

# **ENABLING DESIGN INNOVATION IN AUTOMOTIVE COMPOSITE APPLICATIONS**

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## **Abstract**

Today, many technical and economic factors are triggering increased interest in the use of composite materials for the automotive industry. The reduced cost of composites and rising steel production costs are both significant factors. With higher oil prices, consumers demand lighter, more fuel-efficient cars. New material forms and innovative processes are emerging to help reduce manufacturing cycle times and consolidate part counts. Demand for car customization is enabling lower production volumes better-suited for composite parts manufacturing. Finally, the use of advanced simulation tools and increased domain expertise is spreading from aerospace and car racing engineering into mainstream automotive design and production.

However, the real enablers to any revolutionary breakthrough in composites need to be considered more closely:

Engineers must be given the ability to reconsider the rationale and the way automotive components are designed, in order to fully integrate all the benefits of using composites

Engineers must be given the appropriate tools to freely explore alternative new methods of using and incorporating composites into the engineering and manufacturing of production cars

In this presentation, the ingredients of Renault F1 Team's unique success in composites design, as well as other significant automotive initiatives, will be presented to the audience. These proofpoints will demonstrate how actual design freedom, domain expertise, and excellence in the mastering of composites complexity can be leveraged to develop innovative solutions that unlock the potential of composites for advances in real world practical automotive engineering.

## **Realizing the Benefits of Composite Materials through Design Freedom**

Today, we are closer than ever to widespread use of composites in the automotive industry. Traditionally, the commercial auto industry has confronted several practical challenges to the use of composite materials in large-scale production, such as high cost of materials, time-consuming manufacturing processes, and perceived high risk or lack of experience. For these reasons, the significant use of composites in commercial vehicles has seemed like a faraway dream. But innovative companies, lured by the benefits that composites promise, have been addressing these challenges.

Automotive engineers are revolutionizing composite part manufacturing processes to meet "speed-to-market" demands and cost reduction mandates. More than ever before, manufacturers are rising to the challenge of incorporating increased flexibility and innovation into their automotive designs while complying with government and consumer requirements. New, non-metallic materials have become more pervasive across a wide range of automotive manufacturing parts and disciplines including chassis components, frame design, and fuel

systems - and manufacturers are realizing significant business, economic and engineering benefits as a result.

For example, with composites, engineers can consolidate, and thereby reduce, the number of parts needed in the production of a chassis or car body. As a result, companies such as Renault achieve much shorter manufacturing turnaround while lowering tooling costs and enabling customization flexibility. Composite parts are lighter than steel or aluminum thereby reducing the weight of the vehicle. This lowers fuel consumption and improves vehicle performance. In addition, composites are more resistant to the effects of corrosion than metals. Vehicle maintenance costs are typically lower when using composites as compared to all-steel parts. As the cost of steel rises, manufacturing companies are finding that lower-priced composite materials such as carbon-fiber composites and no-crimp fabrics are a more attractive option than traditional metals.

In addition, evolving technologies such as sheet molding composites, resin transfer molding or resin film infusion offer manufacturing strategies that are more cost-effective than steel. As more is learned about these techniques, and risks are reduced, engineers will become more comfortable with composites and will more readily incorporate these materials into production vehicles.

Yet, in order to effectively achieve these benefits, engineers cannot take a “black metal” approach to automotive manufacturing and simply replace metal parts with composites. Rather, engineers must be given the freedom to explore, investigate and develop new, groundbreaking composite designs and manufacturing processes and parts while ensuring that products can actually be produced according to mandates or specifications. What good is a new design if you can’t actually manufacture the product on spec and on time!

In light of this, automotive engineers are increasingly relying on specialized engineering software to design parts made of composite materials and help automate manufacturing processes. Specialized engineering software that is fully-integrated into 3D CAD systems transforms the end-to-end design and manufacturing process. Engineers, for the first time, can achieve complete digital product definitions that ultimately enable faster design innovation and more accurate development of automotive parts composites materials than ever before.

The following paper highlights recent real-world success stories and opportunities in hard and soft composites manufacturing to demonstrate the value of specialized design environments for enabling unprecedented composites manufacturing innovation.

## **Structural Composites – From Racing to Series Vehicles**

Working in the deadline-driven environment of Formula One racing, the engineers of the Renault F1 Team faced a daunting competitive challenge. The team needed to design and manufacture key parts of a composite race car chassis in less than six months that would meet a number of demanding weight, strength and performance specifications as well as recently-mandated impact and safety requirements. Other parts such as the front wing had complex curves that could cause unexpected shifts in plies as they were laid up, resulting in weak spots.

