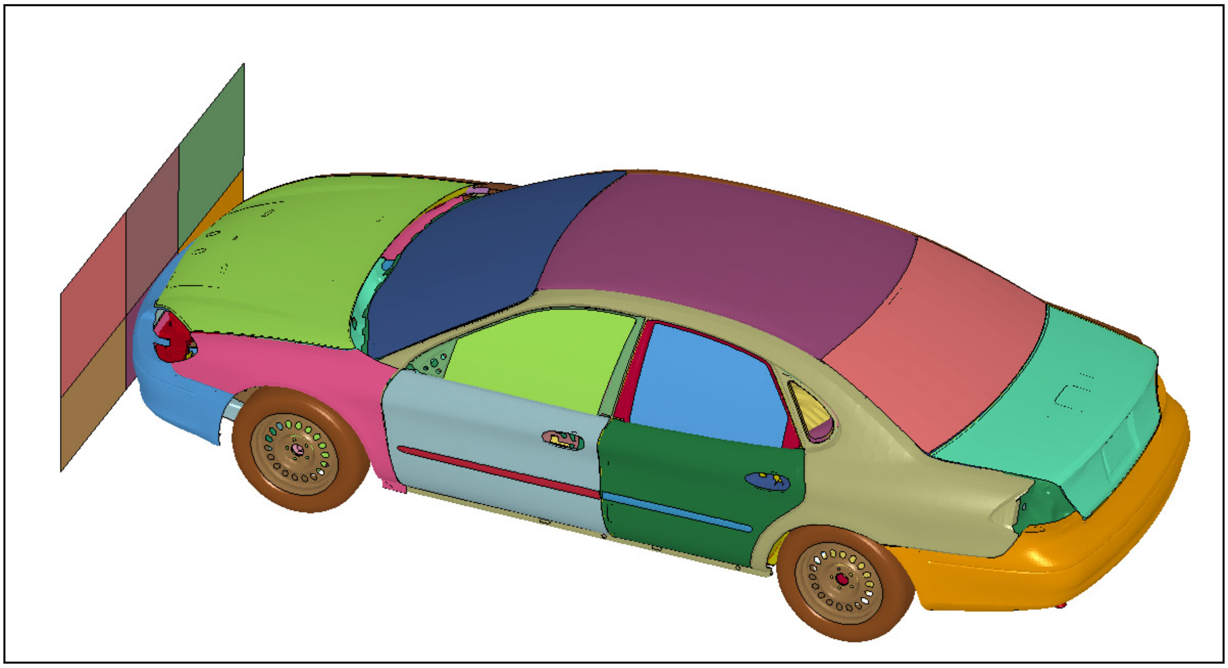

Fig. 1: Crash FE Model

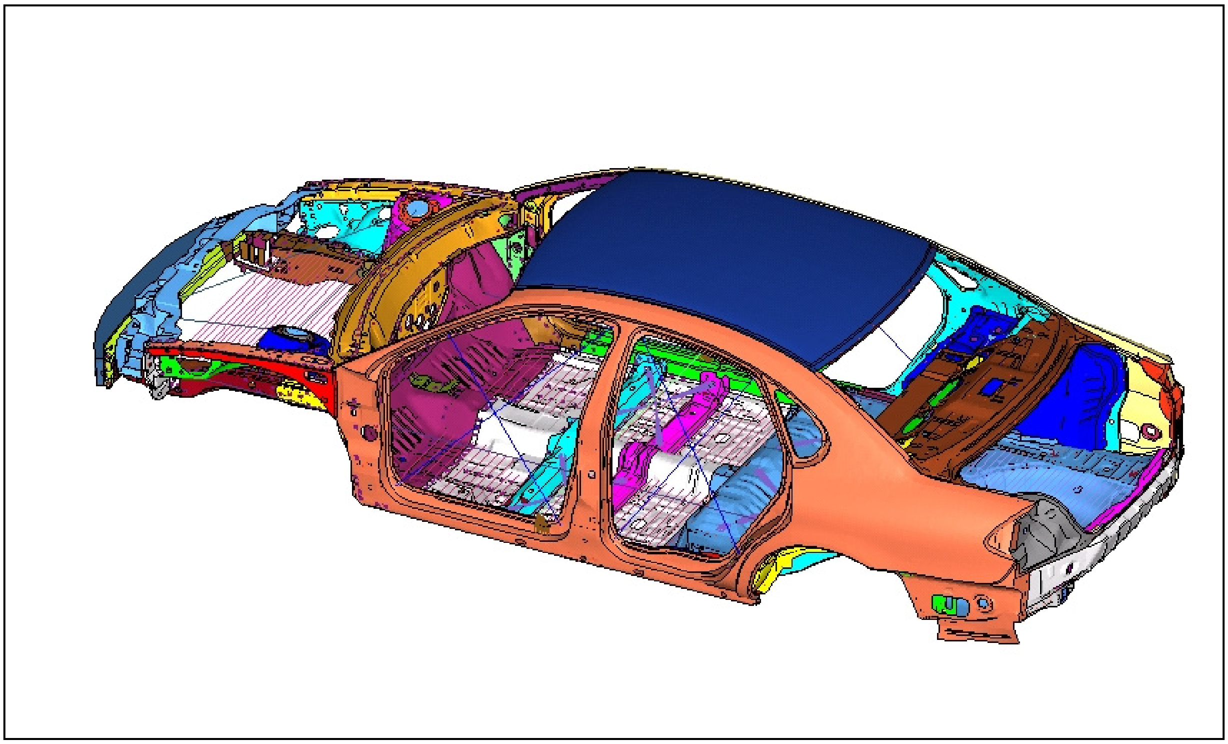

Fig. 2: NVH FE Model

Since the purpose of this activity was to showcase the MDO process, the scope of the work was reduced to two NVH load cases i.e. Static Torsional Stiffness and Static Bending Stiffness and one crash load case i.e. U.S. NCAP. As the only frontal crash load case was defined, the variables were localized in frontal zone of the car. LS-DYNA [1] explicit solver was used for simulation Crash load case and NASTRAN was used for NVH load cases.

DEP's Meshworks5.0 [2] was used to parameterize the full vehicle model as the tool's advanced morphing procedures provided methods of applying the parameters defined on the Crash model, automatically onto the NVH model. This resulted in drastic reduction of pre-processing