COMPOSITE DESIGN INNOVATIONS: THE NISSAN TRUNK DIVIDER HYBRID PANEL

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Abstract

The 2007 redesigned Nissan Sentra includes a unique trunk divider panel system that utilizes several different composite materials. The multi-piece (hybrid) main panel consists of a compression molded SMC 'inner' panel, an in-mold carpeted flax fiber-filled polypropylene 'outer' panel, integral glass-filled grocery hooks, and two-way latching mechanism.

The divider panel is mounted to the vehicle via a compression molded SMC 'upper' panel that mounts to the vehicle's sheet metal package shelf, as well as two glass-filled polypropylene hinges that mount to the vehicle's trunk floor.

To add versatility, the panel can be used in a closed position to form two trunk compartments, folded flat to the floor to transport wet or muddy items, or removed entirely from the vehicle for clean-up or outside use.

This system meets all required cost, mass, performance / functionality, and quality targets. This presentation will focus on the design, development, materials, testing, and manufacturing methods applied to bring this 'hybrid' composite system to market.

Introduction

The use of composites in automotive applications is as varied as the vehicles they are used on. From powertrain components, to body panels, to key structural members, the industry has long looked composites for mass reduction, design flexibility, robust performance, and cost savings.

One area where composites are gaining a foothold is in the interior space of the vehicle. For the aforementioned reasons, OEM's are looking to these materials to provide an answer to the following question: *How does one find a balance between packaging environment, weight, cost, function, and performance - without sacrificing any of them?*

Nissan looked to the supply base to answer that question. The answer found its way into the 2007 Sentra as the 'Divide-N-Hide™' trunk system. By using a variety of composite materials, the program team was able to create a unique hybrid trunk divider system that merges form with function.

Why was a composite hybrid system the solution? The composite hybrid system was the obvious choice because it met the cost, performance / functionality, and quality targets that were required by the customer, and ultimately, the owner of the vehicle that would be using it. Several of the significant program targets will be discussed in the next section.

Performance and Analytical Modeling

To achieve customer expectations for functionality, durability, mass, and cost, the divider panel system design needed to meet a wide range of performance objectives. Since the panel itself is used both in and outside of the vehicle, it needs to be lightweight (less than 4.5kg), durable, and easily removable.

Additionally, since it is used within the trunk compartment, it needs to withstand load cases of up to 667.5N (150 lb.) while remaining functional with in-vehicle temperatures ranging from –40^0 to 70^0C. To meet packaging criteria, the panel could be no thicker than 30mm.

Figure 1: Typical views of the divider panel system

System Performance Objectives

Although there are a substantial number of design and performance specifications required, the table below highlights the *most* significant *system* performance objectives that were considered during the development of the program. Note that specific load cases and performance targets are omitted for confidentiality, but general information on performance targets is reviewed.

Additional specifications pertaining to the upper reinforcement and the hinges are not included, as this presentation focuses mainly on the hybrid nature and design of the divider panel itself. However, all component details will be discussed in the 'Program Design Review' section to illustrate the total scope of the trunk divider system.

Key Design Objectives		
		Performance description
1.	Load - latch assembly	Individual loading distributed over latch mechanism. No loss of function, no permanent deformation during any testing (thermal cycle and high temperature included).
2.	Load - panel - trunk side	Individual loading at the CG of the panel. Must pass prescribed deflection targets. No loss of function, no permanent deformation during any testing (thermal cycle and high temperature included).
3.	Load - panel – cabin side	Individual loading distributed using 100mm diameter disc @ all four corners. Must pass deflection targets. No loss of function, no permanent deformation during any testing (thermal cycle and high temperature included).
4.	Thermal cycle testing	Load at CG of flat panel. Four thermal cycles. Must meet required maximum sag and permanent deflection targets. No loss of function.
5.	Panel thickness	< 30mm
6.	Panel weight	< 4.5kg
7.	Water retention	Must retain 1.98L (67 oz.) on cabin side.
8.	Grocery hooks	Fold flat condition. Must meet prescribed load requirements for individual hook and combined hook load cases. Total grocery hooks: 4.
9.	BSR	No BSR conditions.

