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Technical Article

Pressure Forming: Past, Present, and Future

This white paper is based on a presentation that Steve Murrill, Chairman of the Board and former President of Profile Plastics, shared with the Society of Plastics Engineers (SPE) in 2016. Steve's history of pressure forming dates back to the 1980s but is as important now as it was just a few years ago. Today, heavy-gauge pressure forming is a well-established, commercially viable manufacturing method for producing parts with tight tolerances, attractive finishes, and lower tooling costs than injection molding can provide.

The Origins of Pressure Forming

During the early 1980s, discussions began among a group of vacuum formers who were part of the Thermoforming Institute of the Society of Plastics Engineers (SPE), a leading trade association at the time. The owners of eight vacuum-forming companies started talking about ways to improve the appearance of thermoformed parts so that thermoforming could compete with injection molding for low volumes of large, cosmetic parts.

John Grundy, the founder of Profile Plastics and its owner during this time, was an important part of these discussions. A talented engineer, John involved himself in all aspects of pressure forming, which, like vacuum forming, is a type of thermoforming. John's contributions to the plastics industry became so great that the SPE Thermoforming Division named him Thermoformer of the Year in 1993.

Pressure Forming Drivers: Molded-In Features and Lower Mold Costs

Back in the early 1980s, John Grundy and his vacuum-forming colleagues began discussing the idea of thermoforming with a negative mold to enhance the appearance of molded-in features, especially undercuts, which are difficult to achieve with positive parts. These vacuum formers developed small experimental prototype molds to demonstrate some of the possibilities. They soon learned that applying a little pressure to the back side of the sheet, against the mold, allowed them to create tools with fine molded-in details and textures. Moreover, greater pressure produced parts that looked like they'd been injection molded.

During this time, Profile Plastics prototyped a box-like part using a sheet-fed pressure former, a machine that Profile had purchased as a used vacuum former. Designed and built by Brown Machine, this 5-ft. by 10-ft. unit was a special-purpose machine that formed and then die-cut parts at the forming station. Die cutting required the machine to have two platens and locking bayonets, which hydraulically squeezed the platens together. The die-cutting feature had little marketplace value, however, and the original owner sold the machine to Profile.

Fortunately, this machine arrived on our shop floor at the same time that John Grundy and the other vacuum formers were searching for answers. Profile's experimental part then made the rounds among thermoformers and industrial designers. Industry publications learned of this development and were eager to know more. After some initial successes, news about pressure-forming's possibilities began spreading throughout the plastics industry.

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Among thermoformers, tooling sources were exchanged and insights were traded, including about pressure-forming applications. As designers learned more, they were eager to try pressure forming because the mold costs were significantly less than injection molds. As the marketers of this era explained, pressure-form molds cost 25% of comparable injection molds. The lead times for tools were also a lot less since pressure-form molds took only six weeks while injection molds took 16 weeks.

Early Pressure Forming Projects and Troubles with Trimming

The first projects for pressure forming were expensive business machines and medical diagnostic equipment. The volumes were low, sometimes as little as 200 per year or 500 total parts over a product's lifetime. The piece part costs were easily five times greater than injection molding; however, pressure-form molds cost five times less than injection molding tooling. Soon, advocates of pressure forming described it as the perfect process for highly cosmetic, low-volume applications.

There was a post-processing problem, however. Pressure-formed parts require trimming but widespread acceptance of CNC machining for thermoformed parts was still nearly a decade away. At the time, Profile had one of the first five-axis CNC trimming machines. It was built by Thermwood Corporation in 1979 and then, as now, Thermwood was innovative. Although the machine-builder's vision was clear, the equipment was difficult to program, unreliable, and expensive. Consequently, all of Profile's early pressure forming projects required hand trimming.

Because hand trimming is slow and imprecise, Profile could not produce 100 to 200 sets of parts quickly. Some projects required four or five different fixtures just to hand trim a single part. This increased the risk of problems, and rejection rates soon exceeded 10%. In addition to part defects and material yields, thermoformers were concerned about parts mating and matching. Most pressure-forming projects involved multiple parts, and hand-trimmed tolerances were typically ± 0.030-in.

Faster, Cheaper Molds vs. High Development Costs

Back then, hiding trimmed edges through innovative part design was paramount. Fewer mating parts per application were preferred, and family molds were discouraged because the challenges of hand trimming risked leaving an assembly short of parts. If that happened, filling a complete order with an equal number of each part would require additional material and processing.

