DEVELOPMENT OF LIGHTWEIGHT, HYBRID STEEL / GMT COMPOSITE IP CARRIER TO MEET WORLD CRASH REQUIREMENTS ON PASSENGER VEHICLES

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Abstract

A new, 2-piece, hybrid steel / glass-mat thermoplastic (GMT) composite instrument panel (IP) carrier reduces weight, noise / vibration / harshness (NVH), and cost while simultaneously improving parts consolidation and assembly vs. traditional, steel-intensive, multi-piece systems. In fact, for the first time ever in a single carrier design, this IP retainer meets or exceeds all world crash requirements. The award-winning design is currently featured on 6 IPs in 12 vehicles from Ford, Volvo, and Mazda. This paper will discuss design, development, and testing of this common carrier, plus the technology breakthroughs that helped make it possible.

Background

The IP – and especially its carrier – plays a very important structural and safety role in a passenger vehicle. Functionally, it forms the skeleton of the cockpit, providing the base architecture off of which IP components are attached and function. The carrier:

- Holds the front-end of the passenger compartment's command center,
- Is the component from which the IP topper pad, airbag, instrument cluster, center stack, knee bolsters, and glovebox assembly are attached,
- Supports the steering column,
- Ties left and right sides of the vehicle together at the A-pillars,
- Stiffens the front end of the vehicle for a crash,
- Holds the airbag deployment canisters and heating / ventilation / air conditioning (HVAC) system, and
- Transfers loads for opposing sides of the vehicle during offset crashes to prevent crushing inwards into the passenger compartment.

IP carriers are required to pass rigorous testing because they must withstand high loading during impact. Unfortunately, requisite safety standards and tests vary by geography, making it difficult to design a common carrier for multiple geographies without over-engineering.

The IP including its carrier are important components of the larger cockpit module, which is one of the most challenging systems to design and manufacture in a vehicle. This is due both to the complexity of its design and its role in maintaining passenger safety in the event of a crash. The cockpit is also heavily component oriented and influenced by the design culture of a given OEM. Most cockpits are characterized by mature designs and make use of traditional components.

Despite all this, there is tremendous opportunity for innovation in the cockpit module and particularly with the IP carrier because these systems tend to be component, cost, and weight intensive, and because the majority of them still make use of very traditional design and materials of construction.

Taking a New Approach

Tier 1, Faurecia (www.faurecia.com) has developed an innovative new design methodology that permits the production of multifunctional components and integrated cockpit systems. Called Syntes, this new cockpit strategy is intended to:

- Meet or exceed all global safety requirements and cost targets,
- Commonize components and systems across multiple platforms and models,
- Reduce weight, systems costs, part count, and warranty issues, and
- Retain each vehicle's signature look and feel.

The system is highly integrated, increasing performance while simplifying manufacturing and assembly. It integrates more than a dozen separate features and is lighter than traditional steel-intensive cockpits. Such an approach facilitates the creation of robust products while ensuring efficient space utilization, lower mass and systems costs, and lean production with the ability to assemble via conventional production methods on existing production lines.

The new hybrid-material IP retainer is an important component of this integrated cockpit system and makes use of Faurecia's 10+ years of experience with hybrid structures. The same carrier and integrated cockpit system is now used with 6 IP designs, on 12 vehicles, for 3 OEMs sold worldwide – the Ford® Focus® and C-Max®[1], the Volvo® S40®[2] and V50®, and the Mazda3®[3] passenger vehicles. These modules benefit from both the evolution in and adaptation of technologies such as injection- or compression-molded, long-fiber-reinforced thermoplastic (LFT or LFRT) composites with a polypropylene (PP) matrix; or steel overmolding (insert molding); and vibration welding of plastics. Also important are still-evolving computer-aided engineering (CAE) technologies that help ensure more efficient use of package space and faster design-to-production cycles via new software that optimizes component thickness, geometry, and load path.

Balancing Design Needs Using a New Tool

Instead of taking the usual component-by-component approach, a cockpit teardown and functional analysis is first performed as part of the new design methodology. To better balance often competing design needs during the advanced engineering phase, the company uses a comparison matrix. This tool helps the team more objectively select new concepts where functionality and geometry differ from current production models and provides support for the design and synthesis of systems under development. It works as follows:

- The generic functional analysis is the backbone of the tool.
- From this, a generic checklist for each functionality being studied is created. Key features and requirements are considered, such as:
  - Passive safety,
  - Environmental performance,
  - Recyclability,
  - Weight saving,
  - Durability,
  - Climate performance,
  - Ergonomics,

[1] ® Ford, Focus, and C-Max are Registered Trademarks of Ford Motor Company.
[2] ® Volvo, S40, and V50 are Registered Trademarks of Volvo Car Corporation.
[3] ® Mazda and Mazda3 are Registered Trademarks of Mazda Motor Corporation.

- Storage space,
- Design & equipment performance,
- Noise, vibration, & harshness (NVH) performance,
- Serviceability,
- Fire resistance, and
- Suitability for manufacture via conventional OEM assembly process.

- OEM specifications are used to assign the weighting (importance) associated with each item on the checklist.
- Finally, concepts are proposed for quotation and the results of each are consolidated onto a graph such as that shown in Figure 1.

