BONDED HYBRID AUTOMOTIVE FRONT END CARRIERS[1]

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Dow Automotive[2]

Abstract

The front-end carrier (FEC) refers to the part of a car that supports most of the cooling package, headlights, latch and various other components. It also ties the upper and lower longitudinal rails and plays a role in the global and local structural stiffness of the car. The trend is to use such a FEC in a module that is supplied for assembly after the engine is mounted. FECs are currently a combination of plastics, to give form and various functions, and metal, to withstand mainly crash loading. Methods such as mechanical fasteners or over-molding are being used to form the hybrid plastic-metal part.

Dow Automotive offers a new solution that combines its application development capability and materials R&D. This concept consists of an injection-molded plastic (LGF-PP) bonded to an e-coated metal reinforcement using BETAMATE[3] LESA adhesive. This approach enables a closed-box profile with a continuous joint between the metal and the plastic that is not possible using traditional methods. The result is a significant increase in the stiffness/weight ratio as well as reduction in package space utilization. It also offers better design flexibility compared to other hybrid solutions and provides better bending and torsional stiffness. This paper will outline a prototype development demonstrating the technology as well as developments related to current programs.

The Case for Metal-Plastic Hybrids

One of the main advantages of plastic is the ability to mold complex shapes and integrate various functions into a single part. This eliminates parts and process steps. In an ideal world the engineer would like a material with the density and moldability of plastic and the stiffness and strength of steel. An attempt to get closer to this ideal leads to the development of plastic composites, in various forms, to help boost the mechanical properties by adding glass, carbon fiber or other reinforcements, while maintaining the fabrication advantages. In most cases the designer has to compromise based on costs, packaging space, performance and weight to achieve an acceptable solution.

In recent years the trend in the automotive industry has swung towards the use of metal-plastic hybrid systems. The aim here is to use the metal for the majority of the mechanical performance and combine this with the functional integration and complex shapes, which the plastic enables. This is now becoming the norm, for instance, for front-end carriers, where the metal-plastic combination form an upper cross-member to contribute to the stiffness of the car and withstand loading such as latch pull [1, 2]. Examples are to be seen on Ford, VW, Audi, Renault, Nissan and other vehicles.

A study of the choice of plastics and the methods to combine these in a metal-plastic hybrid

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was presented in a past SPE conference [3]. This showed that the performance of a long-glass-fiber-filled polypropylene material bonded to the metal reinforcement with the aid of BETAMATE LESA adhesive gave superior performance to the other methods of forming hybrid systems. Some of the data for torsional stiffness per unit mass is shown in Figure 1.

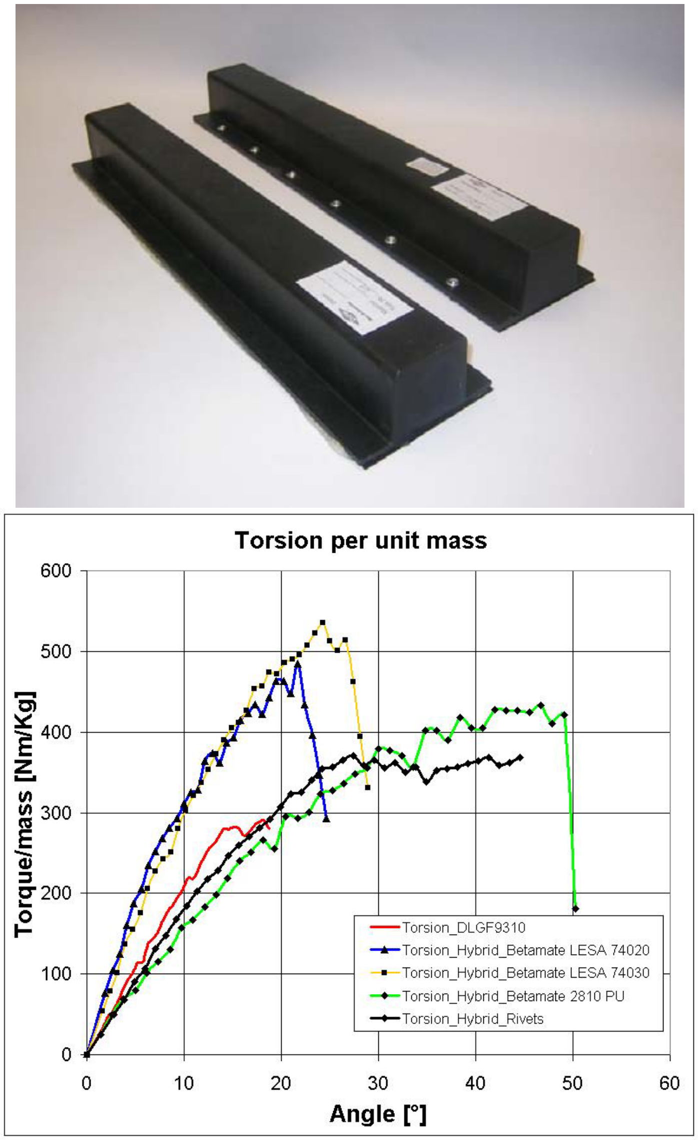

Figure 1: Torsion results per unit mass for various joining techniques in a metal-plastic hybrid beam