Still, advocates promoted pressure forming as a bridge to injection molding. Customers could use it to get products to market faster and then use more expensive and slower-to-produce injection molds afterward. Yet these high expectations led to intense pressure to develop the rest of the pressure-forming process on the fly. Specifically, thermoformers need to address how to attach pressure-formed parts to each other and to machines.

There weren't any rules books that explained how to handle these unknowns, but part designs needed to be completed quickly—and with high development costs because of the speed-to-market that pressure forming was supposed to provide. After a while, pressure formers noticed that its early adopters were entrepreneurs with varying levels of success.

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Three Pressure Forming Success Stories

At Profile, there were three significant examples that more than paid for our development costs and provided us with increased confidence in the possibilities of pressure forming.

Profile Plastics won both awards for a medical cart enclosure used in surgical procedures. The cart has 10 pressure-formed enclosure parts: seven for the primary cart and three for a secondary cart. “They can be used independently, or they can be attached together,” said Mike Diaz, technical sales manager at Profile Plastics. The enclosure parts are formed from polycarbonate-ABS to meet stringent requirements for rigidity, chemical resistance, heat and a highly cosmetic appearance.

To this day, this first example may be the most successful pressure-formed part ever produced. It’s probably no surprise that the application was developed by John Grundy himself, back in 1986. The project, an air conditioner Plenum for the emerging “computer room” market. It was designed to replace a metal box and improve the appearance in the conditioned space. In 1987, this part became the winner of the first SPE Thermoforming Institute parts competition.

The second success was with a company called Life Fitness, which was developing its Club Exercise bike. This was a four-part application where, with some trepidation, we broke our “no family tools” rule. Over a seven-year period, however, we produced over 70,000 bike shrouds. Life Fitness chose injection molding for its next-generation model, but the project was profitable and paved the way for our other early success.

The third was a project with Eastman Kodak, which wanted to introduce a new electronic color printer quickly. On the same day injection molds were started, the company asked us to produce two pressure-formed covers. Injection-molded parts would eventually replace our pressure-formed ones, but the two types of parts looked alike. In the six months before their injection molded parts arrived, Eastman Kodak bought 5,000 sets of pressure-formed parts from us.

The Importance of Part Design in Pressure Forming

The A/C Plenum that John Grundy developed demonstrates the importance of part design to thermoforming success. The capstone part measures 2-ft. x 4-ft. and is made from a sheet of pre-colored Royalite R59 FR ABS that is .25 in. thick. The finished product is an assembly of 2 pressure-formed parts, 9 vacuum-formed parts, and a hardware kit. Everything is packaged in the customer’s box and shipped.

This part design has not required changes and is still an active and profitable application. By 2016, Profile had produced over 50,000 units with a total revenue in excess of $12MM. The fact that one of our first pressure-forming applications continues to be a model shows why part design matters. Based on successful applications like this, we have refined the list of requirements that we use when evaluating potential new opportunities.

The Best Applications for Pressure Forming

The best products for pressure forming usually have a electronics onboard and two or more mating parts; however, each additional part increases the degree of difficulty exponentially. High-end applications require more parts, but this makes the economics of pressure forming more attractive. Larger parts are also a good choice, but consumer products with pressure-formed parts usually aren’t economically viable. Still, a pre-colored sheet with an acid-etched mold texture provides more value than parts painting.

Pressure-forming requires frequent part measurements against the customer’s print or 3D model. This is time-consuming, and the part tolerances on customer drawings are typically too tight. Pressure-formed parts also require considerable trimming. This usually takes twice as long as forming, and the CNC trim fixtures must hold parts consistently. In addition, most pressure-formed parts require back-side milling to adjust the fit. Across multiple parts, the de-mold temperature affects the consistency of the fit.

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Pressure Forming Costs vs. Vacuum Forming Costs

Why does pressure forming cost more than vacuum forming? In part, it's because pressure forming machines are significantly more expensive than vacuum forming equipment. The molds that are used in pressure forming are also more expensive, and molded-in features such as louvers, logos, and openings add value along with costs. For many pressure- forming applications, such as medical equipment, expensive flame-retardant sheets may be required.