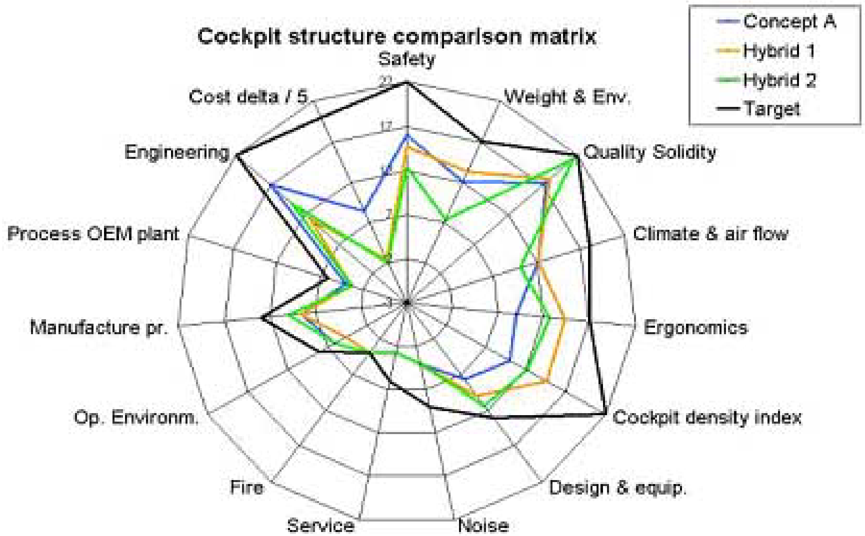

Figure 1: A comparison matrix is used early in the development program to evaluate the potential for various designs to meet program objectives and constraints. The matrix shown here represents an actual study of various hybrid cockpit concepts.

Use of the comparison-matrix tool allows the team to weigh the ability of different concepts to fulfill all of the project's objectives and constraints. This analysis evaluates most of the program's criteria – from research to serial production, industrial risk, planning management, and potential of performance breakthrough. During the analysis, different concepts are previewed and their compatibility and potential for meeting program goals are estimated. At this brainstorming stage, possible implementation of innovative technology and / or use of multi-material systems is also analyzed.

Not surprising, cost and weight reduction remain the central design constraints for hybrid cockpit design, yet they also provide the greatest opportunities for innovation. By graphically comparing program requirements with the potential of various designs to satisfy those needs, the cross-functional approach represented by the matrix ensures that mandatory performance parameters are considered and met. For instance, not only are design and processing considered, but failure-mode and effect analysis (FMEA) is also evaluated to alert if implementation of the developmental system might require changes to the existing manufacturing process.

Initiating a Development Program

Concept development for the first integrated cockpit design began with an advanced engineering project at Volvo Car Corp. in 1996. A year later, a formal partnership (Volvo / Faurecia) was established to deepen the advanced engineering project and to ensure that all core competencies required for developing the program were available. The project was heavily expanded between 1999 and 2001, becoming an international, cross-brand development and industrialization project. The integrated cockpit system resulting from this program was launched in 2003 on an entire transverse-mounted-engine platform within the Ford Group representing collaboration amongst Mazda, Ford, and Volvo for the models previously noted.

Rethinking the IP Retainer

A traditional metal IP carrier (Figure 2) is essentially a steel tube – often called the cross-car beam (CCB) – off which hangs multiple components, including:

- 2 end brackets (to secure the IP to the body-in-white (BIW) on each side of the car),
- 1 cowl top brace,
- 1 steering column bracket,
- 1 fuse-box door bracket,
- 1 footwall brace,
- 1 tunnel brace,
- Central display-unit structure, and
- Several glove-box brackets.

This system provides excellent crash resistance and stiffness, but is heavy, labor intensive to assemble, and can lead to NVH issues due to all the components and their fasteners.

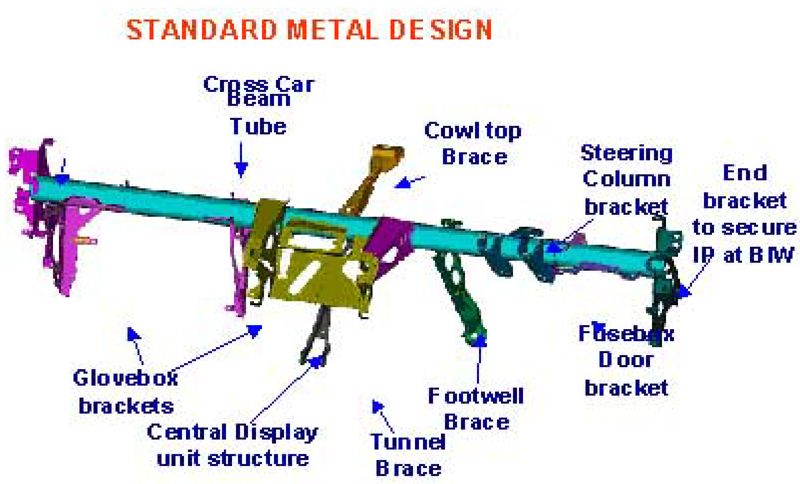

Figure 2: Traditional metal carrier with multiple components and bracketry, including the cross-car beam. This design has been replaced by a single-piece hybrid steel/composite design, which saves mass and costs and simplifies assembly.

In a significant departure from traditional IP carriers, the structure that emerged from the advanced engineering phase was a 2-piece hybrid retainer comprised of steel and 2 types of glass-reinforced polypropylene composite, as shown in Figures 3, 4, and 5. Design of the new hybrid cockpit incorporates the traditional CCB function (now reduced to a small steel tube), while also providing 90% of the cockpit attachment and reference points. It also includes the IP's ventilation and defrosting channels, which are formed as a box section when the lower IP carrier is vibration welded to the upper IP. Moving from a multi-component, steel design to the hybrid composite design was a key element to meeting program goals.