Because of the complex curvature and compressed turnaround time for these parts, Renault engineers concluded that they would need software to simulate lay-up for the complex parts and check for weak spots as early in the design process as possible. They would not have time for extensive physical prototyping. The digital product definition would help them fully understand part performance in advance, in order to avoid manufacturing errors. If the parts

were not designed correctly and manufactured properly the first time, and did not fit together or perform to specifications, the team would lose an entire season.



Figure 1: The 2005 Renault F1 Team won the FIA Formula One Drivers' and Constructors' World Championships with the R25 composite chassis.

Renault utilized specialized engineering software at the start of the development process to design and represent the chassis in a three dimensional model to check for fiber deviation. The chassis was a typical composite “sandwich” with inner and outer skins made up of woven laminate plies. Lay-up for the outer skin alone involved more than 200 plies. The software helped Renault automate much of its composite manufacturing process, speeding the rate of ply lay-up by 62 percent while achieving a 30 percent reduction in flat pattern template creation.

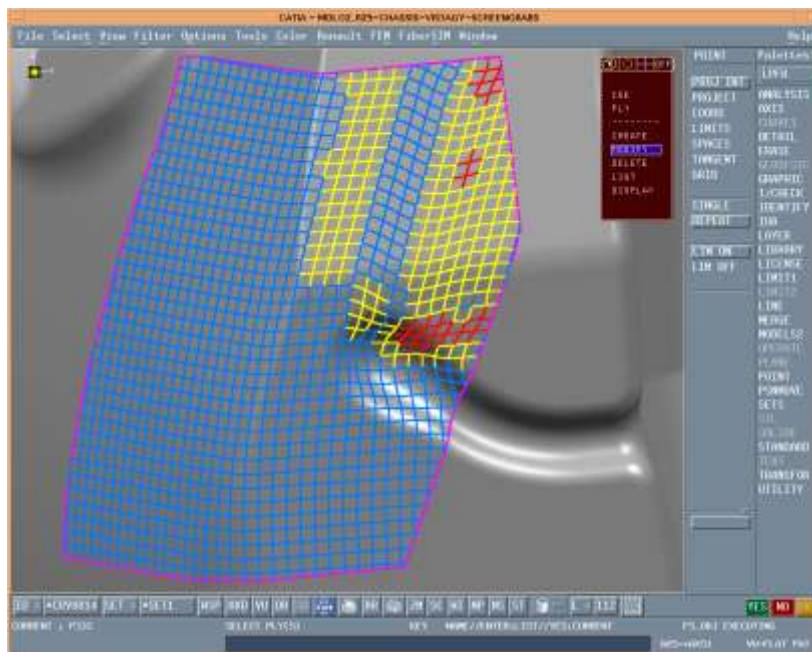


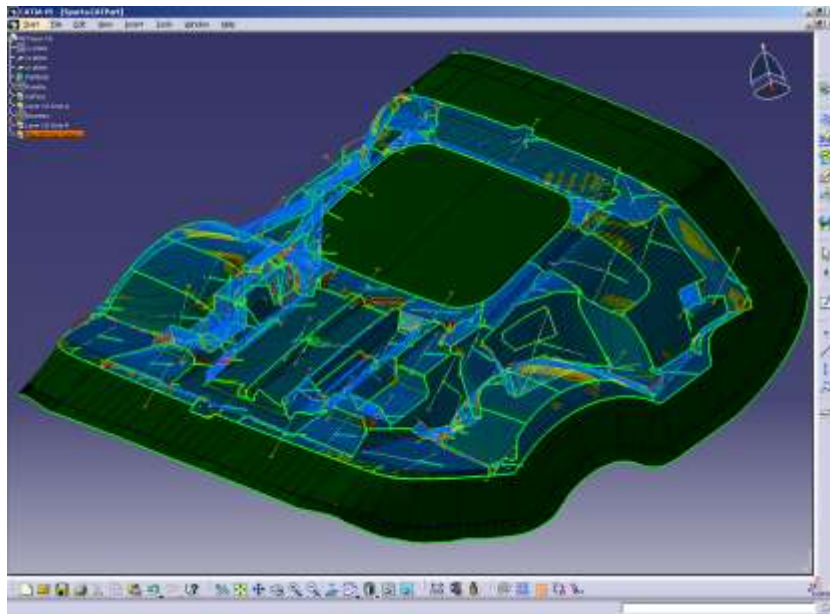
Figure 2: Simulation of a composite ply layup on the Renault R25 chassis. While most of the ply exhibits no distortion (blue), the curvature causes areas of mild (yellow) and severe (red) distortion.