time for design parameter set-up. The types of variables considered were size, shape, weld pitch and feature parameters. The Spot weld pitch was the variable in weld pitch parameter. The feature parameter had the number of beads and their location as the variable. The time consumed for defining all types of variables was half a day.

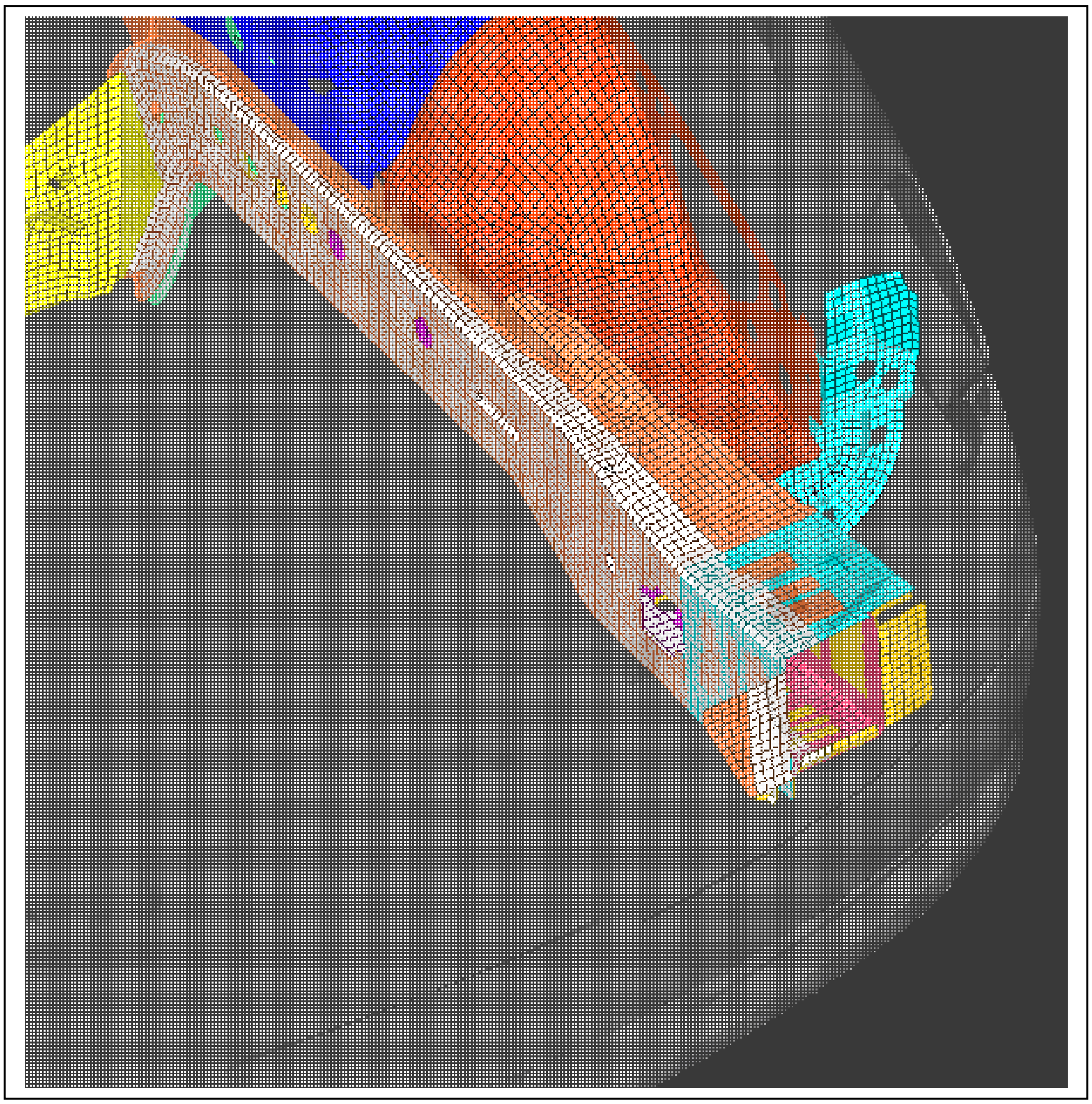

Fig. 3: Sample Design Variable

3. MDO Process

The number of designs generated was 5 times the total number of design variables. The complete MDO setup including the preprocessing took 4 man days to complete. The study was performed on a medium sized cluster with 6 CPUs. The approximations were built for each discipline separately by using Response Surface Model (RSM). For the optimizer these approximations were used in parallel to improve accuracy of optimizer.