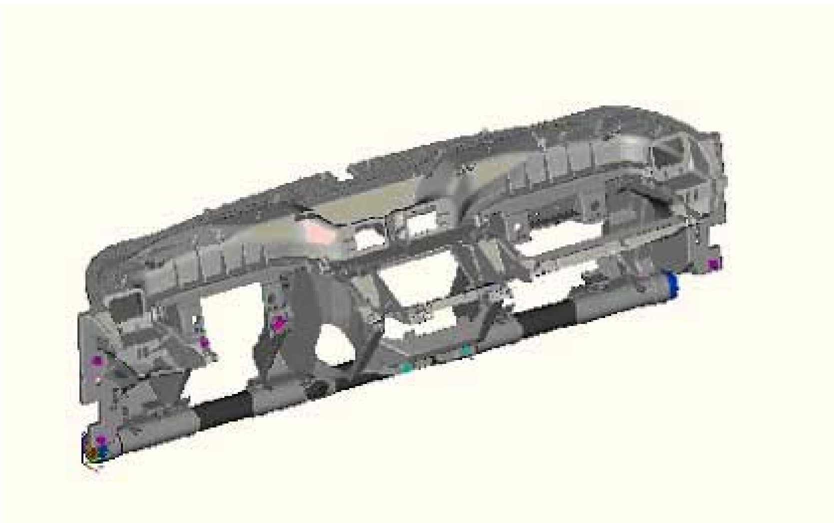

Figure 3: Solid model of hybrid steel/glass-reinforced polypropylene composite cockpit structure: Light grey (middle) component = compression-molded, glass-reinforced polypropylene lower instrument panel (IP) carrier; black (bottom, overmolded with carrier) = steel cross-car beam; and light grey (top) = injection-molded, LFT PP upper IP frame.

Figure 4 shows a model of the upper IP frame, which is injection molded from polypropylene-based long-(glass)-fiber-(reinforced) thermoplastic (LFT or LFRT) composite. This part is subsequently vibration welded to the IP carrier.

Figure 4: The upper IP frame is injection molded from LFT polypropylene with 40% long-glass fiber reinforcement. The lower IP carrier is subsequently vibration welded to the upper IP frame.

Figure 5 shows a solid model of the 1-piece lower IP carrier, which is formed by insert molding a minimized steel cross-car beam with a compression-molded glass-mat thermoplastic (GMT) composite of polypropylene and chopped long-glass fiber. The steel beam is necessary in this hybrid part to meet critical safety requirements that cannot be met with the current composite IP structure alone. The complete hybrid structure contributes to the crash behavior of the complete vehicle body.

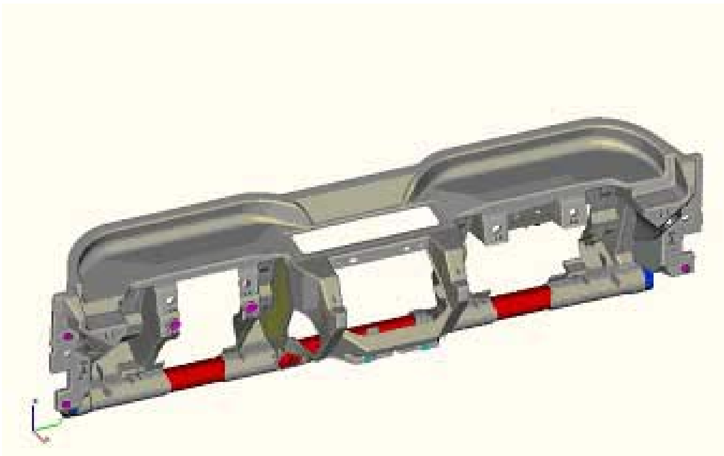

Figure 5: The compression-molded glass-mat thermoplastic (GMT) composite lower IP carrier is reinforced with 40% long-glass-chopped fiber. The cross-car beam (now reduced to a small tube) is insert-molded in the tool in a single operation.

This hybrid steel/composite design features a highly complex molding that incorporates the cross-car beam, and integrates the functions and fixations for the air ducting, airbag support, steering-column support, and knee bolster (see Figure 6). Bushings are added afterwards.

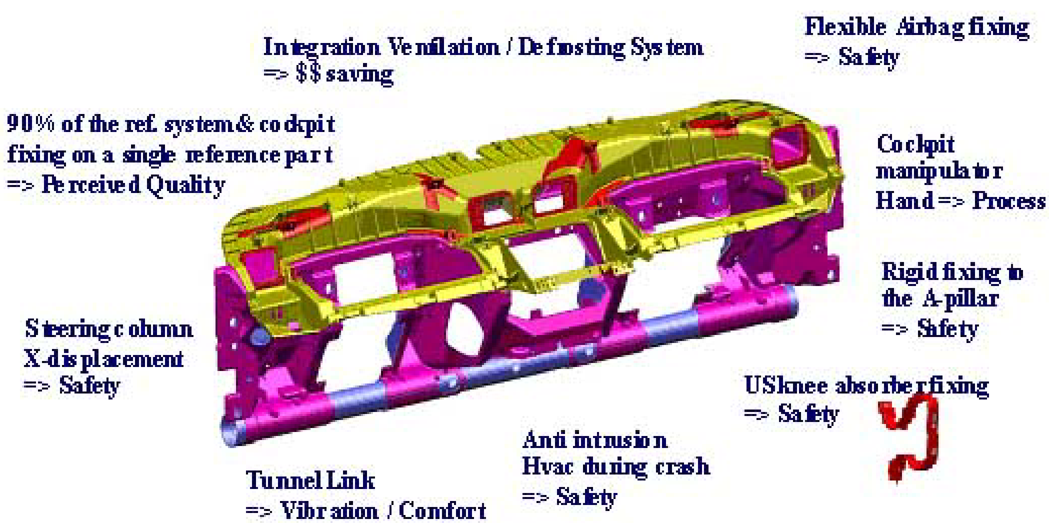

Figure 6: The high-level of functional integration achieved with the hybrid cockpit design allowed for reductions in components, mass, and costs and facilitated assembly.

The design of the hybrid IP carrier greatly simplifies assembly, improves NVH performance, reduces mass, and – for the first time ever with a single carrier design – meets or exceeds all U.S., European, and world safety standards (for full frontal and offset crashes with belted and unbelted occupants) – actually improving crash performance in some tests vs. the baseline steel design. It does all this while reducing overall manufacturing costs, and offering high productivity, and high repeatability and reproducibility (R&R) on low-cost tooling.

