HPPC: DEVELOPMENT OF A THERMOPLASTIC SOLUTION FOR AUTOMOTIVE HORIZONTAL BODY PANELS

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Global Automotive Trends

Today, there are three global trends that call for a thermoplastic solution for horizontal body panels (hoods, roofs and trunk lids):

1. Vehicle differentiation reducing the average annual production per name plate
2. Higher fuel cost demanding lightweight materials
3. Pedestrian safety regulations being enacted in Europe and Japan

Market competition, globalization, new entrants, and increasingly demanding consumers continue to drive automakers to differentiate and segment their portfolios. Over the last twenty years, there has been a consistent decrease on average annual production per “name plate”. Parallel to that, the same market forces are also reducing the life of models.

The combination of smaller annual productions and shorter lifetimes has a significant influence on the exterior styling of today’s cars. Horizontal body panels are the largest exterior parts with the most expensive tooling for steel stamping (the primary material used on them). When annual builds fall below 50,000 units, the cost for depreciating a multi-million dollar set of tools over a small number of parts becomes very high for a metal stamping solution. In this scenario, thermoplastic with a typical tooling cost that is a significantly lower than metal stamping can make a lot of economic sense, even though thermoplastic is a more expensive raw-material than steel.

With expected movements in oil prices, the importance of reducing vehicle weight has increased greatly compared with five or ten years ago. Also, the task of reducing the total weight of a vehicle has become more challenging when automakers add heavy hybrid drive-trains and more electronic components onto their vehicles to deliver the performance and features which consumers are demanding.

Thermoplastics has been, over the last decades, a very reliable and efficient way of weight reduction, delivering typical weight reductions between 30% to 50% compared with the same parts made using steel.

Finally, after decades of increasing the safety of vehicles occupants, regulators in Europe and Japan are now focusing in pedestrian safety. As pedestrian safety is not as an obvious benefit to the vehicle buyer as occupant safety is, it is coming as legislation. The goal of this legislation is to reduce the severity of injuries suffered in collisions at speeds of up to 40 Km/hr, typical of shared- traffic areas.

Pedestrian safety legislations are already having major impact on hood engineering (cost wise and design wise). This is another area that a thermoplastic can be part of the solution.

High Performance Thermoplastic Composite (HPPC)

Targeting these three trends, GE Plastics and Azdel Inc. (joint-venture between GE Plastics and PPG Industries) have been developing a thermoplastic glass fiber composite solution for horizontal body panels, called HPPC.

HPPC technology is based on different GE Plastics resins enabling painting using both online and offline processes, for applications currently made with sheet steel, aluminum and SMC. The target is lightweight but stiff designs utilizing the superior impact strength of these polymers for excellent energy management. With a coefficient of thermal expansion of $<2 \times 10^{-5}$ mm/mm/°C, they fit between aluminum and steel in terms of dimensional stability. The modulus of elasticity exceeds 15,000 MPa.

HPPC is a thermoplastic sandwich composite, combining a glass fiber composite core with a reinforced thermoplastic skin. The concept, see Figure 1, offers significant weight savings over steel, and in contrast to SMC, parts can be formed without post-shrinkage and without warpage at excellent surface quality, eliminating the need for post-treatment.