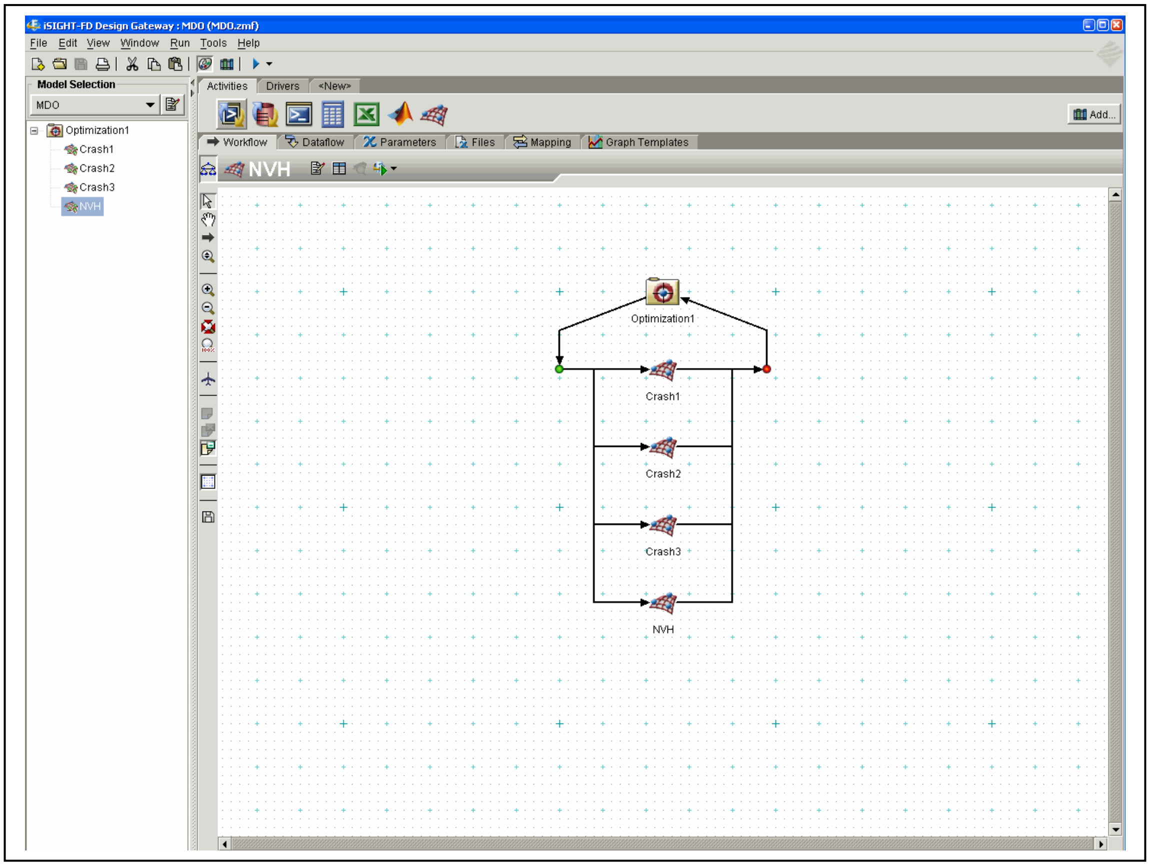

Fig. 4: MDO Workflow

4. Conclusion

Both numerical and exploratory optimization algorithms were used to target the objective of minimum mass. Variations in optimization problem definition were also evaluated to from single objective driven problem to multi-objective problem. The details of the results are yet to be published.

5. Summary

By means of engaging MDO at proper milestones of design cycle, the true power of this process could be realized. Due to ability of the tools to work on full vehicle detailed models and improved hardware resources, MDO has come to forefront of several organization's design cycles. At present there is no need to approximate the FE models and make those trade-offs in the design optimization activity. Reducing the complexity of FE models not only reduces the accuracy of prediction but also puts constraints on the type of load cases and disciplines that can be evaluated as certain load case needs to have detailed modeling as a requirement.

Once we have validated FE models, running MDO to evolve a better design is preferred direction the direction these days. It makes the engineers more productive as they can now focus on value addition to the design with access to the results from the MDO studies. With the MDO process in place, the engineers have the ability to perform various studies as the design requirements change during the design cycle.

6. References

[1] LS-DYNA Keyword User's Manual Version 971, Livermore Software Technology Corporation, 2008

[2] Meshworks5.0 User's Manual, Detroit Engineered Products Inc., 2009