Table I: Divider panel system design criteria

Other standard performance targets were also required for the system. Examples of these are flammability, chemical and abrasion resistance, weathering, moisture resistance, and ball drop testing.

Together, these specifications presented a significant challenge to the design team. Finding the right combination of materials to withstand the stringent loading conditions, meet the mass target, fit the packaging constraints, and perform to the multitude of other targets, led to the design of the hybrid divider panel system.

Analytical Modeling

During the design phase of the project, significant reliance on finite element analysis (FEA) was required. In an environment of ever-changing styling and ongoing design modifications, the use of analytical tools to predict change impact was essential to keep a program on track. Being able to predict the effect of a change to how it performs in validation, and subsequently in the field, is critical.

The information below shows a normalized example of how expected FEA results correlate to actual performance of the divider panel during physical testing. The target for deflection is noted as 100% (actual testing targets are proprietary), with actual testing results shown as a percentage relative to it. The panel performs even better than predicted, and exceeds program expectations.

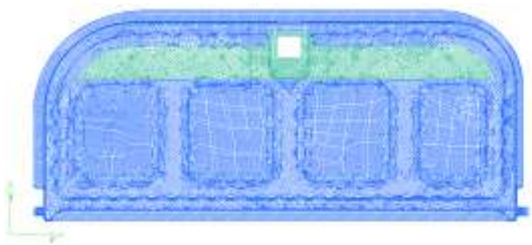


Figure 2: FEA model and physical test part.

Correlation – FEA to Physical Testing		
Load case	**FEA predicted deflection**	**Actual test deflection - percent of target**
Upper left corner	100% (mm)	79%
Upper right corner	100% (mm)	93%
Lower right corner	100% (mm)	64%
Lower left corner	100% (mm)	86%

Table 2: Correlation of FEA to physical testing.

Program Design Review

The trunk divider system is composed of three main components: 1) the 'hybrid' divider panel assembly *(1100 x 30 x 460mm)*, 2) the upper reinforcement *(865 x 115 x 125mm)*, 3) and the divider hinges *(150 x 25 x 90mm)*. As stated previously, the main focus of this section will be on the divider panel design.

Figure 3: Exploded view of divider assembly (including upper reinforcement and hinges).

‘Hybrid’ Trunk Divider Panel Assembly

As stated previously, the divider panel assembly is the showpiece of the system. Its multi-purpose functionality gives the vehicle owner many options for cargo transport and configuration. As a divider panel, it creates two separate compartments in the trunk, for short and long term storage options, and the ability to hide items. It also folds flat to the floor, SMC side up, to allow for the transport and storage of wet or dirty items. Its two-way latch can be actuated from either side of the panel, and the integrated cargo hooks add to its functionality. The carpeted flax trim panel closes out the trunk side, and provides harmony with the rest of the trunk interior.

All of these functions are packaged into a lightweight, easily installed and removed system that is only 30mm thick. It withstands the vigorous validation requirements (listed previously) set forth at the design inception, including cycle durability, thermal cycle, and impact load testing.

The panel assembly consists of the following main components:

1. Low emission SMC (sheet molding compound) structural inner panel.
2. Flax fiber filled PP (polypropylene) trim panel with carpet.
3. Two way latch assembly.
4. Grocery hooks and two-way studs (four each).
5. Miscellaneous finishing components.

Structural Inner Panel

The structural panel is compression molded 30% (50% 1”, 50% ½”) glass-filled, black, high performance polyester SMC. Since this is an interior part, a low odor catalyst was used to reduce styrene emissions. Nominal wall stock is 2.50mm, with local areas thickened to create bosses for attachment points. This grained panel forms the cabin-facing side of the assembly, and serves as the main structural member. Average material property values: tensile strength - 90 MPa, tensile modulus – 11,300 MPa, and flexural strength of 180 MPa.