With a high level of integration, the new hybrid IP carrier offers an optimum balance in terms of production volumes, mass, world crash performance, and mechanical properties. In fact, because the same common system can now be used for so many different styles and platforms, tooling costs were significantly reduced, as was the cost of analysis and crash testing. Additional program savings were achieved through clever tooling design, since an insert is used so the same set of tooling can mold IPs for both left- and right-hand drive vehicles. Owing to the large number of vehicles (and interior designs) this retainer would be used for, parts were customized by using punching dies to create holes to accommodate various components. After the vehicle's useful life, the IP carrier can be disassembled and recycled, since it is made of a polypropylene/chopped glass fiber composite and the steel beam. The beam itself can easily and cleanly be separated from the composite carrier using a standard hydraulic shearing machine, as shown in Figure 7.

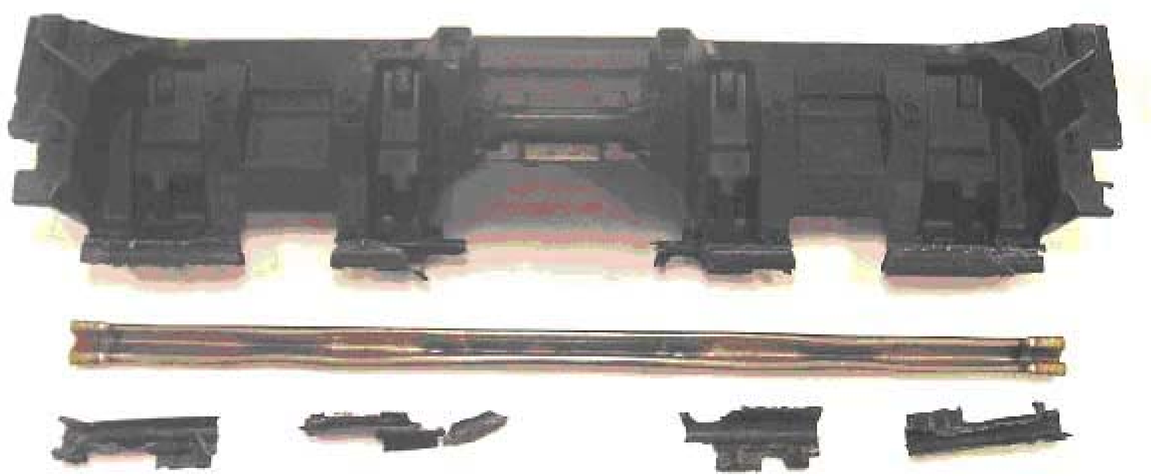

Figure 7: The hybrid steel/composite IP carrier can easily be disassembled and recycled at end of vehicle life. By using a standard hydraulic shearing machine, the beam can cleanly be removed from the rest of the composite carrier.

Technology Breakthroughs Required for Design to Succeed

Several technology breakthroughs were required to make this new hybrid-material IP retainer a reality.

The first problem was to identify a composite material and molding process that would provide sufficient impact strength, plus high flowability to avoid knitlines. This would help ensure the small steel tube (that was now the cross-car beam (CCB)) was fully encapsulated at junction points during molding of the lower part of the retainer, as it is very important for this part to absorb energy during a crash without brittle failure. (Initially, the LFT process had been used to mold the lower IP carrier as well as the upper IP frame due to cost. However, the LFT design could not pass crash requirements for this structural component. Hence, an alternative material / process combination needed to be found.) The second challenge was to find a method of molding the carrier and minimized CCB that did not crush the steel tube.

Faurecia turned to its Tier 2 molder, FPK (www.fpksa.com/index_con_fla.html) from Spain to solve both issues. FPK had been involved with Faurecia on concept development for the IP carrier from 1997 and the early advanced engineering phase. In fact, FPK worked to define the part not only in terms of functional requirements, but also mass and cost goals, plus to meet other desirable qualities such as:

- Reducing the thickness of trim (waste) areas to a minimum while still permitting material flow.
- Optimizing the wall thickness of functional areas by using a rib design, helping avoid overly thick sections.
- Designing part to allow punch-outs (for component insertion) while using the minimum number of steps.
- Defining the joint system and fixation points to avoid as much as possible use of additional steel clips or

inserts.

- Delineating the part's topography to optimize mold construction (e.g. in terms of cooling).
- Characterizing the reference part and locating points to meet fit and finish requirements.
- Ensuring that the steel CCB and associated links would be compatible with the over-molding process while still meeting all safety requirements.
- Optimizing logistics and storage.

To help meet these requirements, FPK went to Quadrant Plastic Composites AG (www.quadrantcomposites.com) to solve the materials portion of the challenge. FPK and Quadrant worked to make the part as thin and light as possible while still meeting the price and impact targets specified.

Quadrant made 2 contributions to the project. First, the company developed a new grade of glass-mat thermoplastic (GMT) material – Quadrant GMT E100F40F1 composite – that not only provided higher impact strength, but also did so while meeting all performance targets at 2 kg lower weight. FPK worked closely with Quadrant to develop the best blank layout pattern in the tool that would allow the complex part to fill without knitlines.

The first part of the solution came from modifying the material. Fortunately, in order to achieve high adhesion between the tube and the composite, no fundamental changes were required to the base resin, or to the glass or coupling agents used in the mat. Adhesion is achieved purely on the basis of shrinkage. However, three minor modifications were needed to meet other requirements of the IP carrier.

