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The Importance of Color in New Composite Applications

by

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Aesthetics, in particular color and finish, of end-use OEM applications are a major driving force in determining the manufacturing method of finished products. OEM demands for cost effective, higher aesthetic quality in finished products drives new technology development and innovation in the industry. Processors who embrace innovations in the manufacturing methods and techniques related to aesthetics are expanding their businesses. Case studies will be presented in support of this hypothesis.

Introduction

Today's buyers are savvier then ever before. Whether purchasing consumer goods or industrial/business goods, they demand a total quality experience, which goes beyond product performance and extends to the quality of overall design and aesthetics.

Cell phones, for example, are evolving from utilitarian to fashion accessory[1]. As further proof, a recent article in EE Times proclaims: "Technology is dead. Welcome to the Age of Design." It is an age where a product's inherent whiz-bang technology is expected to become transparent, while its design increasingly captures the imagination – and disposable income – of consumers.[2]

While buyers are increasingly inclined to consider the technology in the products they purchase as a "given," it's important to realize that it is another type of technology – cutting-edge materials and processing technology – that is making today's design/aesthetic revolution possible. While certainly a key driver in the consumer marketplace, this aesthetic-centric focus plays a considerable role in commercial and industrial applications, as well.

It is, in fact, the desire for excellent aesthetics, increased use of color and complex geometries that has driven – and will continue to drive – technological advances and innovation in materials and manufacturing methods. Processors need to be aware that to increase and enhance their business they need to address customer demands for these product attributes. Doing so enables OEMs and processors to differentiate themselves and their products in an extremely competitive environment.

In particular, four technologies pertaining to polyurethane composites have evolved to meet technical challenges and thereby push the envelope in terms of available aesthetics and color options. They are:

- in-mold coating
- insert molding
- molded in color
- in-line painting of polyurethane composite parts

This paper explores the evolution of these technologies, including how they have helped transform product design and production, and translate into bottom line benefits for OEMs and processors.

In-mold Coating

In-mold coating, the first breakthrough, was initially developed for very large parts. In this process, the molded component is removed from the mold with a finished, high-gloss painted surface installed during the molding cycle. This involves a special high-gloss paint coating being sprayed onto the show surface of the mold cavity immediately before the part is molded. The mold is then closed and the two-component polyurethane mixture is injected into the closed mold, reacts to form the molded part, and chemically bonds to the high-gloss paint yielding a fully finished molded part right out of the mold. The release agent is either contained within the paint coating itself, or is applied to the mold before the coating.

The first application of this process, approximately 15 years ago, was the cab roof of a John Deere combine, in which reaction injection molded (RIM) polyurethane structural foam replaced steel (Fig. 1) with a high-gloss in-mold painted surface. The roof measured approximately 5 feet squared by 6 inches deep. A goal of the project was to reduce part weight from 65 pounds to about 50 pounds, without sacrificing performance or aesthetics.

Previously, there were several steps that needed to be taken for a urethane part to achieve a high-gloss surface that looked like painted metal: it had to be taken out of the mold, sanded, primed and painted. These steps were both costly and time consuming.

The molder for this project, GI Plastek, worked with two paint manufacturers, Valspar and Sherwin Williams, to reformulate two-component polyurethane paint systems to incorporate internal mold release, enabling the paint to release from the mold surface and yet still have reactive sites on the paint for the urethane and paint to bond together. The in-mold coating process eliminates secondary painting operations and results in a high quality, finished part right out of the mold, translating into excellent aesthetics and greater cost efficiency.

This single development of in-mold coating is particularly significant in that it spawned a number of related advancements.

Initially, in-mold coating was applied solely to rigid parts. However, the market's desire for more widespread utilization of this technology led to yet another advance: utilizing the in-mold coating process with elastomeric materials. This required the paint to be reformulated to be flexible and have the same elongation properties as the substrate.

This technique gained favor in a number of large-part applications, including molding fenders and other components for agricultural and construction equipment. For example, in the mid-1990s, Case Corporation switched from steel to an 18 percent glass-filled elastomeric polyurethane RIM system to form the inner and outer fenders for a new series of backhoes. By switching to RIM technology, Case was able to replace a 28-piece, steel-welded part with a one-piece, high functionality, fully finished molded inner/outer fender, yielding a significant cost reduction (Fig. 2).