Front-End Module (FEM) Development

In the most recent development in front-end carrier technology, VW has launched the Polo with a bonded hybrid metal-plastic front-end carrier, using the technology developed by Dow Automotive. This is the culmination of work conducted on the technology development, prototyping and testing [2], which showed significant mass reductions for improved stiffness performance. This development was based on the VW Golf IV, as shown in Figure 2. The stiffness was increased by 50-100%, depending on temperature, and the mass was reduced by 25%.

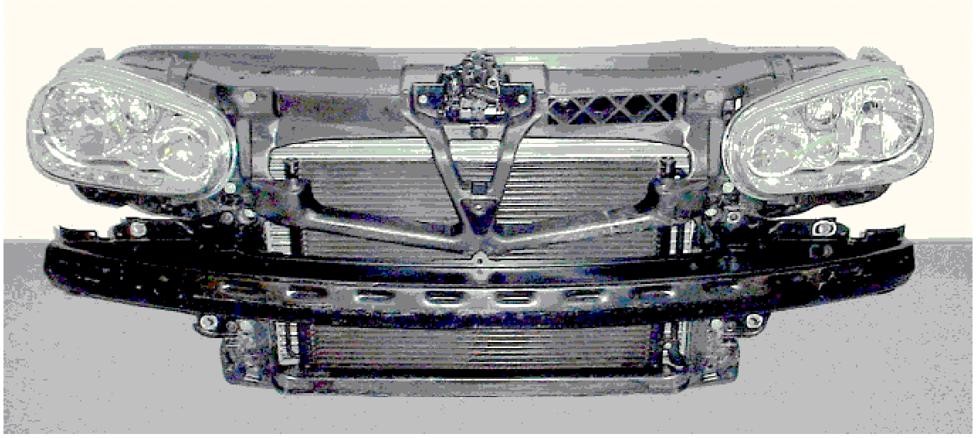

Figure 2: Assembled Prototype FEM with Bonded Hybrid FEC.

Since completion of this work, the technology has been further developed, with improvements in the adhesive[4] performance, which ensures high performance in impact loading, due to the increased elongation properties.

The VW Polo A04GP went into production early in 2005, with a front-end carrier assembled by bonding the metal reinforcement to the LGF-PP injection-molded carrier using adhesive[4]. Working together with Dow Automotive, Volkswagen developed a solution that not only reduced weight, but at the same met all requirements for part rigidity and cost requirements. Weight reduction of 25 % (or 1 ½ kg) per part was achieved in comparison to other solutions. A photograph of the Polo front-end carrier, with the metal reinforcement in position, is shown in Figure 3.

Figure 3: The bonded-hybrid front-end carrier of the new VW Polo, which recently went to production.

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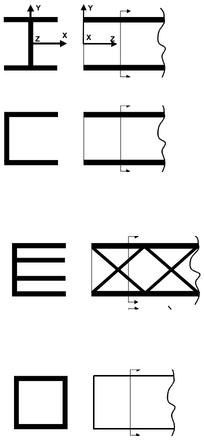
[4] *BETAMATE LESA® adhesive.*

Bonding Approach

The approach proposed and presented in this paper is to bond the metal to the plastic using an adhesive. Adhesive bonding provides a continuous joint between the metal and the plastic and allows a closed section to maximize the moment of inertia and hence the stiffness (Figure 4). A continuous joint distributes the load uniformly and reduces difficulties with stress concentrations. This increases the load bearing capability of the bonded structure. This enables (1) increased total mechanical performance of the structure; (2) reduced weight of the structure for the same performance as other approaches; (3) reduced packaging space to achieve the mechanical performance targets; or (4) a balance of the various benefits according to the requirements.

Design of the bond line and the layout of the parts for assembly can play an important role in the performance and the assembly process. In general the parts can be designed for automatic application of adhesive and the assembly of the parts by a robot. The use of adhesive[4] enables bonding without the use of plasma or flame treatment and eliminates the need for a primer, even on low energy surfaces, such as PP substrates.