Meeting Tougher Thermal Requirements

The first change was that a new package of heat stabilizers was added to the resin matrix in order to meet new Volvo requirements for long-term heat aging. The previous requirement had been no degradation of the polymer for 1,000 hr at 85C. The new requirement boosted the timeframe to 6,000 hr at the same temperatures and conditions – a significantly longer period of time. To meet this tougher constraint, a whole new package of heat stabilizers had to be developed, as it was necessary to balance thermal stability during processing (shorter time / higher temperatures) with this long-term heat-aging requirement (longer time / lower temperatures).

Modifying the Mat Structure

The second modification involved changing the structure of the mat. This allowed Quadrant engineers to fine-tune material properties and material flow in the tool.

On one side of the IP carrier, high impact strength was required. On the other side of this complex part, good flow properties were needed to fill design details without creating knitlines. Normally, the changes made to improve one of these requirements would in turn reduce the other property as well. For example, in GMT materials with chopped mats, higher impact is usually achieved by using a higher proportion of glass fibers of longer length. In contrast, better flow and filling of design details with these materials is usually achieved by using more glass fibers of shorter length. Hence, it was difficult to meet both requirements simultaneously with a single material.

Quadrant was able to achieve the desired property balance by manipulating mat properties. This is a unique capability the company has vs. other GMT producers: the ability to cut the fibers to specific lengths <u>prior</u> to making the mat in order to change molded-part properties. Other suppliers make mats from continuous glass fibers, then needle the mat once made to break up the fibers. But needling that way can make it harder to control fiber length and distribution ratios, and can lead to broader variations in fiber length as needles wear and grow less sharp. By cutting the fibers before the mat is made, Quadrant can very strictly control fiber length and can achieve 4 distinctly different lengths – 25, 50, 75, and 100 mm – plus better control the ratio between those fiber lengths. Careful work led to development of a "recipe" with just the right ratios of short-to-long fibers to provide the best balance for enhanced flow and high impact for the IP carrier.

Optimizing Blank Size & Layout Pattern

The third modification Quadrant made to its material was to make the resultant blanks thicker – from their normal 3.8 mm to a custom 4.8 mm thickness. The thicker material made it possible to produce parts with fewer blanks, which reduced handling time and logistics costs for molding the lower IP carrier. Furthermore, the thicker blanks helped to improve the blank layout pattern. One of Quadrant's unique capabilities is that it can supply blanks cut to custom sizes at high precision – on the order of +/1 mm. Narrow tolerances were critical for this part due to its large number of fixation points. Hence, variation in the weight and dimension of blanks had to be very low or there would have been unacceptable variations in the mass and thickness of the resulting part that would have meant mating surfaces would not have matched up properly. By using a computer-controlled robotic process for precutting blanks, then delivering the proper sizes to the customer, there was less handling and less chance for variation. Quadrant has multiple laminators on which to produce product and also has the industry's widest GMT laminator at 1,400 mm, so customers with large parts such as this carrier can opt for larger blank sizes to fill their tools.

Developing the best pattern of blank layout in the tool to fill the part without knitlines was tricky. CAE codes for compression-moldable GMT materials are still in their infancy. As yet, they have not evolved to the level of sophistication in predicting blank flow in the tool that mold-filling software provides to predict fill times and patterns for injection-moldable polymers. Hence, determining how many blanks were required, and what their size, thickness, and placement pattern needed to be was a matter of working with a code called Express®[4] optimized by FPK for evaluating likely fill patterns, coupled with experience, hard work, and trial and error. The key challenge to overcome was finding a best combination of blank-size and layout pattern that would allow material to be distributed throughout the tool without forcing the material to split up and then flow back together again. The resulting knitline (or weldline) is notoriously weaker than surrounding polymer. Additionally, if all the flow-fronts in the tool are not properly managed, and one front reaches the tool wall significantly ahead of the others – freezing off too soon – an undesirable orientation of glass can occur. This was initially approached using the Express process simulation software at FPK (Figure 8). The blank layout pattern was further adjusted through many molding trials at FPK facilities for 3 prototype phases (Figure 9).

Developing an Insert-Molding Process

An important task for FPK was to find a method for inserting the minimized cross-car beam into the press and molding the carrier without crushing the steel tube on the downstroke. The size press needed to mold a part the size of this carrier was 2,000 metric tons and it operates at high speeds of more than 50 mm/s. In fact, FPK was awarded a process patent for solving this problem.

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[4] *Express is a registered trademark of M-Base.*

