thermoforming is a method of manufacturing plastic parts by preheating a flat sheet of plastic, then bringing it into contact with a mold whose shape it takes. This can be done by vacuum, pressure, and/or direct mechanical force, but each technique produces complex, custom plastic enclosures from flat sheet stock.

Pressure forming is a thermoforming technology that involves forcing a hot plastic sheet against a mold by introducing compressed air to the sheet’s outer side. Pressure-formed parts compare favorably to injection-molded parts, and are a real asset to designers who require a crisp, high-quality look in numbers too few to justify expensive injection-molding tooling. Vacuum forming involves the automatic draping of a heat-softened plastic sheet over a female or male mold, and is ideal for low-volume production parts with large radii and simple shapes. However, pressure forming is preferable to vacuum forming when the custom plastic enclosure requires complex features that cannot be achieved by vacuum forming alone. For smaller volume runs, pressure forming offers injection-molded quality and details. The pressure applied (up to 100 psi) is approximately five times higher than with vacuum forming, which makes it possible to design highly detailed parts and textured finishes. In pressure forming, air pressure enables design of intricate detail on the mold side, and a higher quality finish that leads to sharp edges, undercuts, and other close-tolerance details.

Heat-resistant materials

The prototype for the Titleist Launch Monitor was made from cast urethane. Although urethane works well for prototypes and trade show models, it cannot meet the demands of fluctuating temperatures, specifically extreme heat. Despite this fact, production began with urethane. The resulting TLM could not withstand the grueling summer weather. Massachusetts-based Acushnet...
Company, which owns the Titleist brand, brought in Carroll Design, based in Lowell, Mass., to finish the CAD models for the TLM. Carroll Design then referred the project to ThermoFab, based in Shirley, Mass., to find better materials and processes than those used in the prototype.

Because urethane has limitations in terms of heat resistance, it became obvious that urethane was a poor choice from the beginning. In the new prototype, which ultimately led to the final product, engineers chose to pressure form the parts of Kydex V103 (UL Std. 94V0), a fire-retardant, thermoplastic sheet with high impact resistance manufactured by Kleerdex Co. LLC.

Kydex V103 is easy to form, with excellent part definition and deep-draw characteristics. The typical value for its heat deflection temperature at 264 psi (1.8 MPa) annealed is 168°F (75.5°C). The typical value for its forming temperature is 325 to 392°F (163 to 200°C). The final TLM main housing is composed of three pressure-formed parts, each of which includes intricate undercuts.

In total, ThermoFab pressure formed nine enclosure parts, the largest three of which were bonded with a two-part methacrylate adhesive to build the rear housing, which measures 24.25 in. wide x 12.38 in. high x 16 in. deep (616 mm x 314 mm x 406 mm). The two-inch undercuts for handles on either side of the rear housing were especially challenging to mold, requiring action in the tooling to allow removal of the part.

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**Fig. 2** — Three-piece pressureformed assembly of Kydex parts are joined with a two-part methacrylate adhesive.

**Fig. 3** — The working side of the launch monitor—these two circular bezels surround and hold the cameras in place.

**Fig. 4** — This square bezel, which fits into the aluminum casting, surrounds and holds the display monitor in place.

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