		Comparison Factors				
		Stiffness			Load bearing Capacity	
		Torsion Tz	Bending By	Bending Bx	Torsion Tz	Bending By
I-Profile	**Baseline**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
C-Profile	**Absolute A**	**1.0**	**1.9**	**1.0**	**1.0**	**1.4**
	Factor per unit volume B	**1.0**	**1.9**	**1.0**	**1.0**	**1.4**
C-Cross-ribbed	**Absolute A**	**54.0**	**2.0**	**1.0**	**6.6**	**1.6**
	Factor per unit volume B	**35.0**	**1.3**	**0.7**	**4.2**	**1.0**
Closed Box	**Absolute A**	**73.0**	**3.7**	**1.1**	**13.5**	**3.8**
	Factor per unit volume B	**54.0**	**2.7**	**0.8**	**10.0**	**2.8**

Figure 4: Comparative Analysis of Stiffness and Load Bearing Capacity of Sections.

Additional benefits brought by bonding include:

- More flexibility in the development process, reducing the costs when changes occur since it may be possible to change one tool design instead of both e.g. changes to the plastic part which are not in the bond line region can be introduced without the need to modify the tool for the metal part.
- Reduced risk of damage to the e-coated metal parts, since handling of the parts is limited to the assembly onto the plastic part. This avoids contact with metal tools, which can chip the coating.
- Careful and well thought out design will enable later extension of metal parts, or variations in the design without changes to the mold for the plastic part.

Future Trends for FECs

It is widely expected that the use of FEMs and plastic-metal hybrid FECs will increase significantly in coming years. There is a trend towards injection-molded carriers since they allow more functional integration. Also, injection molding is widely available and highly used process, allowing production in most parts of the world in large volume with cost effectiveness. The need for better cost management and reduction of weight will inevitably lead to better-engineered solutions using lower cost materials such as PP, with fiber reinforcement to obtain stiffness. Long glass fiber materials are in many cases a good choice to maintain the impact resistance and durability of the structure. Online compounding, introducing additives and glass rovings directly on the injection molding machines is very interesting emerging technology offering cost advantages and flexibility.

In addition to structural and process requirements, the design/geometry of a front-end carrier is driven by additional factors:

- Geometry and design of components assembled to the front-end carrier:
- Cooling unit
- AC Condenser
- Charging air cooling unit
- Additional liquid cooling units
- Styling and design of visible components influenced by the front-end carrier:
- Bonnet / latch design
- Wing/fender design
- Bumper design
- Headlamp design
- Grille and fascia design
- Pedestrian safety regulations, crash and stiffness specifications

Figure 5 shows an example of the regions that influence these factors. Region A relates to the assembly of the various components on the carrier, while region B influences, or is influenced by, the styling of the head lights, the bonnet, bumper mountings and wings.

Current platform strategies at various OEMs promote the idea of using carry-over parts in non-visible areas. For front-ends it could be the use of one cooling unit for different cars built on the same platform. Modifying the exterior design of the bumper fascia, headlights, bonnet and wings then differentiates the styling. The combination of these requirements leads to a modular front-end carrier design (shown in Figure 6).

Part A forms the outer shell and part B forms the lower, inner shell of a closed box. The two parts are bonded together to form a stable, stiff structure. The enclosed space opens opportunities to incorporate air ducting functions and/or fluid reservoirs, as well as providing a structure, which can be tuned to manage energy absorption in pedestrian impact.

