Frequency Optimization of IP (Instrumental panel) & MFD Bracket Using OptiStruct

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Abstract
Optimization demonstrates its potential benefits when it is used in the early product design stage. However, many optimization applications for real-world problems are not straightforward, especially in resolving product issues and meeting product design and manufacturing requirements. Those problems can only be conquered by effectively utilizing established product experiences and optimization knowledge. Product cost and quality are two vital concerns in product design processes. On the other hand, design optimization provides great opportunities to reduce product cost and improve product performance.

This paper presents automotive applications of Topology/Topography optimization methods. A vehicle instrument panel (IP) was identified as a cost saving opportunity by replacing a low-cost material; however, the NVH performance of the entire IP system was degraded due to the material change. In order to resolve the issue, a density approach of topology optimization method was used to find optimal rib deployment on the IP substrate/Upper, so the stiffness of the IP system could meet the design requirements. Through topology optimization, an optimal rib pattern was found; it not only provided a solution to the problem but also significantly improved the IP system NVH performance.

Topography optimization is used in sheet metal design improvement. MFD device is held on the metal bracket. Plane sheet panels exhibit poor stiffness and NVH performance due to their flexibility. A common and cost-effective approach in the automotive industry is to provide beads to the panel. Using topography option we can identify the optimal location to achieve the target design parameter.

Introduction

Introduction to Instrument panel (IP):
An instrument panel is an assembly that consists of a structure, substrate, and the optional assembly of the glove box, AC ducts, demisters (with associated ducts) and registers. Visteon's Instrument Panel is a finished integrated assembly that provides additional value to the customer by offering flexible and cost-efficient solutions, such as variable air speed ventilation and electronic glove box actuation.

Visteon's Instrument Panel can incorporate a variety of technologies (materials and processes) to create cost-efficient product differentiation. As an example, Visteon is able to develop a basic instrument panel infrastructure (structure, ducting, electronics, etc.) and deliver differentiation across platforms by applying one substrate for a lower-end segment and another for higher-end segments; or by applying different grain/texture Visteon can create a specific look/feel to bring about differentiation.
Introduction to Multifunctional device (MFD):

Visteon's color center display with navigation is based on a flexible multifunctional display (MFD) platform that allows for maximum hardware/software reuse and extensive customizations. Architecture combines color display functionality with map navigation. Supports screen resolutions of up to 800x480 (WVGA) enabling map guidance, photo realistic presentation and clear external camera visualization for driver and passengers. Integrates vehicle features such as network gateways, multi format bus types (CAN, LIN, ISO1850) or immobilizer system functionality.

Topography optimization is used in sheet metal design improvement. MFD device is holding on the metal bracket. Plane sheet panels exhibit poor stiffness and NVH performance due to their flexibility. A common and cost-effective approach in the automotive industry is to provide beads to the panel. Using topography option we can identify the optimal location to achieve the target design parameter.
Figure 2. MFD (Multifunctional display device) assembly
Process Methodology:

Optimization Process Chart:

1. **Input**
   - Design Engineer provides 3D CAD Model

2. **Modal Analysis**
   - 1. Check the modes of Assembly
   - 2. Check the local mode of part; which is to be optimize

3. **Topology / Topography Optimization**
   - 1. **Design Space**: Part to be optimized.
   - 2. **Objective**: Increase the first natural frequency
   - 3. **Design Variable**: Adding Ribs / Beads
   - 4. **Output**: Density contour / Shape change

4. **Frequency > target freq.**
   - **NO**
   - **YES**

5. **Update the 3D CAD model on the basis of Optimization**

6. **Modal Analysis**
   - Check the first natural frequency at local & global mode

7. **Design Finalization**
1. Optimization of IP (Topology Optimization):

The IP upper, made from ABS material having average base thickness as 3mm. The assembly consists of HVAC, Ducts, CCB Bar etc. as shown in figure 3. When initial design of IP analyzed, frequency at IP upper location found to be 41.3Hz at mode #5 (refer figure.4).

For stiffer design, frequency must be above 45Hz, as it has to passed in NVH and also in point load cases. To resolve the issue, ribs were deployed on the IP substrate to improve its structural stiffness. Yet, identify the optimum location of the ribs was a challenging task. In this application, a density approach of topology optimization method was used to find optimal rib deployment on the IP substrate, so the NVH performance of the IP system could meet the design requirements. Figure 3 shows the FE model in shaded format of the IP system.