The composite chassis also met all impact and safety specifications and held up well under the physical pressures of Renault F1 Team's 2005 back-to-back victories in the FIA Formula One Drivers' and Constructors' World Championships.

When Ford engineers researched alternative designs, materials, and processes for the deck inner lid of the 2005 GT, they considered replacing a four-part aluminum assembly with a single-piece carbon fiber/epoxy part. They needed a design that could meet a manufacturing volume of 4,600 parts per year while ensuring high quality, strength, and very low weight. Unfortunately, Ford's choice of unidirectional composite tape for the part would substantially increase lay-up times and significantly slow down the manufacturing process.

To compensate for these shortcomings, SPARTA Composites, one of Ford's suppliers, helped the Ford design team simplify several specific part features, such as standoffs and rain channels. Yet, even after simplification, the final part design had evolved from a smooth surface to a series of complex features requiring nearly 270 individual plies for manufacture.

SPARTA needed to utilize specialized engineering software to explore multiple manufacturing strategies for the complex part and reduce the time for creating flat patterns and ply lay-up in order to compensate for the increased number of plies. The resulting design and manufacturing process enabled Ford and SPARTA to build a part that was strong, thin and ultra-lightweight, and could be readily and cost-effectively manufactured based on all specifications. At a mere fourteen pounds, the composite part weighed 75 percent less than a comparable metal component.



*Figure 3: Understanding fiber orientation on this Ford GT deck inner lid was of primary importance to assess part producibility in the early stages of design.*

For mass-produced commercial cars, though the production specifications, processes, demands and requirements are quite different from highly specialized race cars, engineers must similarly explore new designs and manufacturing methods in order to achieve the benefits of composites.

A recent automotive study suggests that at volumes of 100,000 or below, a manufacturing process such as Resin Film Infusion (RFI) could be more cost-effective than traditional metal stamping because of the potential for consolidating parts and increasing design flexibility.

At the request of a major Tier 1 supplier, engineers and analysts studied the feasibility of forming composite automotive parts with RFI instead of metals. The study represented a potential new application for composites in load-bearing parts of a car body. The manufacturer examined the B-pillar from a popular mid-sized sedan. It compared multiple design possibilities and selected the strongest possible configuration that would meet volume goals.

Again, specialized engineering software helped simulate several material choices with varied lay-up orientations and starting points. The simulation clearly revealed potential weaknesses caused by fiber wrinkles and previously unpredicted orientation changes over the complex tool surface. Without this automated simulation technology, the manufacturer would have learned about the weaknesses only after much modeling, trial, and error. Instead, rapid feedback from the software enabled a strong, manufacturable part design in a timely manner.

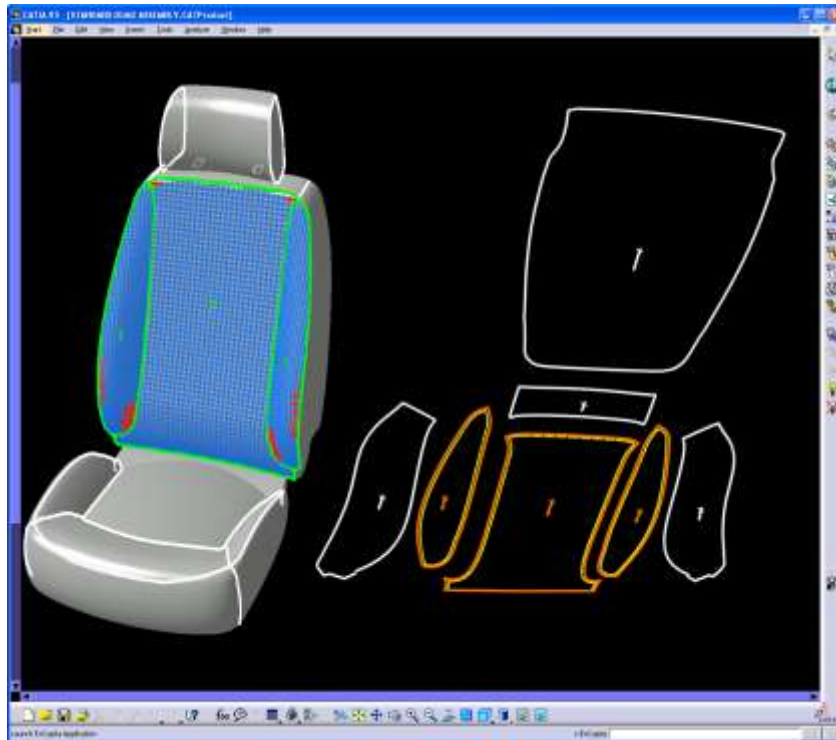
Using the most appropriate methodology reduced the inherent risks in exploring new material applications, ensuring that the series vehicle manufacturer will achieve many of the same benefits that the Renault and Ford teams did by automating their composite manufacturing processes. Because of research like this, engineers hope to learn about more applications for composites design.