One further development, two-tone in-molding coating, was driven by the desire to cost-effectively produce a two-color part right out of the mold.

One of the first applications for this process occurred in the late 1990s for a new model of pallet trucks from Baker Material Handling Corp. (Fig. 3). For this application, an 18 percent glass-filled elastomeric polyurethane RIM system was selected to replace the right and left metal motor compartment panels used on earlier models. The polyurethane RIM system was selected because of its impact resistance, cost effectiveness, insulating properties and capacity for molding variable thick and thin walls.

The processor developed a two-tone in-mold coating process in which approximately one-half of the mold was masked off using a fiberglass and silicone rubber composite. One color was sprayed into the mold, then the mask was removed and the second color sprayed. Essentially, the first color became the mask for the second color. Two-tone in-mold coating offers great opportunities for time and cost savings, not to mention enhanced color options. The project also translated into commercial success: only a few months after their introduction to the marketplace, the redesigned pallet trucks exceeded Baker Material Handling's sales goals.

While in-mold coating produced excellent aesthetics and eliminated post-painting operations, there was still a need to make the process more cost competitive. Molders and materials suppliers worked together to achieve another significant technological advancement: the development of a more cost-effective tooling approach. Up until this point, molds were made of expensive, highly polished steel. However, because of the low injection pressures of the RIM process, mold builders were able to utilize a less-expensive mold material using a nickel shell. A typical nickel shell mold is 1/3 the cost of a highly polished steel mold, which provided additional financial advantages for OEMs seeking to capitalize on the other benefits of polyurethanes and in-mold coating to meet the industry demand for polyurethane parts with a high-gloss finish.

To illustrate, CNH Global utilized nickel-shell molds instead of steel molds when molding the body panels for two versions of its Case IH AFX Series Combines (Fig. 4). In this application, a structural foam polyurethane RIM system incorporating a specially engineered interactive blowing system replaced steel and SMC. GI Plastek utilized the polyurethane RIM process and its proprietary in-mold coating technology to produce panels with a Class A finish right out of the mold. Due to the elimination of downstream operations, such as degreasing, sanding, priming and post-painting, as well as reduced capital costs, in-mold coating coupled with a highly polished nickel-shell mold proved to be a winning combination for CNH Global.

Driven by the increasing focus on aesthetics, in-mold coating technology continues to evolve. New advancements now enable the technology to be used with spray elastomers.

Last year, window and door manufacturer JELD-WEN launched the JELD-WEN Premium Fiberglass Door with PUR-Fiber technology. The new door offers consumers increased dimensional stability, better impact resistance and strength, plus a much more realistic wood-grain appearance than previously obtainable (Fig. 5).

It also offers the door manufacturer opportunities for a more cost-effective molding process. The skins of the doors are molded in a three-step process. First, an in-mold coating is sprayed on the show surface of the mold, then a polyurethane elastomer is sprayed on the in-mold coating, and finally, a customized formulation of a rigid polyurethane system using long fiber technology is added as the rigid substrate of the door skin. A fiberglass chopper is attached to the polyurethane dispensing mixhead, which in turn is attached to a robot. The robot is programmed to move over the open mold cavity while simultaneously dispensing both the long glass fibers and the polyurethane resin in a one-step, open-pour method. At the end of the pour, the mold is closed to form the part. To complete the door manufacturing process, JELD-WEN laminates the composite door skins to a polystyrene core and wood edge frame.

Long fiber technology is helping to automate the polyurethane process for producing composite parts, making them more economical to produce. Because of this technology, JELD-WEN is able to utilize lower-cost fiberglass rovings rather than mats, which also reduces trouble a worker may experience in handling the mats.

Of course, aesthetics are integral not only to how a product looks, but also how it feels. As such, market demand for finishes that offer a greater variety of surface textures has spurred the development of in-mold coating for soft-touch applications, such as vehicle interiors, seats and instrument panels. Another application is the use of spray elastomers to replace vinyl for seating applications for office furniture.

In another application that traces its roots to in-mold coating and is driven by the demand for aesthetics, aliphatic, two component polyurethane spray-on liners are being used to equip Honda and Nissan pickup trucks with bed liners that match vehicle color. This offers a significant improvement over previous technologies, such as thermoformed liners or aromatic spray-on liners that were available in black only.