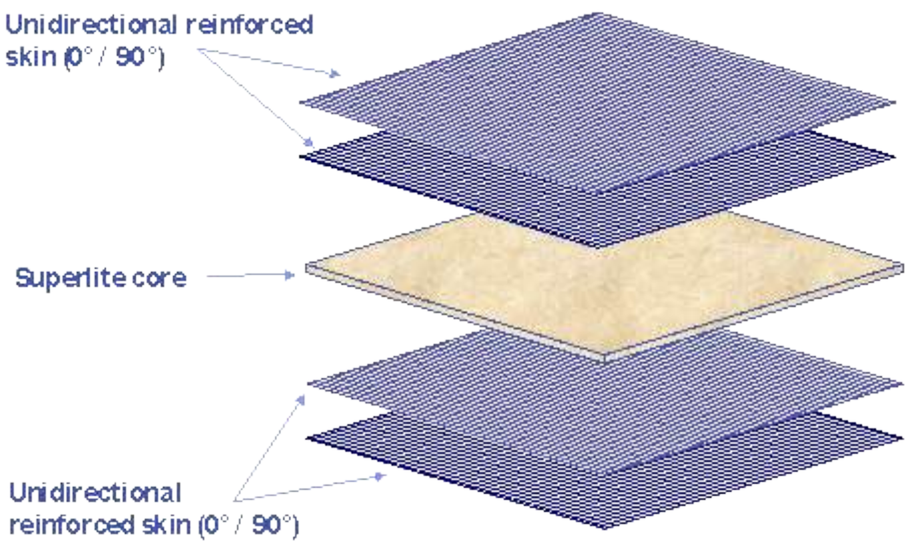

Figure 1: HPPC structure

The target value proposition for HPPC technology is the following:

Part stiffness similar to steel
Weight similar to aluminum
CTE equivalent to aluminum
Part total cost comparable to current solutions
Low tooling cost
Class A surface without post-treatment
Leverage HPPC energy absorption for pedestrian safety (hoods)
Online and offline painting options

HPPC will be a family of multiple products taking advantages of GE Plastics different resins and the flexibility of HPPC sandwich construction. As shown in Figure 2, the first three products that are planned for launch are a non-conductive offline painting HPPC (based on Noryl PPX* PPO/PP blend resin technology), a non-conductive online painting HPPC (based on Xenoy* PC/Polyester blend resin technology), and a conductive online painting HPPC (also based on Xenoy* PC/Polyester blend resin technology).

Offline paintable HPPC is targeted to be available for developmental sampling in the fourth quarter of 2006, while non-conductive online painting HPPC is targeted for third quarter of 2007 and conductive online painting HPPC is targeted for developmental sampling by the fourth quarter of 2007.

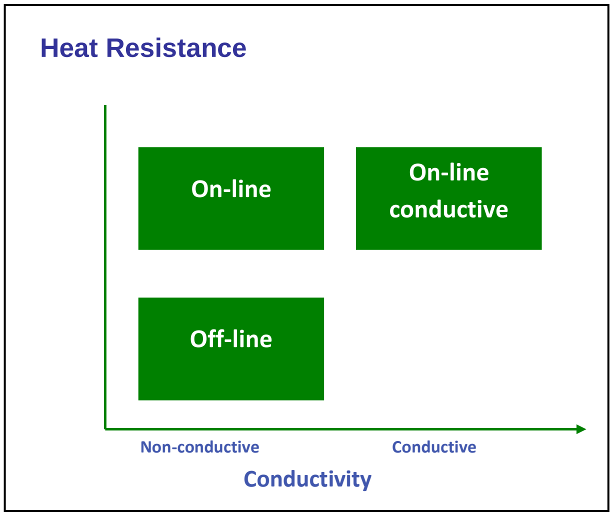

Figure 2: Initial HPPC family of products

HPPC Online Painting Capability

The flexibility of its construction allows differentiation in the core resin system, skin resin system and layer construction within the HPPC family of products. Following initial developments the capability exists to expand the range to include versions with increased stiffness or with pre-finished surfaces. Adding more unidirectional reinforced skin layers will increase the stiffness of the overall system, and the possibility of unpainted solutions is available using Lexan SLX* films (colored or clear plus a woven carbon layer). Figure 3 describes some of these possibilities.

The compatibility of the HPPC resin system with the chemicals used in the e-coat process has been tested in a second step for HPPC online painting validation. The results of initial chemical resistance testing look positive.