There are also differences in forming and trimming to consider. To control color and warp, pressure forming cycles are 30% to 40% slower than vacuum forming cycles. Pressure forming's CNC trimming cycles are also significantly slower because more trimming is required. The points of attachment, or blocks, on a part's backside add costs and trim time. Design for manufacturing (DFM), design for assembly (DFM), and internal process controls increase overhead requirements for engineering and quality resources.

Consistent Enough: Pressure Forming vs. Injection Molding

Pressure forming's value proposition is the "consistent enough" production of plastic parts. Injection molding can provide greater part-to-part consistency, but with significantly greater costs. Pressure formers who forget this reality risk spending too much time and money on process changes and part inspections. Because of statistical process control (SPC), however, injection molding may dictate part acceptance. Yet an SPC-based comparison between these two plastics manufacturing processes overlooks a key difference.

Injection molding is a closed-loop process with a feedback loop that signals variation. Process controls enable the injection molder to adjust the process automatically, or to stop it entirely until the root cause of the variation is identified and corrected. By contrast, pressure forming is an open-loop process. Pressure formers assume that all of the inputs are the same as the last run, and that any variations are within a small, predictable range. That works where fit, function, and appearance are the quality standards.

What happens if there are major variations during pressure forming, and these variations go undetected? Inevitably, the result is a significant number of parts that are unusable and must be scrapped. That's costly for the thermoformer and it raises a critical question. Is it possible to hold tight trim tolerances on pressure-formed parts with a normal variation in the properties of purchased sheets and a normal variation in forming conditions? If so, will the parts fit the trim fixtures as expected?

Pressure Forming Tolerances and Part Measurements

The main problem that pressure formers face is an inability to hold tight tolerances without constantly measuring parts and adjusting trimming programs. It's possible to overcome this challenge, but at a considerable cost. For starters, it takes time to measure each part dimension, confirm what's correct, and determine what's not. There are also measurement errors and part-to-part differences that result in inconsistent trimming. In turn, the result of this trimming may appear to be a measurement error.

Finding the root cause of part-to-part differences requires a significant amount of time from talented people. In the end, splitting the dimensional difference between parts might be what informs the next run. Other adjustments may then be required, and those changes may cause other problems to occur. For pressure formers, there are at least possible solutions with the third option representing the best choice.

The first solution is to expand or loosen part tolerances so that normal processing variations fall within range. This allows pressure formers to present the process as-is but might not meet customer requirements. The second solution is to identify and use metrology techniques to rapidly measure parts during both forming and trimming and to quickly identify process variations. This provides a way to find outliers but it also means tolerating more part rejects and, consequently, higher project costs.

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The third (and best) option is to tighten control of the forming process, the CNC holding fixtures, and measuring techniques to keep process variables within a tighter window. With more timely and more frequent data, pressure formers can identify process variations faster. In turn, this reduces systemic variation through human intervention and supports the production of close-tolerance parts. It also supports greater part-to-part consistency based on the closeness of parts to the drawing or model part.

Achieving this third solution requires improvements to measurement techniques so that monitoring and checking are fast and simple. Otherwise, pressure forming requires a degree of diligence that is manageable but inefficient. Pressure formers also need automated information from sensors that are connected to process controllers. Monitors that provide real-time alerts of process variations as they occur are also critical.

Pressure Forming's Future

When Steve Murrill, Chairman of the Board and former President of Profile Plastics, presented this history of pressure forming to the Society of Plastics Engineers in (SPE) in 2016, the industry had already made considerable advances. Yet cost reductions, quality improvements, part-to-part consistency, and better measurement technologies remain key concerns. Today, the risk of failure is higher than ever. At the same time, companies keep getting bigger – and that includes pressure forming's customers and suppliers. There are also workforce challenges that are more acute today than in 2016.

According to Profile Plastics, numerous challenges came from the primary cart's interaction between the rear top cover and the side covers to achieve a hidden fastening system while maintaining cosmetic alignment between the parts. The thermoformer used complex core pulls on the upper cover to incorporate slots for a work surface table. "This is a very complex tool" with deep draws, Mehta said. The large front cover of the secondary cart presented a challenge with using four-way undercuts, due to the extreme depth of draw.

Continuing advancements in machine vision, in-line measurement, and the proliferation of sensor-based Industry 4.0 technologies now offer manufacturers in general and pressure formers in particular new ways to tackle old challenges. Sound product designs will continue to evolve as well. Take the A/C Plenum that John Grundy, a pressure-forming pioneer, designed years ago.

Contact Profile Plastics to discuss your application

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