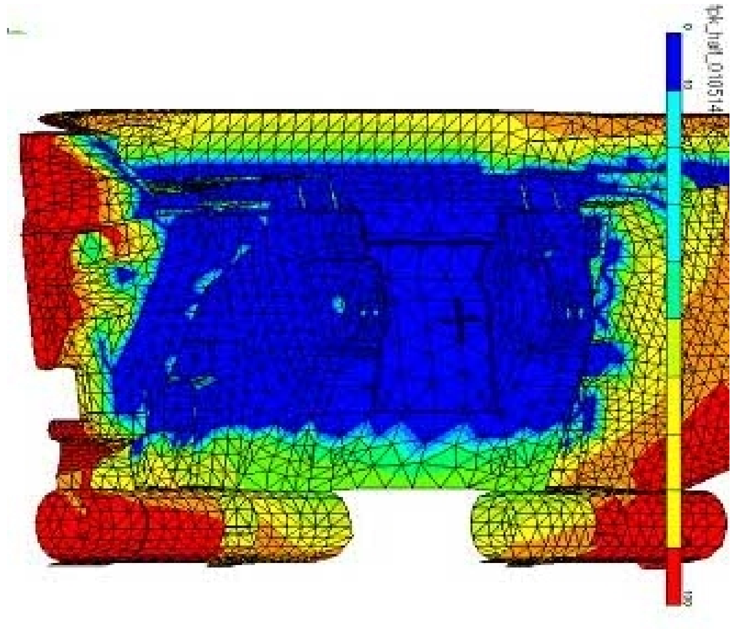
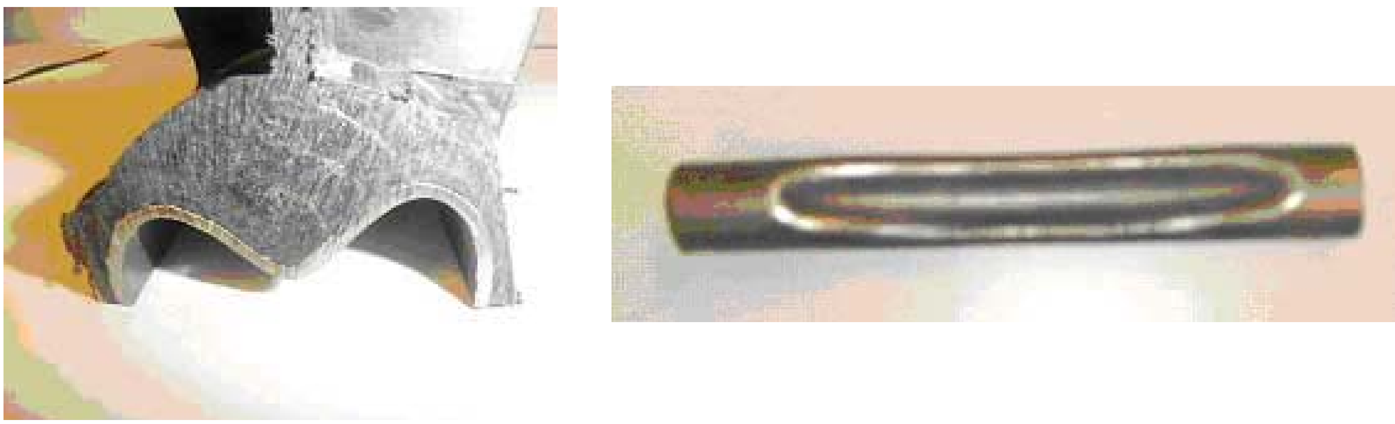


Figure 8: Process sSimulation of the IP carrier's blank flow and fill process using GMT composite with and a specific blank lay-up pattern.

Figure 9: Vertical compression molding press for production of the IP carrier ..

Because the goal was to minimize tube deformations, investigations began with finite-element simulations in the Express code to check the bending elongation of the tube in the mold in response to material flow pressure. Results of this analysis defined a number of positions in which the tube could be placed in the tool. An extreme case was defined as a situation where the steel profile would stack against the mold, blocking material flow. This would lead to incorrect adhesion between the tube and the plastic structure, as well as reduced strength for the steel cross-member. In addition to analyzing the section of the part where the CCB met the composite, the area around the tube intake was also analyzed. By carefully controlling the angle of insertion of the steel tube, FPK was able to minimize the effects of mat and polymer entering the tube cross-section.

Inputs from the CAE work were used to design the part. Despite the input from the finite-element analysis, when the first prototype parts were molded, a failure mode – tube collapse – not previously predicted by any of the simulations was seen (Figures 10 & 11).



Figures 10 & 11: Two views of the steel cross-car beam showing tube collapse, an unexpected failure mode not previously predicted by computer simulations.

Once this situation was explored, the search began to find a combination of steel material and tube thickness that would be able to withstand the pressure in the tool cavity without collapsing. Many trials took place at FPK to evaluate various combinations of steel quality (*particularly yield stress*), tube thickness (*which together with steel quality are key factors controlling the tube's ability to resist collapsing*), plus the compression molding process parameters. Although it was clear that going with higher strength steel in a thicker cross-section would prevent collapse, it was also apparent that this change would prevent the concept from meeting 2 program goals – to reduce cost and weight.

Hence, FPK's next efforts were focused around designing and testing a system and process to prevent tube damage during over-molding, which subsequently came to be called the anti-collapse system. In principle, this system works by inserting a mechanical device into the interior of the steel tube before the flow phase of the molding cycle, which allows the tube to maintain its shape and structural integrity during the downstroke and subsequent flow pressures exerted by the composite material (Figure 12). This process development, which was designed, developed, and commercialized by FPK, is now patent protected[5]. Use of this technique allowed FPK to maintain the integrity of the CCB during molding, while also meeting other project targets for performance, cost, and mass.

[5] *Development is now protected under European Patent EP 1238773..*

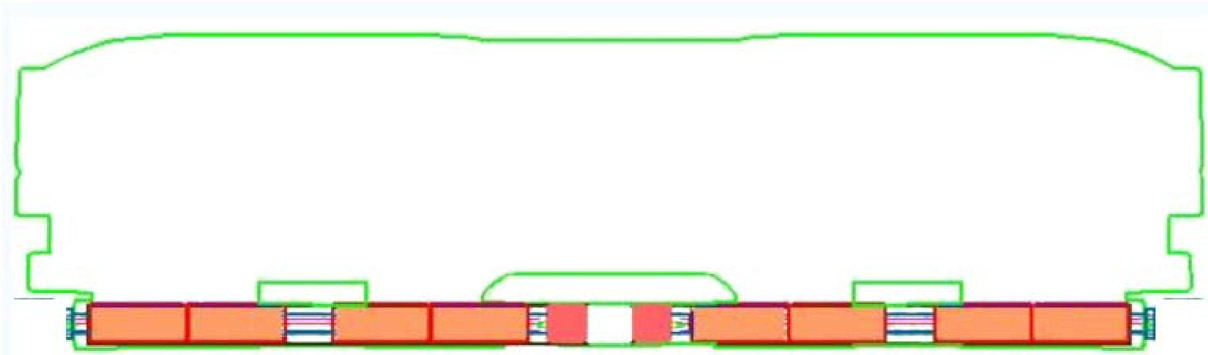


Figure 12: Schematic of the anti-collapse system developed and patented by FPK to ensure CCB integrity while also meeting program goals for mass, cost, and performance.