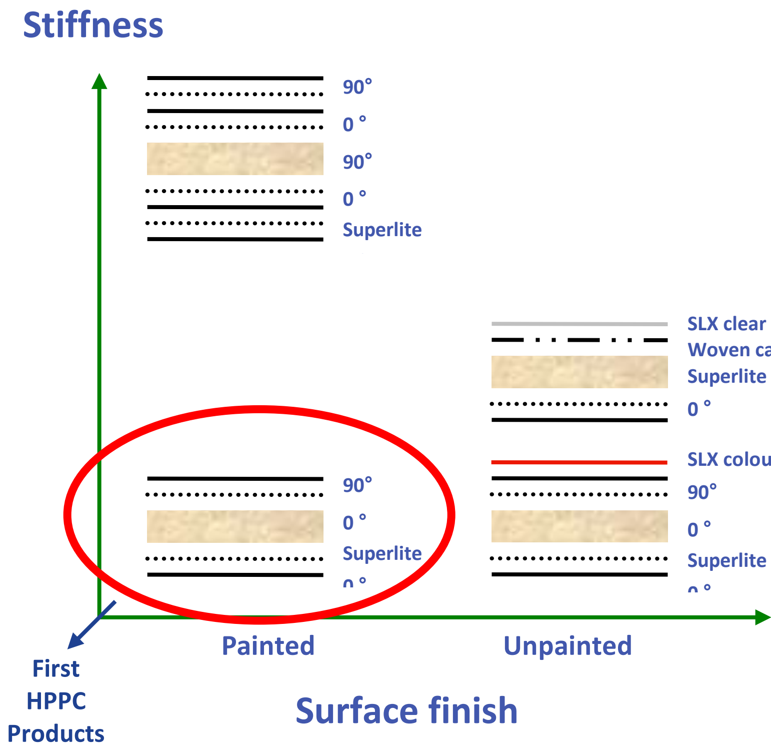

Figure 3: Future HPPC possibilities

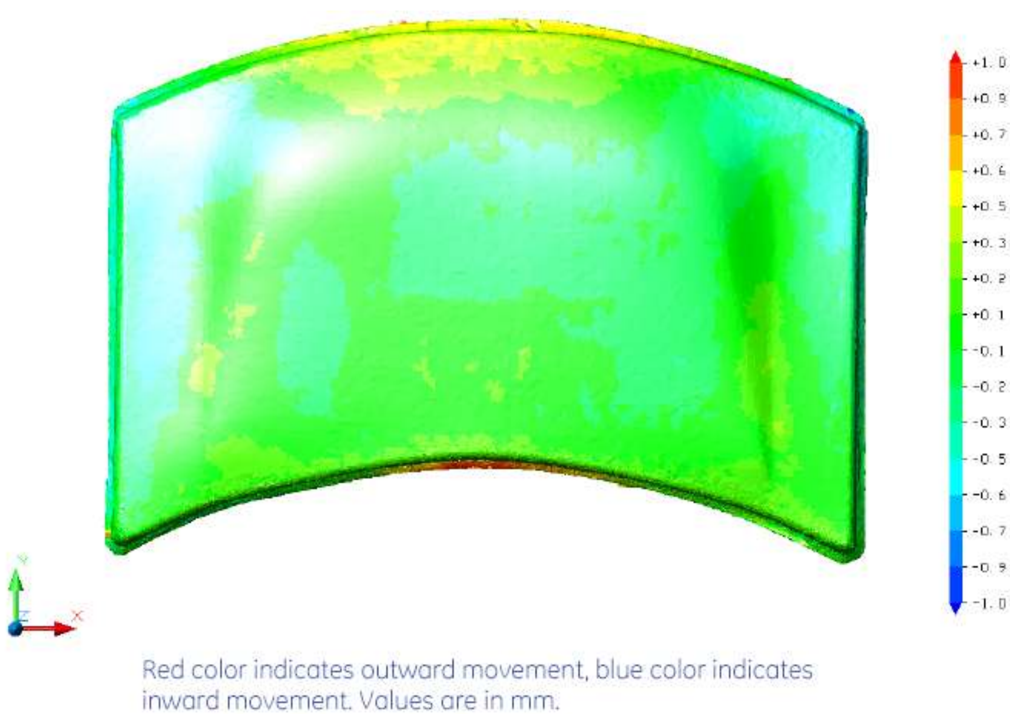

Figure 4: Dimensional comparison before and after 60 min. cycle at 210° C

Class A Surface and Cycle Timing

In order for HPPC to be a viable product for horizontal body panels, its ability to deliver Class A surfaces out of the has to be demonstrated. In addition, for HPPC to be economically attractive for annual productions up to 50,000 units, a cycle time for a part with the size of a hood skin should be around 2 minutes. One method to achieve these targets which GE Plastics and Azdel have been pursuing is a conversion process based on Inductive Mold Heating.

Azdel acquired, on March 31, 2006 an exclusive license to utilize the Cage System (Trademarked by RocTool) for Transportation Devices with a Class A surface using

thermoplastic materials in thermo compression and thermoforming processes. The exclusive license is valid for the life of the patents. Azdel has the right to sub-license this technology for others to fabricate molds or manufacture parts.

Azdel and GE Plastics have been working with RocTool and their cage system molding technology for approximately 2 years. During this initial development period, the companies have jointly designed and commissioned 3 exterior body panel tools ranging in size from a 1:4 scale automotive hood tool to a full-size scale automotive hood tool. Figure 5 shows a part molded in the 1:4 scale hood and Figure 6 shows full size developmental hood.

Figure 5: 1:4 scale hood

Figure 6: full size developmental hood

The Cage System uses electric induction to heat the surface of a tool. A special tool construction is utilized to reduce the thermal mass of the portion of the tool that is heated, hence a fast cycle can be achieved to heat and cool the tool.

The goal of the development work has been to reduce the cycle time required to produce a class A, thermal plastic composite body panel by an approximate factor of 30. Although this goal has not been fully realized yet, a line of sight to its fulfillment has been established.

In addition to Cage System, GE Plastics has combined proprietary conversion process features in order to tailor-made the process for fast cycle large automotive body panels. The combination is named Induction Molding. Fig. 6 shows an overview of the process.

