한국소음진동공학회 2013년 추계학술대회논문집, pp. 358~359

Multi-Disciplinary Design Optimization of New Vehicle Body Structure with Crash, Noise, Vibration and Durability

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1. Introduction

Multi-disciplinary Design Optimization (MDO) is a field of engineering that uses optimization methods to solve design problems incorporating a number of disciplines. These days, automotive engineers should consider harder trade-off configurations among the limited design allowance when they make design studies on a newly developed vehicle. In order to achieve a good weight reduction with a reasonable compromise among the major automotive performances such as, Crash, NVH(Noise, vibration and Harshness), Durability, etc, the engineers must need a methodology based on a multidisciplinary approach. The path needs to be paved with efficient idea to be applied to the complex automotive performances. This paper shows a study on the multidisciplinary design optimization of a newly developed vehicle body structure with 6 important measures.

2. Multi−disciplinary Design Optimization

The formulation of a design optimization is normally the first step in the whole design process. It starts with selection of design variables, constraints, objectives, and models of the disciplines. A further consideration is the priority of the interdisciplinary coupling in the problem. This study considered total 75 factors as the design variables as shown in Fig. 1 and total 6 performances

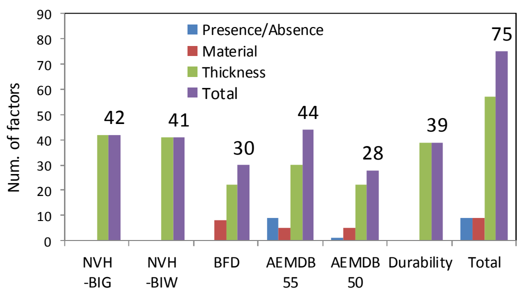

Fig. 1 Performances vs. Number of factors

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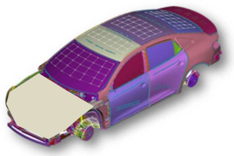
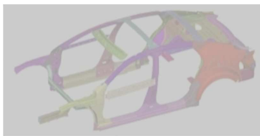
. In order to decrease the number of calculations required for each DOE (Design Of Experiments), the design variables of each performance are reduced to the factors that are really effective in the performances as follows.

NVH performance was estimated with two kinds of models: BIW(Body in White) model and BIG(Body in Grey) model as depicted in Fig. 2. Total 32 IPI(Input Point Interance) and total 58 VTF(Vibration Transfer Function) were selected as the responses of BIG NVH performance. In case of BIW NVH one, two modal frequencies were also watched during the study: 1st torsional and 1st vertical bending modal frequencies. As the design variables, most of structural members were selected as described in Fig 2. (c).



(a) BIG model

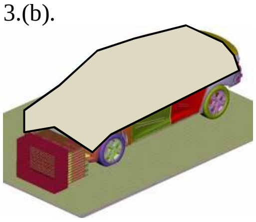
(b) BIW model



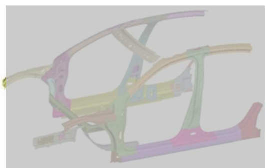
(c) Design variables

Fig. 2 BIG and BIW for NVH

3 kinds of crash simulations were considered. BFD(Frontal Deformable Barrier) is a frontal offset crash on a deformable barrier at 65 km/h with 40% overlapping as given in Fig. 3.(a). As the design variables, most of the structural members in the front and center parts of BIW were chosen as given in Fig 3.(b).



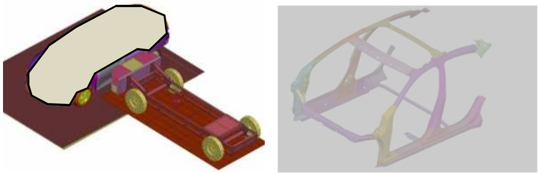
(a) BFD model



(b) Design variables

Fig. 3 BFD(Frontal offset crash with 40% overlapping Deformable Barrier at 65km/h)

AEMDB55(Advanced Europe Movable Deformable Barrier) is a side crash at 55 km/h. It is evaluated in the Korea NCAP crash test. Fig. 4.(a) shows how the model was instrumented. Fig. 4.(b) means the design variables, mainly the center body structural members. AEMDB50 is the performance for the Euro NCAP crash test. It is similar to AEMDB55 excepting the velocity of 50 km/h.