The steel tube is fully encapsulated at junction points by the GMT composite during molding (Figures 13, 14, and 15), with the resin matrix flowing completely around the beam at these locations. Careful control of process parameters – particularly pressure – helps provide strong knitlines. Drop tests developed by Faurecia have not shown any issue with separation of CCB and composite carrier.

Figure 13: Owing to 2 technology breakthroughs – a special grade of GMT material and a patented process to prevent crushing of the steel tube during molding – the CCB is fully encapsulated at key junction points on the lower IP carrier.

Figures 14 & 15: It was very important to maintain strong knitlines at junction points between the CCB and the GMT carrier. This was accomplished by careful control of process parameters, particularly pressure.

Evaluating the Performance of the Design

To ensure the safety and effectiveness of the design of the new cockpit and its IP carrier, and make certain this system met all cockpit criteria identified in the comparison matrix, the standard battery of computer-aided engineering (CAE) simulations and actual molded part testing was performed. The design faired extremely well as can be seen below.

Airbag Packaging

The new design allowed safety-packaging rules to be maintained without affecting styling (see Figure 16). Hence, the system is compatible with various airbag deployment loads and with other OEM requirements at standard test temperatures.

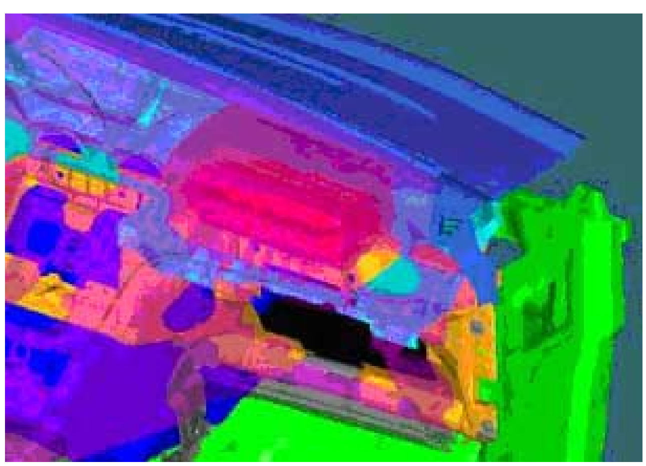


Figure 16: Packaging of system relative to body-in-white (BIW) and with passenger-side airbag, center stack, and IP topper pad in place.

Airflow Testing

The hybrid carrier's design met all OEM ventilation and defrosting requirements. Ducting was created from the box section formed when the upper IP frame was vibration welded to the lower IP carrier. This innovation improved the cockpit's compactness, but did require co-development of ducting and structural functions by a single team.

Assembly

The hybrid design successfully passed the manipulator requirement during loading of the cockpit into the vehicle. It provided for a good assembly process using a single cockpit assembly line. The plastics-intensive design facilitated use of smart wire-harness guides.

Crash Testing

The integrated cockpit / hybrid IP carrier design met full frontal and offset crash requirements for all 3 OEMs as well as U.S., European, and Japanese safety standards. As such, it is the first IP system to meet all global safety standards with a single concept. Figure 17 displays acceleration vs. time curves showing results of non-destructive drop testing of the IP at a rate of 1.8 m/s. Predicted PAM-CRASH™[6] simulations vs. measured values showed good correlation.

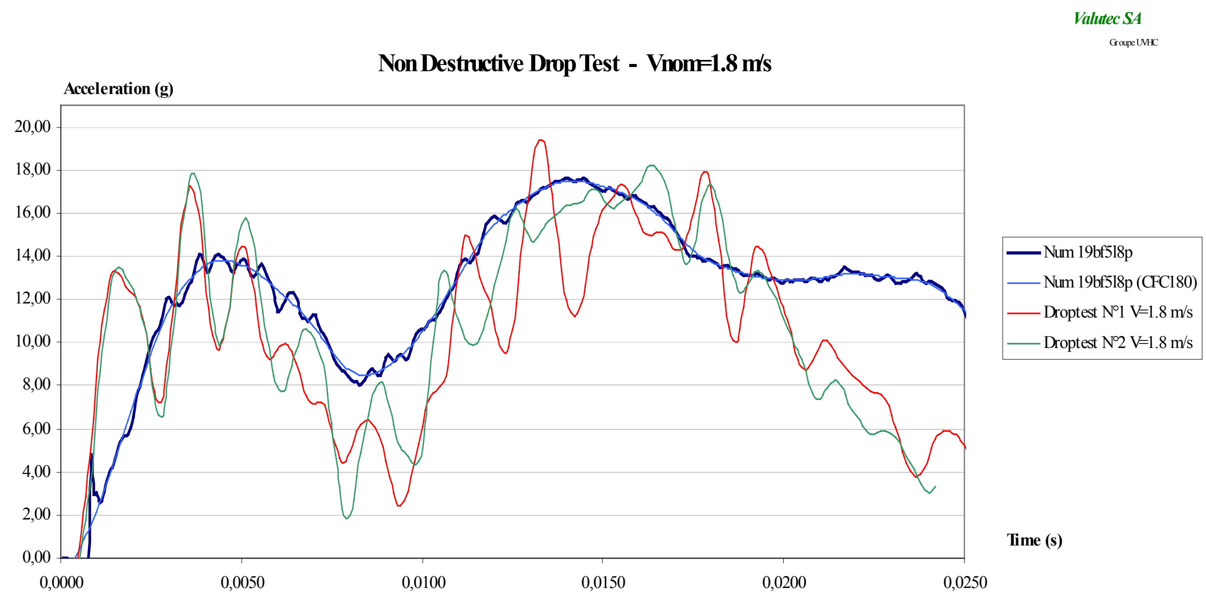


Figure 17: Predicted simulations vs. actual non-destructive drop testing of IP carrier showing good correlation between the two sets of values

Fit & Finish

This new structure met all required tolerances for the cockpit-gap chart.