Incorporated (molded) into the panel are several key features. These include the pivot / mounting features that interface with floor hinges, the bosses for both the grocery hooks two-way latch attachments, recessed pockets to help meet the liquid retention requirement, and a hand-hold to lift the divider up easily from the horizontal position.

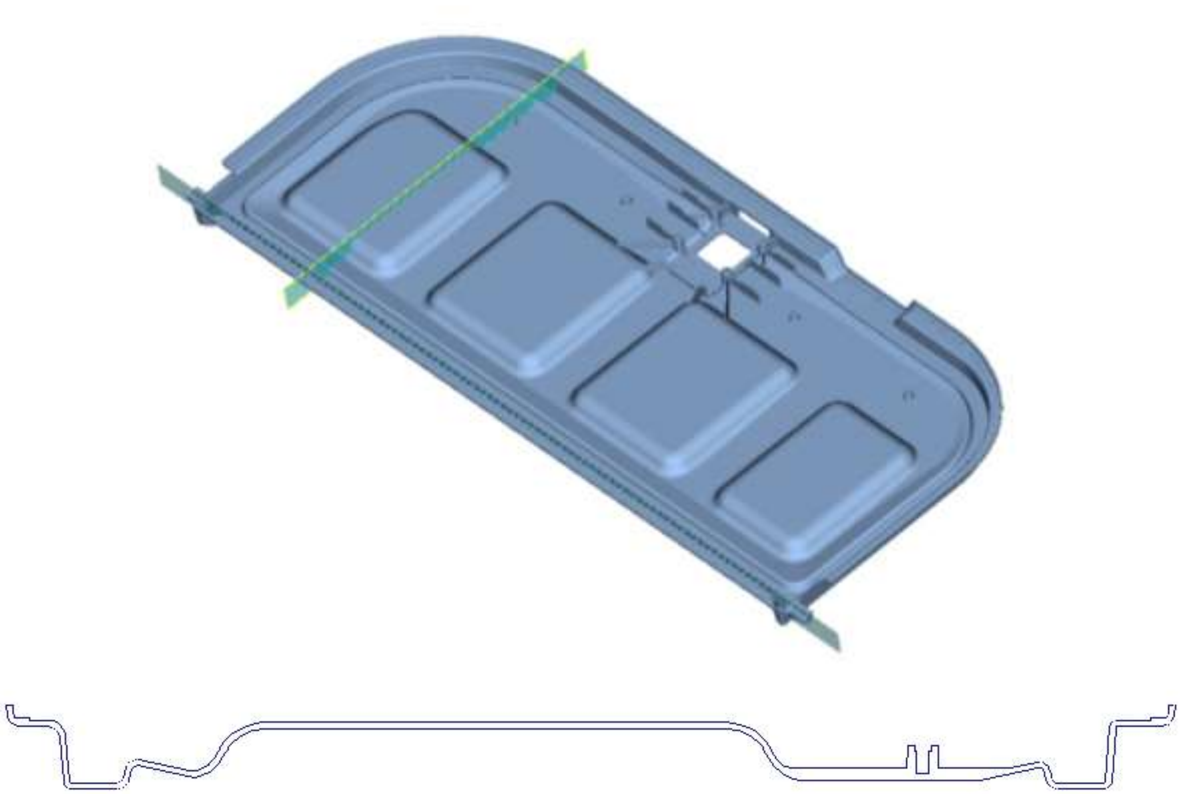


Figure 4: Y-section shows boss geometry for cargo hooks and water management pocket.

Figure 5: Z-section shows slide-formed pivot points.

Flax/PP Trim Panel with Carpet

The flax/PP trim closeout panel is a combination of flax (50% PP, 50% flax fibers) and a 6.5 oz. polyester carpet. The flax mat and the carpet are molded together in a 2-station press consisting of a heated platen (200-230^{O}C) for pre-heating the flax, and a cool (15^{0}C) forming tool to keep the exposed carpet fibers undamaged during molding.

During the molding process, the polypropylene in the heated flax blank co-mingles with the polyester fibers in the carpet blank and forms a mechanical bond, eliminating the need for adhesive, and a secondary operation.