(a) AEMDB model (b) Design variables

Fig. 4 AEMDB55 and AEMDB50(Advanced Europe Movable Deformable Barrier at 55km/h and 50km/h)

Durability has been done with the critically damaged areas including not only structural panels but also spot-welds. And so, the whole BIW structural panels were picked as the design variables.

The design variables consist of mainly thickness modification, some material variation and some presence/ absence of structural parts as shown in Fig. 5.

(a) (b) (c)

(a) 46 parts for panel thicknesses

(b) 9 parts for panel thicknesses and material variation

(c) 9 parts for presence or absence

Fig. 5 Three classes of design variables

Once the design variables, constraints, objectives, and the relationships among them have been chosen, the MDO problem can be expressed as

Find $\mathbf{x}$ Eq. 1

Minimizes $J(\mathbf{x})$ Eq. 2

Subject to $\mathbf{g}(\mathbf{x}) \leq 0$ Eq. 3

and $\mathbf{x}_{lb} \leq \mathbf{x} \leq \mathbf{x}_{ub}$ Eq. 4

where $J(\mathbf{x})$is an objective: the total weight of the BIW steel parts, $\mathbf{x}$ is a vector of design variables which are described in Fig. 1 ~ Fig. 5, $\mathbf{g}(\mathbf{x})$ is a vector of inequality constraints which are defined with the targets of each performance, and $\mathbf{x}_{lb}$ and $\mathbf{x}_{ub}$ are the vectors of lower and upper bounds on the design variables.

To find the optimal design candidates that have lots of trade-offs among the objective and constraints, this study has considered statistical models using RSM(response surface model). And then Genetic algorithm has searched the multiple borders based on the statistical models to find the optimal candidates as shown in Fig. 6. So, the applied process is allowed to find better balanced compromises between the objective and multiple constraints. Fig 6. shows that the resultant trade-off between the objective and the sum of all performance violation. Relevant to the priority among criteria, different weighting factors on the criteria can generate various cases of trade-off. In this study, some of weighting factors among the performances were defined to compute the sum of the violation.

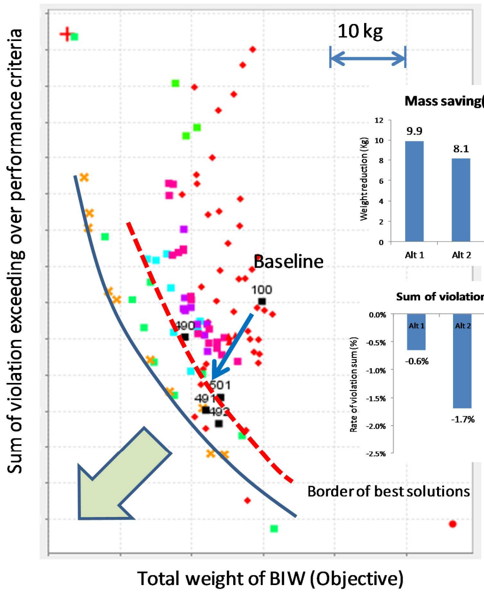


Fig. 6 Trade-off graph for optimal search

3. Conclusions

This study has been addressed to find effective balanced proposals for a newly developed vehicle body structures. Reminding the goal to reduce some weight of the body structure and to improve the level of baseline design performances, we've proposed three configurations from this study. They could save from minimum 5.5kg up to maximum 9.9kg. This weight reduction came along with compatible performance improvement as well. Therefore, the proposed optimal configurations present a satisfactory compromise among the different disciplines, even though it is quite complicated to get a balanced state in NVH, crash and durability because these are usually contradictory.