## **Soft Composites Design and Auto Interiors**

In response to customer demands for improved driving comfort and style, automotive interiors have become increasingly sophisticated. Automotive manufacturers have come to understand that car purchases are now based heavily on the interior look and feel of the vehicle as much as on the external shape and features. In fact, recent automotive industry studies show that select interior comfort options are more highly desirable than some safety features.

Interior designers working with major OEMs contend with many of the same cycle time, cost, volume and innovation challenges that automotive engineers deal with, and sometimes to an even greater competitive degree, when designing and manufacturing their products. For example, these engineers must design and build huge numbers of new seat models every year. They are required to consider critical factors such as “time-to-prototype” and material waste reduction, the interaction of styling and engineering, and integration of seat components. Some of the most complex engineering challenges pertain to soft trim interiors, and specialized design software offer potential solutions.

For example, today’s seat covers represent a particular set of issues for engineers. They must conform to a number of functional requirements including safety and aesthetics, comfort, heat, and moisture control. Integration with sensors and IFE systems are standard on many car models and new multilayered fabrics and engineered textiles are constantly being developed and utilized on vehicle models every year. In order to produce required product output, trim designers must figure out complex flat patterns in order to correctly cut materials while reducing the time it takes to achieve a prototype, in turn, reducing manufacture time.



*Figure 4: View of an automotive seat showing producibility simulation and “orange peel” display generated in 3D. Specialized software simulates material conformance and generates resulting net flat patterns, shown in yellow on the right and seam allowance shown in orange.*

Also, genuine and composite materials used in seat covers have become increasingly expensive, and the traditional development process for seat covers involves a high level of flat pattern rejects and numerous prototypes, which results in high development costs in addition to time spent on manual simulations. Engineers are constantly straddling the line between style and engineering in order to demonstrate the production of seat design while integrating covers with other seat components including foam and suspension structure, the frame with adjusters and safety devices, and electrical components.

By efficiently creating their new design using a specialized software environment, companies can reduce material waste as well as decrease the time to prototyping, saving on the guesswork required to represent flat patterns for the seat covers. In particular, engineers are able to automatically simulate and verify the conformance of the cover to the shape of the seat in order to quickly produce accurate flat patterns critical for material cut out. The material simulation results can also be used by visualization software to create photo realistic rendering of virtual prototypes that allow fabric options to be viewed realistically in a three dimensional environment.

This approach saves on material waste and improves part-production accuracy, while simulating how style may affect engineering and how seat components might interact with each other. In addition, the seat engineers are now in a position to directly and electronically generate many forms of detailed data from their CAD-integrated seat definition for Bill of Materials, quality control, PPAP requirements, restricted substances and end of life vehicle (ELV) compliance.

Such a specialized design environment enables engineers to quickly respond to changes in interior design demands and create completely new, innovative interior designs without the laborious manual testing and mistakes of traditional prototyping and manufacturing processes.

## **Conclusion**

The automotive industry is opening its arms to the increased use of composites and specialized design software in order to achieve benefits that will generate a competitive advantage. Almost every automotive engineering discipline can be improved through the use of composites – from chassis and structural elements to door panels, seat covers, and interior or exterior structures. Manufacturing organizations can benefit from composites through the use of specialized software tools that help compress production time, obtain rapid feedback about alternative designs, and explore a wider range of designs, materials and processes while minimizing risk and cost considerations.

Though extensive use of composites in the commercial automotive industry is not widespread yet, more and more manufacturers cannot ignore the benefits at a time when competitive advantages such as low cost and rapid time-to-market could be the difference between success and failure.