Care must be taken during the forming process to make sure the carpet stays in place to eliminate wrinkling. To make this happen, Velcro is used in the forming tool (at either end) to hold the carpet under tension during panel assembly molding.

The typical process for manufacturing the panel is as follows:

1. Place precut flax/PP blank on heated platen.
2. Place carpet blank and previously heated flax blank onto cool form tool.
3. Cycle mold, remove formed / carpeted part along with trimmed off-fall.
4. Send panel to next station (if required) for cooling and secondary operations such as punched holes and openings for the cargo hooks and two-way latch.

Figure 6: Raw flax/PP and carpet, through hot plate / cool form tool, to final carpeted panel.

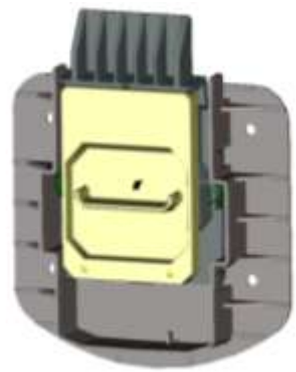
__Two-way Latch Assembly__

The two-way latching mechanism is another crucial piece of the divider panel assembly. Functionally, it needs to actuate from either side (cabin or trunk), and be glow-in-dark from the cabin side. Latch actuation efforts cannot exceed prescribed targets, and it must not interfere with the panel closing efforts.

The latch itself must also be robust enough to withstand 20,000 functioning cycles, along with passing the distributed load testing over itself with no loss of function or deformation. Additionally, it must package within the 30mm panel thickness to meet the fold flat requirement.

The main components (main latch pawl, trim plate) are 40% mineral filled nylon, the secondary pawl (cabin side) is an unfilled nylon 66 (glow-in-dark) which is pad printed with universal graphic opening instructions. Other components include the required springs and o-rings for efforts and BSR elimination.

Figure 7: Latch mechanism illustrations.



__Grocery Hooks with Two-way Studs__

There are four grocery / cargo hooks incorporated into the panel as well. These are made from 45% glass-filled black PP. They are attached to the SMC substrate via two-way steel threaded studs. Functionally, the hooks need to withstand the downward forces that grocery bags will place on them without pullout, loss of function, or deformation – which they do. However, to eliminate thread creep-back over time, a small amount of adhesive is used on each end of the threads.

Figure 8: Cargo hook illustrations.

Miscellaneous Finishing Components and Part Assembly

All that is left now is the assembly of the 'hybrid' divider panel. First, the flax/PP trim panel is bonded to the substrate via a black two-part epoxy adhesive. Lap shear testing at –30^{0}C, ambient and 80^{0}C was performed to make sure that the flax/PP stayed bonded to the SMC. Next, the latch is installed to the SMC substrate via 4 screws through the trim plate, into molded bosses. Finally, the four cargo hook sub-assemblies (cap and two-way stud) are threaded into the bosses in the SMC panel and held in place with a small amount of the two-part epoxy.

Upper Reinforcement Assembly

The upper reinforcement panel is compression molded 30% (50% 1", 50% ½") glass-filled, black, high performance polyester SMC, with the same low emission catalyst as the divider panel. It also includes several different clips, rivets, and rubber bumpers, and a locating plate, whose functions will be described in this section. The primary function of the upper reinforcement is to provide a support structure where the divider door can both latch and distribute rear shifting loads.

Figure 9: Front and rear views of the upper reinforcement.

Reinforcement Presentation to Vehicle

Installation to the vehicle is handled in two simple operations. First, it is loaded to the sheet metal package tray and temporarily held in place via two up-facing bayonet clips, and two tabs on the outboard ends of the upper panel itself.

Correct presentation to the vehicle is accomplished by using an upstanding pin on the center locating plate to guide the reinforcement into a punched hole in the package shelf sheet metal. Second, it is permanently affixed to the vehicle by two M6 bolts that are driven through two U-clips on the top of the reinforcement. No additional attachments are required. Rubber bumpers, Teflon tape, and a nylon sleeve are used in various locations to eliminate system BSR.

