Driven by advances in technology, consumer experience, and an increased response to environmental pressures; innovation in the automotive industry is reaching unforeseen levels. As vehicles become more complex and sleeker, integrated touch film technology is becoming ever more important. Film Insert Molding (FIM) is increasingly being used to manufacture plastic parts for automotive interiors, helping to achieve smooth, high-quality finishes on components such as integrated displays, capacitive switches and high wear interfaces. In this paper, we will examine how automotive designers can overcome some of the challenges arising from the changing demands of the market using high-performance, formable hardcoated films. More specifically, we will discuss how to balance the optical requirements of the display with the aesthetic appeal of a tailored and harmonized, integrated surface.

Market advances driving innovation
The automotive industry is undergoing a transformation in the race to electrify and fully automate self-driving vehicles. Increasingly complex technological advances coupled with a shift in consumer expectations are revolutionizing both the form and function of the traditional automobile. Driven by a focus on enhanced user experience, automotive OEMs are challenged to balance functionality, aesthetics and weight to create vehicles that not only enhance consumer experience, but also work to comply with ever expanding safety requirements and increased environmental pressures.

As technology advances, automotive displays are becoming a key aspect of a vehicle’s interior. With display technology becoming an integral part of day-to-day life through the use of smart phones and tablets, consumers expect to see this technology replicated in their vehicles.

Smart surface embedded displays with integrated capacitive touch screen functionality are becoming a requirement for the modern vehicle. Not only do these displays increasingly mimic the performance and feel of smart phones, according to the IHS Markit Model-Level Automotive Display Forecast\(^1\); they are also increasing in size and number. Instantly readable displays are a means of deciphering complex information about the vehicle. Automotive display systems also provide a familiar way for users to access expanded capabilities and features that would otherwise be subject to a steep learning curve.

In addition to the consumer demand for high-quality aesthetics, regulation has also been driving demand. For example, the US Department of Transportation mandate requires all light vehicles (e.g. passenger cars, multipurpose passenger vehicles, trucks, buses, and low-speed vehicles rated at 10,000 pounds or less, gross vehicle weight) to be equipped with a rear visibility system. The ruling, which went into effect on May 1st, 2018, necessitates the presence of a high-quality display screen with good readability and image clarity. This is somewhat complicated by the shift towards electric vehicles. Automotive designers not only need to optimize the functionality of the display, but also do so in a way that does not increase vehicle weight to the point of affecting the car’s range per charge.

Where, in the past, vehicle interiors had a myriad of buttons and toggle switches, recent concept cars reveal elegant sweeping curved surfaces with seamlessly incorporated capacitive touch switches, alongside displays and touch screens. Whilst these features hold significant aesthetic appeal, they also reduce the complexity of the assembly and weight.

---

\(^{1}\) IHS Markit Model-Level Automotive Display Forecast (2019)
Key challenges facing OEMs
Despite its abrasion resistance and optical properties, the use of glass as a first surface for automotive displays presents limitations, particularly in light of current aesthetic and light-weighting trends. Although glass is still being used with success within the industry, the growing demand for large, curved, integrated displays with increased functionality presents challenges for automotive designers. Given that most light-emitting diode (LED) arrays are flat, a degree of innovation is necessary to seamlessly integrate and harmonize them into the sweeping curved cockpit design.

Glass presents obvious issues for bezel-free integration into the cockpit surface to achieve a harmonious and seamless design. The density of glass is also significantly greater than plastics. As display areas increase in size and number within the cockpit, weight becomes a greater factor for the design engineer.

High gloss first surfaces provide good readability. However, this can be impaired by strong, sharply defined, or moving reflections. These optical challenges are further complicated by the variety of viewing environments, for example from the high level of reflection and glare of bright sunshine, to decreased screen brightness at night. A delicate balance between glare avoidance and optical functionality must be achieved to ensure the visualization of display images. Special attention must also be paid to durability, resistance to fingerprints and ease of cleaning. Given the limitations of integrating glass into a curved cockpit surface, there is a pressing incentive for OEMs to explore alternative solutions that better address the demands of the market.

Balancing readability and aesthetics
It is essential that cockpit displays are readable at a glance. As the car moves, incident light (light that hits a surface) moves across the cockpit of the vehicle. If the light hits a high gloss display surface, it will reflect a distinct image – rendering the display unreadable. An antiglare coating is required to diffuse the incident light, breaking up the reflected image. This happens because where light is incident to a high gloss surface, for example at 15 degrees to the normal, it will all be reflected at -15 degrees around the normal: this is specular reflection. If all light is reflected this way, as it would be with a high gloss surface, the reflected image will have distinct edges and therefore be highly distracting to the driver. An antiglare surface is textured, which means that the surface has small slopes. The light will still be reflected around the normal to the surface, however the normal is now variable. The 15-degree incident light is therefore reflected at multiple angles, so the reflected image becomes indistinct, making the display more readable.