![Figure 3: FE Model of IP Assembly (Baseline Model).](image)

**Step 1: Finding the first natural frequency for initial (Baseline) design.**

The initial design of IP assembly taken for Modal analysis. The solution obtained from the OptiStruct solver for modal run showed that the frequency at the IP upper location was 41.3 Hz at Mode #5 (see Figure 4).

![Figure 4: Result contour for modal analysis of baseline IP Design.](image)
**Step 2: Design optimization**

Topology Optimization tool in OptiStruct was selected. The IP was meshed with quad & tria elements having global element size of mesh is 8 mm. The IP upper was divided into designable (green) and non-designable (brown) segments (see Figure 5). The non-designable segment includes elements that are beyond the scope of any possible optimization.

![Designable and non-designable segments of the IP upper.](image)

**Figure 5. Designable and non-designable segments of the IP upper.**

The details of optimization are as follows:

Desvar = “topology”
Base Thickness = 3mm.
mindim = 24mm.

The mindim (DTPL) is taken 3 times the global element size. For safe manufacturability of rib, its height should not be greater than 3 times that of thickness of the IP base. Hence, the value of height was chosen to be 8mm. The response chosen for desired optimization was of “frequency” type. Since we are concerned with the frequency of the IP upper location, the mode number for the response was chosen as 5.

The objective of the optimization assigned was to maximize the frequency of the IP upper and the corresponding modal load step was referenced for the same.

**Step 3: Results & Discussions**

After 06 design iterations, an optimal thickness pattern from topology optimization results was found and shown in Figure 6; and the contour plot shows important region for Rib addition in red color. Contour shows the Rib height value (max. 8mm) that needs to be kept.

![Topology optimization results for IP Upper Location](image)

**Figure 6: Topology optimization results for IP Upper Location**
Step 4: Manual optimization

The suggested design modifications were performed to capture the Rib patterns (yellow color) from optimization result (see Figure 6). Rib of height 7mm and thickness of 2mm (must be less than base thickness) were used to add. refer below figure7.

Figure 7. Manual Rib Addition after Optimization result

Step 5: Modal Analysis

The IP assembly with manually optimized design was analyzed and the frequency obtained on IP upper location is raised to 47 Hz at Mode #8 (see Figure 8).

Figure 8. Modal contour for frequency of optimized upper IP

The final IP upper location obtained a frequency of 47 Hz with increased in mode number from 5 to 8.
2. Optimization of MFD Bracket (Topography Optimization):

The MFD bracket, made from SPH (steel) of gauge 2mm and is mounted with the help of four bolt locations (shown by green circle) refer figure 1. When the initial MFD bracket design was analyzed for normal modes, the first natural frequency was found to be 64.74Hz (Bracket isolated) & with display unit assembly found to be 96 Hz. For a robust bracket design, the first frequency should be greater than 85Hz (isolated) & with display assembly above 100 Hz, to avoid any possible resonance with IP and body vibrations. As on assembly level; its effect on first Natural frequency will be lesser. Hence, it was required to optimize the existing design to ensure robustness of the bracket and the attached display module.

Since packaging is a major constraint in the assembly of brackets and modules, major changes in dimensions and shape were not possible for optimizing the existing brackets. Thus, the optimization technique selected was Topography optimization.

**Step 1: Finding the first natural frequency for initial (Baseline) design.**

The bracket assembly was prepared without assembly to reduce the run time although the frequency value obtained is higher than that obtained in the complete assembly. The solution obtained from the OptiStruct solver for modal run showed that the frequency of the bracket was 64.74 Hz (see Figure 1).

![Figure 9: Result contour for modal analysis of baseline bracket.](image)

**Step 2: Design optimization**

Topography Optimization tool in OptiStruct was selected. The bracket was meshed with tria elements to avoid the error caused by distortion of quad elements during optimization run. Global element size of the bracket mesh was kept to 1 mm for effectively capturing the geometric details and swage patterns. The bracket was divided into designable (brown) and non-designable (yellow) segments (see Figure 10). The non-designable segment includes elements that are connected to rigid and are beyond the scope of any possible optimization.
The details of optimization are as follows:
Desvar = “topography”
Minimum width = 6mm.
Draw angle = 60 deg.
Draw height = 4mm.