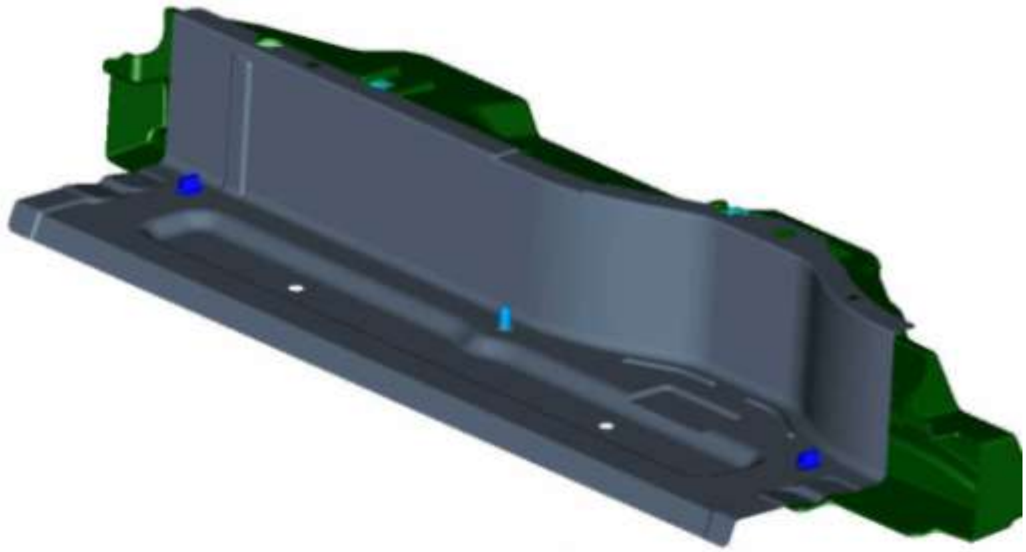


Figure 10: Interface between the bayonet clips (x2) and center locating pin with package shelf.

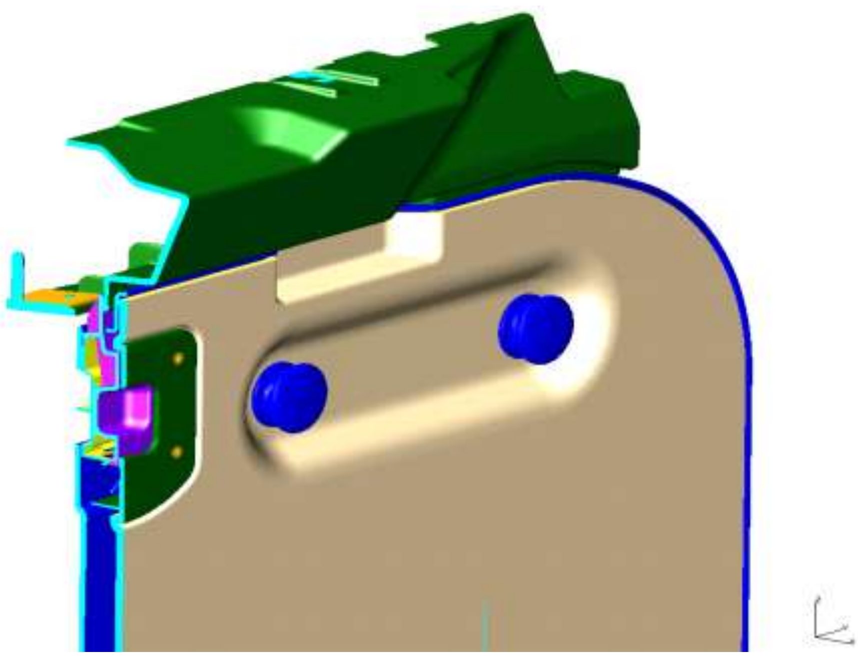


Figure 11: Section view of stack-up between the divider panel and the upper reinforcement.