The underlying concept of in-mold coating is continuing to evolve in order to fill different types of applications that demand improved aesthetics. In another recent advancement, a procedure similar to in-mold coating is being used during the pultrusion process to add long-lasting color to window frames. In the process patented by Tecton, a die is placed around the profile. Acrylic resin is injected over the profile during pultrusion. Because the color is added in-line, it eliminates the time, expense and eventual surface defects of post painting. This also makes it more economical for the manufacturer to offer a range of colors to satisfy the consumers' appetite for aesthetic quality and variety. Looking to the future, more environmentally friendly water-based UV curable polyurethane coatings are now in development that also could be processed in-line for this type of application.

Insert Molding

Another technology that has opened the door to other exciting design and aesthetic options is insert molding. Initially this thermoplastic injection molding technology was used to decorate small parts for automotive instrument gages and designer cell phone covers. Over time, refinements made it possible to use insert molding to add color, style and texture to large components, as well.

In this process, pre-decorated films, vinyl or fabric preforms can be placed into the mold prior to injection of a polyurethane RIM system. The injected polyurethane material bonds to the inserted decorating material, thereby allowing a decorated part to be produced in the mold, greatly reducing secondary finishing costs. Insert molding also offers processors the ability to vary texture, color, aesthetics and functionality from model to model, part to part without changing the mold.

The technology has its beginnings in the early 1990s. As mentioned, it has significantly evolved in response to market demands for aesthetics. As an example of an early application, vinyl or fabric outer skins were vacuum formed into a mold cavity. A glass mat was then placed into the mold cavity and followed by the injection of a rigid polyurethane foam (Low Density SRIM system). The result was a lightweight composite door panel that could offer a variety of finishes, fabrics and textures which could be used to differentiate high- and low-end vehicle models.

The technology has evolved, progressing from vinyl, to fabric, and now to film. An early illustration of the marriage of SRIM and insert molding is the SMART Car Roof. In 2000, the SMART Car Roof was produced with the long fiber injection process.[3] In addition to the long fiber SRIM, the exterior surface of the part, a sheet of thermoplastic film, was placed into the mold cavity and the interior surface of the roof module, the headliner material, was placed into the other half of the mold prior to injection of the polyurethane long fiber SRIM substrate. This efficient process produces a completed roof with each molding cycle with extremely high quality aesthetics at a lower cost than traditional roof module construction.

A more recent example of an innovative use of insert molding for an automotive application is the sun shade featured on the 2005 Toyota Avalon (Fig. 6). The sun shade is formed with a two-component polyurethane system used in compression molding of natural fiber mats alone, or fiber-reinforced sandwich panels. The polyurethane system was chosen over other materials due to its extremely lightweight properties, high degree of stiffness and thermal dimensional stability. To mold the sun shade, which is roughly 32 inches wide by 21 inches long, the composite polyurethane system is sprayed onto the fiberglass mat and paper honeycomb core, placed into a two-sided mold and formed into the final part. The resin impregnates the mat and core, forming the strong, lightweight composite part that is then assembled with other components to create the complete sunroof unit, reducing part cost while providing aesthetic, functional parts.

On the horizon, new advancements combining reinforced polyurethane resin composite materials with plastic-metal hybrid (PMH) design technology will offer automakers the ability to offer consumers a wider variety of roof styles and options (base roof, sunroof or panoramic roof). One roof module concept utilizes PMH to create a roof frame welded to the body-in-white structure that is capable of going through on-line electro-static coating (E-coat) processes. The frame becomes a common footprint upon which a variety of roof modules constructed with polyurethane composites protected by coating and film can be attached to the vehicle with adhesive (Fig. 7). Not only does this increase the options for consumers, but it also reduces OEM labor hours and the number of assembly stations. Modular assembly also reduces the foot print on the assembly floor and decreases capital investment at the OEM level.[4]

One innovative non-automotive application that demonstrates the design possibilities of combining RIM technology and film insert molding is a refrigerator door from Italian molder GMP Polyurethanes S.p.A.