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[6] *PAM-CRASH is a trademark of ESI Group.*

Homologation Requirement

When subjected to the homologation process, the new design met U.S. Federal Motor Vehicle Safety Standard (FMVSS) 208 requirements as well as additional OEM demands for safety. A careful design review / safety inspection found no sharp corners in critical locations that might affect head or knee contact (an example of which is shown in Figure 18). Thanks to early and frequent input from the cross-functional team during design characterization, CAE analysis permitted the development of an efficient systems solution.

NVH Analysis

The hybrid cockpit successfully met the 35-Hz program requirements for body-in-white (BIW) frequency when loaded (Figure 19). It also met an important steering column overhang requirement. The reinforced-plastic composite was found to spread stiffness to help avoid the risk of local phenomena such as noise/vibration/harshness (NVH) or squeak and rattle issues. Because of this, the design did not need additional felt, which is often added to reduce NVH values.

Moving from a multi-component, steel design to the hybrid composite/steel carrier was a key element to meeting Faurecia's program goals for its integrated cockpit system. The challenge was to create sufficient flexibility in the design so the finished IP could provide a unique appearance for each model. In contrast to a conventional carrier, the new compression-molded GMT composite/steel design features a highly complex, 2-piece molding that incorporates the cross-car beam, and integrates the functions and fixations for the air ducting, airbag support, steering-column support, and knee bolster.

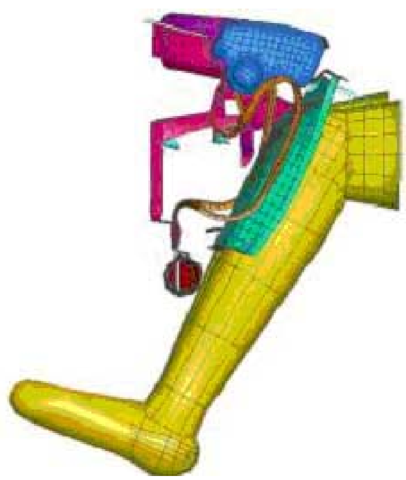

Figure 18: Early & frequent input from cross-function teams during characterization allowed the design to pass homologation inspection. Sharp corners & tight radii were avoided in key locations that might otherwise have affected head or knee impact..

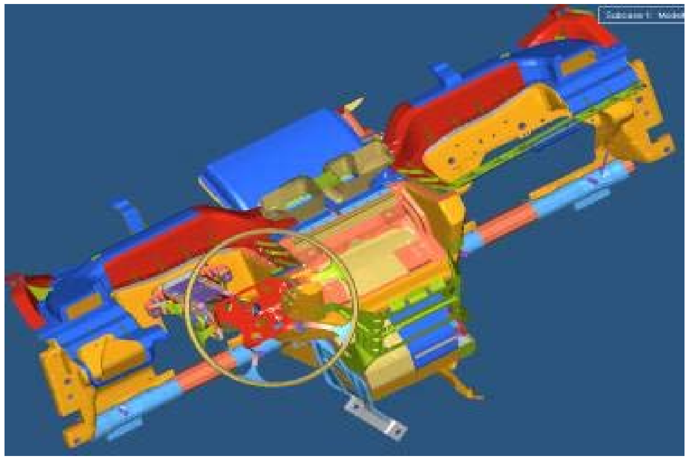

Figure 19: Solid model used for NVH analysis.

The design of the hybrid IP carrier greatly simplifies assembly, improves NVH performance, reduces mass 2-3 kg, and – for the first time ever with a single carrier design – meets or exceeds all U.S., European, and world safety standards (for full frontal and offset crashes with belted and unbelted occupants) – actually improving crash performance in some tests vs. the baseline steel design. It does all this while reducing overall manufacturing costs 12%, and offering high productivity (>6,000 parts/day) and high repeatability and reproducibility (R&R) on low-cost tooling.

With a high level of integration, the new hybrid IP carrier offers an optimum balance in terms of production volumes, mass, world crash performance, and mechanical properties. In fact, because the same common system can now be used for so many different styles and platforms, tooling costs were significantly reduced, as was the cost of analysis and crash testing.

In fact, because the same common carrier can now be used for so many different styles and platforms, tooling costs were significantly reduced, as was the cost of analysis and validation testing vs. using multiple designs. Additional program savings were achieved through clever tooling design, where an insert is used so the same tooling can mold IPs for both left- and right-side drive vehicles. After the vehicles useful life, the IP carrier can be disassembled and recycled, since it is made of a polypropylene/chopped glass fiber composite and the steel beam.

Throughout the development and evolution of the hybrid carrier and cockpit design, the system's performance was verified in parallel by functional CAE analyses – not just performance requirements such as product airflow, but also process analysis and tooling design. The IP carrier's structure became the core of the complete cockpit development process and also served as a backbone for master reference points and the cockpit assembly process during production.

Finally, the new design passed all required performance tests for all vehicles on this platform. The program was accomplished within the timeframe set for launch.

Hybrid Cockpit Summary

This new hybrid design:

- Meets or exceeds best-in-class, world-benchmarking standards,
- Integrates both ventilation and defrosting systems and crash boxes (for cost savings),
- Allows for flexible airbag fixation (for assembly ease),
- Prevents intrusion of the HVAC system during a crash,
- Provides less vibration in the tunnel link (for greater passenger comfort),
- Uses common tooling with inserts that allow for modification for different designs, e.g. carriers for both left- and right-hand drive vehicles can be molded from the same tooling via use of innovative design and a tooling insert (for significant tooling-cost and time savings),
- Reduces testing requirements across multiple platforms, since a common design is used (vs. using multiple designs for each platform/model).
- Locates 90% of the cockpit fixing points and reference system on a single reference part (for greater perceived quality, and new and improved functionality).

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