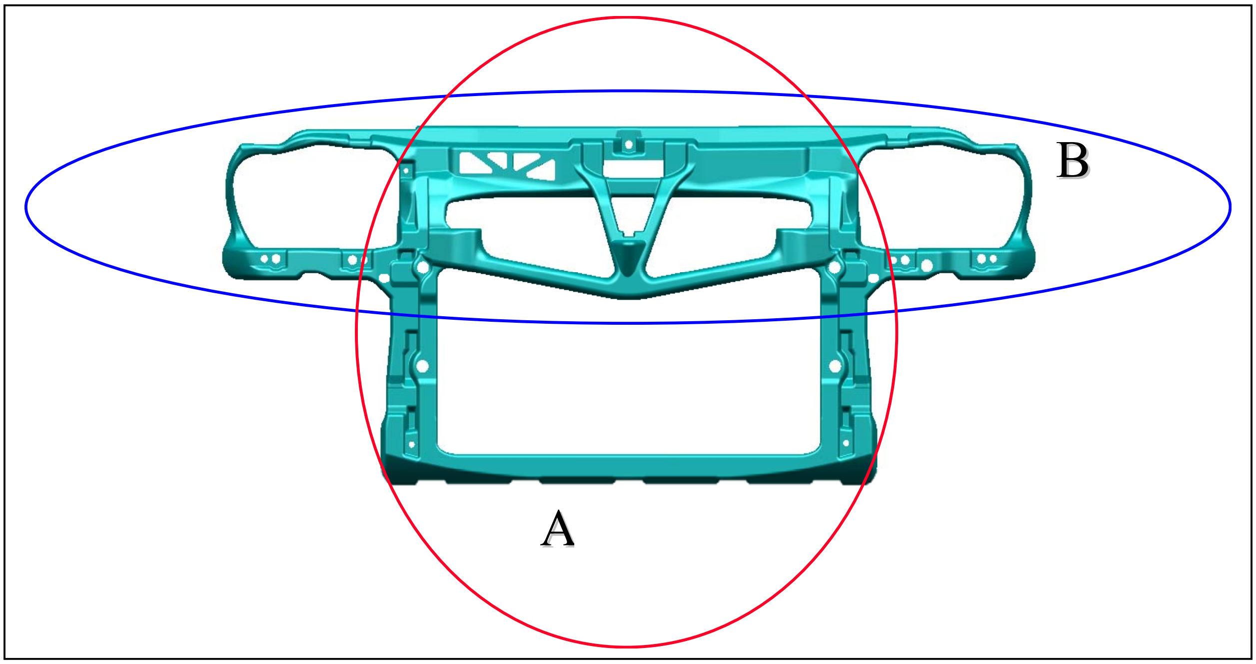


Figure 5: Platform and design driven areas on front-end carriers

Additional simple metal reinforcements can be added in the same bonding process to manage crash performance.

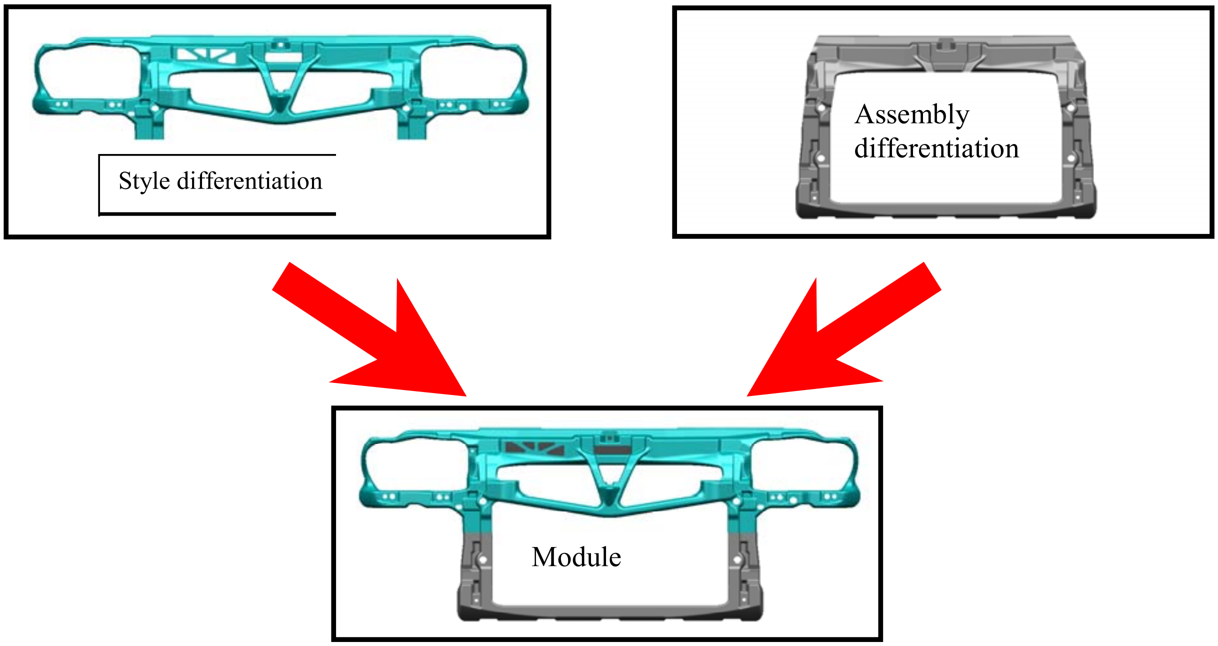


Figure 6: Functions of components making up the front-end module

Conclusions

Hybrid plastic-metal systems will play an important role for the future due to their better stiffness/weight ratios. It is expected that hybrid solutions will take on a much broader meaning than the injection overmolding approach, extending to compression overmolding or a trend towards bonded systems, which offer the possibility to further increase stiffness through closed sections, and increase development flexibility because of interdependence in design. Also some of the new requirements such as pedestrian safety and recycling will highly influence the FEC designs, leading to designs that balance stiffness and structural behavior to meet increasing mechanical demands and assemblies that address disassembly and recycling needs.

Further integration of functions and front-end components will be also another important factor in driving future FEC solutions. Integration of hood and possibly fenders into the FEM is one possibility, adding a new dimension to the meaning of front-end module.

References

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