Films are often used if the surface of the molded part is required to have particular properties, such as soft-feel characteristics or resistance to UV rays or wear and tear. A few years ago, GMP created a refrigerator door that is as much fashion statement as it is functional. GMP developed a new surface finishing technique that takes advantage of the outstanding adhesion between polyurethane and film. The patented process cut costs by eliminating the need for post-painting, while at the same time achieving an improved surface finish. Furthermore, GMP’s process eliminated the use of sheet metal for the skin of the refrigerator door.

In this application, the thermoplastic film formed a durable, protective outer skin with a wide choice of color options that are applied directly to the film. Apart from the film and thermoplastic interior liner, the doors consist entirely of polyurethane. GMP backed the thermoplastic film with an approximately 4mm thick layer of a structural foam polyurethane RIM system that created a rigid, dimensionally stable outer shell with no need for sheet metal. Then GMP filled the space between the shell and the inner liner with insulating polyurethane foam. The result: a self-supporting door that satisfied all stability, thermal insulation and surface finish requirements.

In addition to interesting aesthetics, benefits included shorter production time due to elimination of post-painting; cost reduction leading to greater competitiveness and greater freedom of design than with conventional sheet metal skin.

The demand for bold, bright graphics made insert molding a natural for sporting applications, such as waterskis and wakeboards. Previously, graphics were applied as decals, which can peel and fade in punishing sporting applications. An early example of using film insert molding in this market is the EP (Exceptional Performance) Wide Track™ water skis from Wellington Leisure Products in the late 1990s (Fig. 8). To add muscle to the skis, Wellington selected a polyurethane structural foam RIM system to give the ski a low-density, high-strength performance core. The skis were formed in a parabolic shape: wide at the front, narrowed at the center near the binding and widened again at the back. The bold, four-color graphics were incorporated into the ski’s top surface via a propriety process during molding.

The concepts and technologies utilized for insert molding have continued to be refined and are now widely used for a variety of applications, such as automotive bezels, cell phone key pads and other applications where durability, style, color and/or texture is desired.

Molded in Color

In conjunction with the rising importance of aesthetics is the increasing demand for customization. Once again, technology has evolved to help processors meet this demand.

Because RIM is a closed-mold, two component liquid molding process, it produces cosmetically good-looking parts right out of the mold. Parts retain their good appearance because the color is molded in. In addition, molding in the pigment also eliminates the time and expense of post-painting the components.

However, traditionally, changing colors in urethane processing has been labor intensive, and therefore, quite expensive: In order to change colors after finishing a batch it has been necessary to either flush the batch tank, pumps and delivery lines or set up a separate line – both expensive alternatives. However, technology has evolved from two-component mixheads to three- and even four-component mixheads. The third (or fourth) stream, the pigment, can be added at the mixhead, enabling the molder to quickly and easily vary color from shot to shot without having to flush the entire system, thus saving significant labor and cost of waste materials. This enables molders to create private label, via custom colors, out of the same mold, resulting in greater cost effectiveness and increased market share.

This technological advance is exemplified by The Structural Plastics Design Awards winner in 2002 in the Electrical market category, the Impact Innovator™ glass door from Hussmann Corporation, a subsidiary of Ingersoll-Rand. The award winner was an electrically heated, multi-pane glass freezer door with an elastomeric polyurethane RIM frame. The polyurethane RIM system offered a number of advantages for this application. Combined with a case frame of non-conductive pultruded fiberglass, the doors contributed to a 25 percent reduction in energy consumption, according to Hussmann. Hussmann used an elastomeric polyurethane RIM system to form the doorframe and chemically bond the triple-pane insulating glass window assembly to the molded frame. The resulting frame was seamless, strong and significantly less thermally conductive than aluminum, the traditional material used in this application. The RIM process also allows Hussmann to mold the door's steel hinges and other hardware into the frame, rather than adding them during a secondary operation.

In addition to all these benefits, it is also significant that the latest technological evolution in molded-in color enables the manufacturer to mold the doors in custom colors for its supermarket customers (Fig. 9). This ability to customize the doors according to customer preference resulted in increased market share for the manufacturer.

Another example using molded-in color to customize products to meet customer need is a modular ramp system offered by RIMSTAR (Fig. 10). The ramp system, formed from a solid elastomeric polyurethane material, helps people and vehicles safely cross over electrical cables and hose lines without harm to themselves or the cables and hoses. Molding-in color enables RIMSTAR to cost effectively offer the variety of custom colors its customers demand for product differentiation.