Divider Hinges

There are two divider hinges in the system. They are injection molded 45% glass-filled black PP. In-molded hooks are provided to create mounting locations for the cargo net that comes with the vehicle. Foam tape is added at the bottom of each hinge to eliminate BSR, and to seal against water intrusion from the slots in the trunk floor where they mount.

Figure 12: Views of the divider hinges.

The primary function of the hinges is to provide a mounting location and retention for the divider panel at the trunk floor, in either the closed or the folded-flat positions. In addition, the panel required an installation / removal angle of 45 degrees. The illustrations show the design solution that met these requirements, and also helps met the shifting load requirements that the system is exposed to.

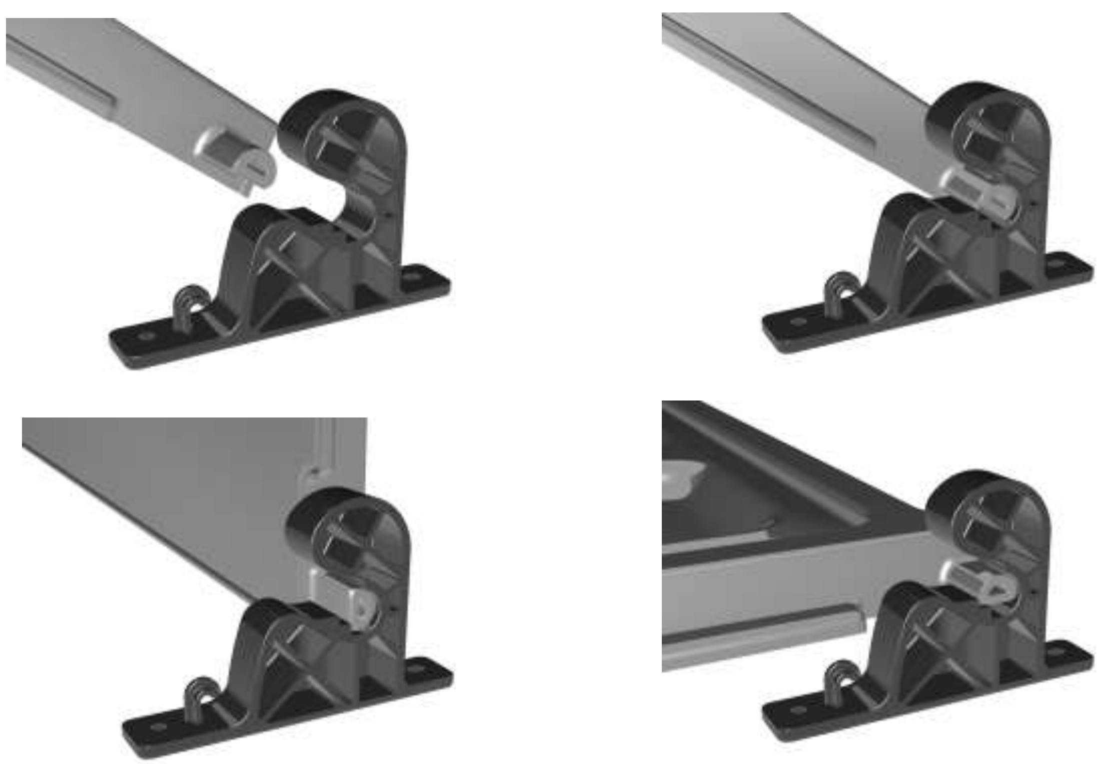


Figure 13: Install / remove position, along with latched, and fold flat pivot / hinge views.

Summary

As composite system suppliers seek expansion within existing markets, and target new uses for their products, the convergence of quality, innovation, and service is essential for success. The trunk divider hybrid panel system is an outstanding example of the 'designed solution' approach necessary to be competitive in an extremely challenging automotive industry.

The use of a variety of composite materials can unlock the very attractive combination of cost, performance, customer functionality, and quality that other material options cannot achieve. Finding the right balance in that combination, without compromising any of its pieces, was the key that the design team used to create a hybrid composite system that showcases innovation at work.

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