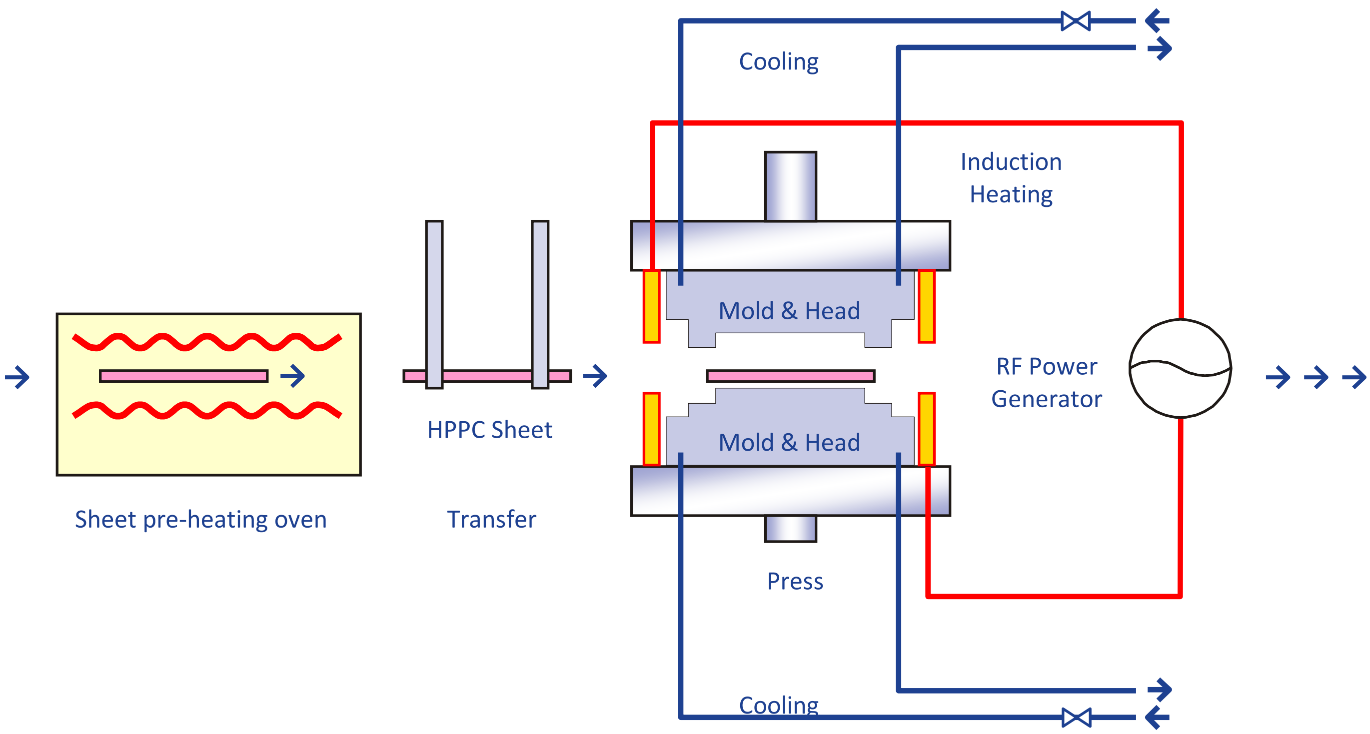

Figure 7: Induction molding process overview

To achieve a Class A surface, beside the conversion process, the unidirectional reinforced skin used in HPPC construction is also critical. During the second half of 2005 and the first quarter of 2006, an intense data based comparison of several available skin technologies was conducted. Several technologies were analyzed, including unidirectional filaments, woven fiber tows, and fabric weave, in combination with fabrication processes based on solvent, slurry, powder, melt, co-mingled fibers, and film stacking. Unidirectional filaments showed to be the best option to achieved the right balance between mechanical performance, aesthetic performance, and cost.

Pedestrian Head Impact

In order to evaluate the performance an HPPC hood in relation to pedestrian protection regulations, a version of the non-conductive online paintable HPPC has been characterized in high-speed impact tests; multiple proprietary hood inner structure design solutions were created; and these solutions are currently under CAE evaluation for pedestrian head impact performance. After an inner design is selected, a full size generic hood (inner plus outer) will be built and tested in GE Plastics facilities in Moka, Japan. HPPC pedestrian head impact performance testing is expected to be completed by the end of 2006.

The high-speed material characterization showed very promising results, such as:

Tensile behavior that does not vary significantly with temperature

A repeatable impact behavior

Energy absorbing characteristics with reasonable stiffness and deformation behavior, and

High speed tensile testing shows the modulus remains the same at different loading rate. The material shows strain rate behavior indicating it is insensitive to loading rate.

Green PBT polyester

In a major move that significantly reduces the emission of greenhouse gasses during the production of plastic resins, GE Plastics have developed a proprietary chemical process to convert PET bottle waste into virgin PBT polyester resin. It will be possible to use this PBT resin in the production of the Xenoy* blend used in online paintable versions of HPPC. This opens a significant opportunity for automakers to manufacture large body panels with a considerable content of post-consumer recycled product.

Conclusions / Further Work

Further work in this development is under way on several fronts, including: optimization of non-conductive online painting HPPC; addition of conductivity to it; development of a offline painting HPPC; optimization of Induction Molding for better surface and reduced cycle time; optimization of skin layer for better surface; and part design development, simulation and prototyping for pedestrian head impact performance.

So far, all initial signals show that HPPC can be a viable and very attractive solution option for thermoplastics to get into automotive horizontal body panels.