

Simplified CAE Models for Upfront Development of Instrument Panel

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ABSTRACT

The Automotive industry's use of digital technology such as Computer Aided Engineering (CAE) to perform virtual validation has progressed to effectively replace a large percentage of physical validation. This is primarily due to the increased accuracy and cost/time efficiencies that virtual validation offers compared to conventional physical prototyping and testing. With product development (PD) cycles becoming more compressed, CAE has assumed a more significant role in early, advanced design and structural evaluation. One of the areas where CAE is widely employed is in development of the Instrument Panel (IP) commonly referred to as the dashboard. For the purposes of this study, the term IP represents the plastic/polymer structure only, and not the full IP sub-system. The IP sub-system includes the structural member, the Cross Car Beam (CCB) assembly and all the IP mounted modules.

The primary objective of this exercise is to guide upfront IP design using a simplified representation of the IP sub-system. The CCB assembly is represented as a parametric, simplified and scalable beam model. This simplified CCB model can then be used to simulate the IP sub-system as soon as the studio "class A" surface data is available in conjunction with assumptions for the masses of key IP mounted modules. The exercise is expected to yield a reliable process to guide the IP design, for structural stiffness objectives, at early stages of the PD cycle. To prove the effectiveness of this process, it is implemented on several IPs from different vehicle classes, and the global frequencies of the resulting simplified models are compared to the fully contented, traditionally built models.

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INTRODUCTION

Simulation typically follows design as it requires Computer Aided Design (CAD) data for modeling and then analysis. Mature CAD data is usually available very late in the PD process and CAE is used to iterate and fine tune the design. Most systems and subsystems have several structural requirements, some of which require the fine details of the design to be available for effective simulation. On the other hand, there are several requirements that can be quite effectively evaluated with preliminary macro-level design data. There is great value in this upfront analysis as it can give the design team scope to virtually verify and weigh alternate design ideas very early in the PD process, with little impact on timing. This study focuses on the Normal Modes Analysis to obtain the natural frequencies of the sub-system as they are very effective indicators of the stiffness of the overall structure.

Many original equipment manufacturers (OEMs) and their suppliers are looking to leverage existing CAE models by adapting legacy versions using morphing tools for quick feedback during development [1]. For Tier 1 suppliers, this agility is vital. For IP suppliers, there is an additional challenge of incorporating the interfacing structure and other modules that complete the full IP sub-system. A full IP sub-system, in addition to IP trim parts, typically includes the main structural component otherwise referred to as the Cross Car Beam (CCB) assembly and the key modules such

as the Steering Column, Instrument Cluster, Passenger Air Bag, Energy Absorbing brackets, the HVAC module, and Center Stack components. Majority of these are developed in parallel by the OEM or other suppliers. This concurrent development adds complexity to early virtual assessments. However, for effective and accurate development of the IP, it must include the full IP sub-system. It is therefore imperative that IP manufacturers possess in their capabilities, the ability to perform upfront analyses of IPs at a sub-system level.

One of the alternatives to enable this upfront simulation is the usage of modified/morphed legacy models that could act as surrogate data for simulation. Another option is to use simplified/generic structural or background information to assist the development of the main components of concern. For Tier 1 suppliers of IPs, this latter method is more suitable as the background information may not be readily available.

At the start of any IP design program, the main theme of the IP design is defined by the OEM. This is usually represented as a surface and is referred to as the 'Studio Surface'. As the studio surface is the earliest resource available for the plastic IP, it is of great value to early, upfront simulation studies. With the objective of using the studio surface as the plastic structure for simulating the IP sub-system, the

next step is to develop a process to accurately represent the remaining parts of the IP sub-system, the CCB assembly and all the add-on modules mounted on IP.

PROCESS DEVELOPMENT

The process to develop the CAE model for upfront simulation of an IP sub-system using the studio surface as the basis involves the following three main steps:

1. Represent the main structural component of the IP sub-system, the CCB, with a generic and simplified structure.
2. Approximate all the add-on modules of the IP using the masses with the appropriate mass moments of inertia (MOI).
3. Use the output from the first 2 steps to develop the simplified IP sub-system model using the Studio Surface as the basis for further analyses.

All the modeling and analyses in this study are performed using Altair tools: HyperMesh and Optistruct (RADIOSS) [2]. Further, the scope of this study is restricted to comparing the 1st global frequencies of the IP sub-system using normal modes analysis and hence the resultant simplified models are capable of being used for normal modes analysis only.

CCB Parameterization

The first step in the development of the simplified/parametric IP sub-system as described above attempts to reduce the CCB to a simple 1-d beam model.

Formulation of 1-d Model (Using Normal Modes/Stiffness)

To develop a simplified/parametric and valid 1-d model of the CCB assembly, the various features of the CCB assembly are separated into the following 3 groups based on the physical structure of the CCB assembly: 1. the main CCB tube, 2. the two end brackets and 3. intermediate support brackets on the tube.

The first consideration for CCB parameterization is identifying all design variables of the CCB tube.

- Identify an average cross sectional shape and thickness for the tube
- Identify appropriate subdivisions to account for various support bracket configurations.

A 1-d beam with a circular cross-section of 50 mm diameter and 1.5 mm thickness is the best approximation for the CCB tube of the 4 vehicle classes that are considered. Although one out of four designs shows curvature in the main tube, a straight main tube design is chosen for easy adaptability into various IPs.

To account for the various support brackets and content among the 4 classes of vehicle IPs, subdivisions needed to be made along the length of the main tube. 5 mm length is chosen to provide sufficient

nodes to connect support brackets at any position along the length of the main tube.

The second consideration for CCB parameterization is identifying the design variables for the two end brackets.

- It is critical to determine a nominal cross sectional shape and thickness that will be representative of the stiffness of end bracket design yet remain adaptive and simplified.
- Identify appropriate subdivisions to account for varied locations of end bracket vehicle mounts and the distance between the two.

End brackets are generally L-shaped, C-channel or 2-piece designs. A 1-d beam element with L-shaped cross-section is sufficient to represent the attaching scheme to both the CCB tube and the body-in-white (BIW) mounting locations. A 3.0 mm thick 1-d beam with length, width and height of 90 mm x 50 mm x 130 mm approximates the end brackets of the 4 classes of vehicles considered.

Having three 1-d beam elements will account for two attachments to the vehicle and also allow for adjusting the distance between BIW attachment locations.

The third and final consideration for the CCB parameterization is the approximation of all the intermediate brackets on the CCB that support the weight of the entire IP and other brackets that attach to the floor and front-of-dash.

Every IP has its own unique structural bracket scheme, based on structural and functional requirements, the mass of the components in the assembly and their location. The challenge for this step is to approximate the stiffness of the various structural members of the CCB using a generic 1-d beam. The steps followed to obtain the properties of this generic 1-d beam are:

- Obtain the stiffness values for all the intermediate support brackets at the IP attachment locations for several IP subsystems.
- Divide the stiffness values by the distance from bracket IP attachment to the center of the CCB tube to obtain the normalized stiffness values.
- Identify the critical brackets based on strain energy plots of the normal modes.
- Average the normalized stiffness values of the filtered list of brackets to obtain the target normalized stiffness values.
- Isolate the cross-section and thickness of a 1-d beam element that match the normalized stiffness values obtained earlier.

The above procedure resulted in a 24 mm x 8 mm x 2.0 mm thick C-section beam as the best approximation for the intermediate brackets of the 4 vehicle classes that are considered.

Figure 1 is an illustration of the detailed CCB and its simplified version as obtained using the steps described above.