The latest development in molded-in color is injecting multiple streams (colors) simultaneously to create one-of-a-kind visual effects. Brunswick is using this technique on its newest line of high-performance, reactive technology bowling balls to create a unique, distinctive swirling pattern.

In-line Painting of Polyurethane Parts

While RIM technology has been utilized for 25 years for automotive fascia and body side moldings, today's applications demand higher performance in processing and part performance. One recent breakthrough is the elimination of post cure with an elastomeric polyurethane/polyurea reinforced RIM (RRIM) system and subsequent post painting.

Previously, RRIM molded parts were required to be baked at 120 degrees Celsius and above to complete chemical reactions, attain complete physical properties and de-gas parts prior to painting. More recently, RRIM was used for pickup truck fenders where it replaced SMC or steel. In these cases, the RRIM material is required to be cured at 190 degrees Celsius prior to priming and assembly in order to improve properties such as modulus and sag and to prevent out-gassing during paint processing.

Automakers realize the greatest manufacturing efficiencies if all body panels are first assembled, then painted. However, some urethanes can blister, become brittle and decompose in the high cure temperatures of the electro-deposition coating (ELPO) bake, which is part of the vehicle painting process. While there are alternatives – such as attaching the RIM parts to the vehicle after the ELPO process – they require extra steps and part handling that translate into additional cost – something they would prefer to avoid.

An elastomeric polyurethane/polyurea RRIM system used for automotive exterior body panels, such as car and truck fenders, is capable of replacing SMC and metal in part due to its stability at high temperatures, and therefore, its ability to withstand the ELPO process. Other advantages of this polyurethane RRIM system include lighter weight (which translates into better fuel efficiency), superior corrosion resistance and lower equipment and tooling costs. It also offers more design freedom and a DOI (distinction of image) or mirror finish comparable to painted steel parts.

Conclusion

An increasing appetite for enhanced aesthetics and customization is transforming product design and development. In-mold coating, insert molding, molded-in color and in-line painting of polyurethane composite parts are among the technologies that have continuously evolved to help molders and OEMs find solutions that address this demand. Furthermore, these adaptive technologies will continue to push the envelope to meet the aesthetics challenges of tomorrow.

Because the focus on aesthetics shows no sign of abating, processors should embrace new technologies as a means to differentiate their products and thereby gain a much-desired competitive edge.

Biography

Harry George
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Mr. George has 25 years of experience in Thermoplastic Injection Molding and Thermoset Polyurethane Reaction Injection Molding in the areas of product design, tooling design, process engineering and market development. For the past 8 years, he has been the Business Manager for the Specialty RIM and Composites business at Bayer MaterialScience LLC headquartered in Pittsburgh, PA

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2 "It's Design, Not Technology," EETimes, February 27, 2006.
3 "Reaction Injection Molding (RIM) Technology – New Horizons," H. George, Sept. 30, 2000.
4 "An Integrated Automotive Roof Module Concept: Plastic-Meta Hybrid and Polyurethane Composite Technology," C. Korson, LANXESS Corporation, D. Stratton, Bayer MaterialScience LLC.

Figure – 1
John Deere Combine

Figure – 2
Case Corporation Backhoe

Figure – 3
Baker Material Handling Corp. Pallet Truck

Figure – 4
CNH Combine

Figure – 5
JELD-WEN Premium Fiberglass Door with PUR-Fiber Technology

Figure – 6
Toyota Avalon Sun Shade

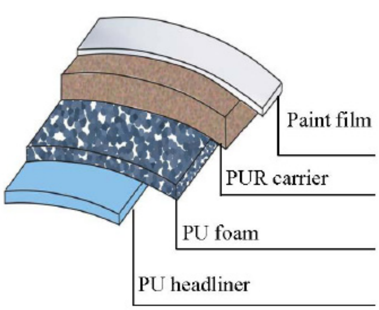

Figure – 7
Roofing Module Materials Cross Section

Figure – 8
Wellington Leisure Products EP (Exceptional Performance) Wide Track™ Water Skis

Figure – 9
Hussmann Corporation Impact Innovator™ Glass Door

Figure – 10
RIMSTAR Modular Ramp System