The draw height is the maximum height of the beads that can be created on the geometry. It depends on the gauge of the bracket. A safe value for manufacturability is 2-3 times that of thickness of the bracket.
Hence, the value of draw height was chosen to be 4mm. Due to packaging constraints, the direction of beads on the bracket has to vary in order to successfully mount the modules without penetration. Hence two optimization runs were given with different “bounds” values. This would help in effectively choosing and combining swage patterns from both the results.

Thus, the bounds given for the bracket optimization iterations were:
1. Upper bound = 1 and Lower bound = 0
2. Upper bound = 0 and Lower bound = -1

The response chosen for desired optimization was of “frequency” type. Since we are concerned with the first natural frequency of the bracket, the mode number for the response was chosen as 1.

The objective of the optimization assigned was to maximize the frequency of the bracket and the corresponding modal load step was referenced for the same.
Step 3: Results & Discussions

The results obtained from the optimization study yielded two design solutions (see Figure 6) for achieving the desired frequency of the MFD bracket. For efficient manufacturing and packaging, features from both the design were to be combined to get the required optimized design.

Figure 11. Topography optimization results for (a) positive upper bound and (b) negative lower bound

Step 4: Manual optimization

The initial design modifications were performed to capture the bead patterns of the above two designs (see Figure 7). Beads of height 3mm and width of 7mm were used to add stiffness and bottom bead pattern increased from 2 to 3 refer below figure.

Step 5: Modal Analysis

Simulate to Innovate
The bracket with manually optimized design was analysed and the first natural frequency obtained for the bracket was 88.13 Hz (see Figure 12).

![Modal contour for first natural frequency of optimized bracket](image)

*Figure 12. Modal contour for first natural frequency of optimized bracket*

For ease of manufacturing of the bracket, a selection of features added on the bracket was removed (yellow circled region) in a way to minimize the modifications made on the bracket without a substantial drop in the frequency (see Figure 9). This would help in reducing the bracket manufacturing cost.

The final MFD bracket obtained a frequency of 87.26 Hz without assembly with Display unit and 105.22 Hz when assembled with the Display unit (see Figure 13).

![Final MFD bracket design and modal frequency of 87.26 Hz.](image)
Benefits Summary

Cost is a driving force in today's competitive market. Automotive suppliers face persistent cost pressure from the OEMs due to fierce market competition. This competitive environment requires automotive manufacturers to utilize advanced technology to identify and implement cost saving opportunities with CAE solutions being among the most effective. Using PP material, a cost savings will be achieved but the NVH performance of the IP system was degraded. With effective utilization of Optimization, Rib optimal addition can be made. Which lead to more cost effective than material change.

The design, optimization and selection of electronic brackets are iterative processes. Due to the sensitivity of the brackets, it is generally tough to correctly predict the effect of a certain modification on the frequency of the bracket. Hence, with the conventional methodology the productivity as well as accuracy of the results is compromised with. The improved methodology discussed above, was found to be more successful in the cycle of bracket design-optimization-selection.

Challenges

Adding of rib normal to IP surface is difficult to make in FEA tool because of the curved feature of the surface. Rib dimension also need to be checked regarding manufacturing constrained & packaging. The beads added through the bead feature in HyperMesh are not consistent in height around bends in geometry. Hence, it is difficult to successfully capture the feature as intended using FEA modelling tools.

Future Plans

In competitive automotive world, cost saving is the major driving member among the automotive companies. It is planned to replace the ABS material with P/E MD15-Hostacom-12Material for IP substrate in all possible vehicle with optimal rib design using optimization. Modern luxury vehicles have a number of electrical brackets. It is planned to discretize the improved methodology into viable steps and implement it in the day to day optimizations performed on various electrical brackets in the vehicle.
Conclusions
Two automotive applications using Topology & Topography optimization techniques demonstrate an innovative way of solving real-world engineering problems. By effectively utilizing the topology/topography optimization, a significant cost savings on automotive component was realized. The proposed design not only showed the cost advantage over the original design but also provided better NVH performance for the entire system. This is evidence of the potential benefit of design optimization for future products with similar applications. The proposed optimization approach helped resolve the issue in a timely manner. The optimization applications presented in this paper attempt to share innovative ways of improving product design and inspire more use of optimization applications in industrial communities.

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