The location of the display in the vehicle interior will have an impact on the amount of incident light it is subjected to. At dashboard level there will be a higher level of incident light than at knee level and subsequently on the level of antiglare texture in the coating required to diffuse the reflected light. This is important to consider because the presence of the antiglare texture has a number of associated visual effects; including a loss of clarity and increased haze. Clarity and haze are related to the gloss level of a surface, so where the display requires smaller features to be readable, a glossier, higher clarity surface may be required.
Another important factor associated with clarity is optical path length between the first surface and LED. For example, a high gloss surface will have high clarity, so the optical path length can be longer, and the image can still be readable. Antiglare surfaces do cause some scattering of transmitted light, leading to a loss of clarity and resolution due to the refraction of the source light; however, because this is proportional to the optical path length, the effect can be managed. If the design requires a greater distance between the display and the first surface, for instance where a flat display is to be integrated within a curved dashboard; it may be necessary to have a higher gloss level first surface for small details in a display to be readable.

Sparkle is another key consideration in determining the optimal first surface. The effect is dependent on the pixel size of the display—the coarser the pixel, the more of a problem sparkle becomes. The resolution of the human eye is 0.3mm at a distance of 1 meter. Typically, this is too poor to resolve individual pixels.

The variable surface structure of an antiglare coating scatters light to improve display visibility, however; the textured features can act as lenses. If they are of a similar size or periodicity as the display pixels, the light emitted from each pixel will be refracted by the textured features that cross the pixel area, resulting in images that appear grainy (sparkle), and can impact readability. This is an important factor to consider in selecting a first surface for a display, because the periodicity and size of antiglare features are dependent on the gloss unit of the texture. The first surface antiglare finish can be adapted to minimize sparkle for a given display pixel size.

Interaction of Optical path length and antiglare
Blur only noticeable with high antiglare levels and a long optical path length

Key factors when addressing display readability:
- Distance*
- Location
- Pixel size
- Resolution

*Between the LED and first surface
Having the choice of a range of gloss and antiglare finishes takes seamless display integration in the vehicle cockpit from concept to reality.

**Innovative solutions to meet future trends**

Though current trends in the automotive industry present significant challenges for OEMs, these challenges can be overcome though the use of high-performance, hardcoated films. MacDermid Enthone Industrial Solutions’ XtraForm™ films, for example, are formable and hardcoated with deep high gloss and antiglare finishes. Delivered using a highly advanced variation of FIM, the XtraForm process, the films are designed to be UV cured for maximum formability, whilst maintaining scratch and chemical resistance. These durable films not only provide the smooth, high-quality finish that modern consumers demand, the antiglare surfaces hide finger marks. In addition, XtraForm films offer a range of textures of different gloss units, which is essential for adapting to current market trends.

In conclusion, the choice of a display first surface is based on a combination of the aesthetics, the resolution of the display and the optical path length in equal measure. The key to seamless integration lies in the availability of a range of textures with different gloss units. Designers can select from various levels of gloss to match the texture around the display and its location within the cabin; whilst also considering the optical requirements to ensure readability. Furthermore, the hardcoats are formable so the first surface of the molding can be continuously shaped over a large area if desired. MacDermid Enthone works in partnership with OEMs to find the best solution, based on each OEM’s specific requirements. Once the optimal solution has been determined, further support is offered through MacDermid Enthone’s proprietary XMAPP™ service. XMAPP is a quality performance system for applicators using XtraForm products and processes, designed to help manage the challenges involved in developing high-performance parts and collaborating with suppliers across the supply chain. This gives OEMs the confidence that the same product quality and consistent processes are available worldwide.

Working with MacDermid Enthone offers a unique combination of technical expertise, experience and support that enables OEMs to be responsive to the changing automotive display market. Not only does this allow for the effective delivery of tailored solutions to address a complex set of variables; but also, an ongoing commitment to unrivaled quality and consistency to drive innovation in the future.

To find out more information on MacDermid Enthone’s hardcoated automotive films and proprietary XMAPP service, contact ISenquiries@macdermidenthone.com or visit industrial.macdermidenthone.com/products-and-applications/hardcoated-films

**Martin Herbert:**

Product development manager at MacDermid Enthone
He has a Master’s degree from the University of Cambridge in Metallurgy and Materials Science.

**Source:**

1. The IHS Markit website provides information and analytics for diverse industries: https://ihsmarkit.com/research-analysis/automotive-display-panels-to-increase-11-percent-in-2018.html