Rotomolding's Modern Edge

The State-of-the-Art

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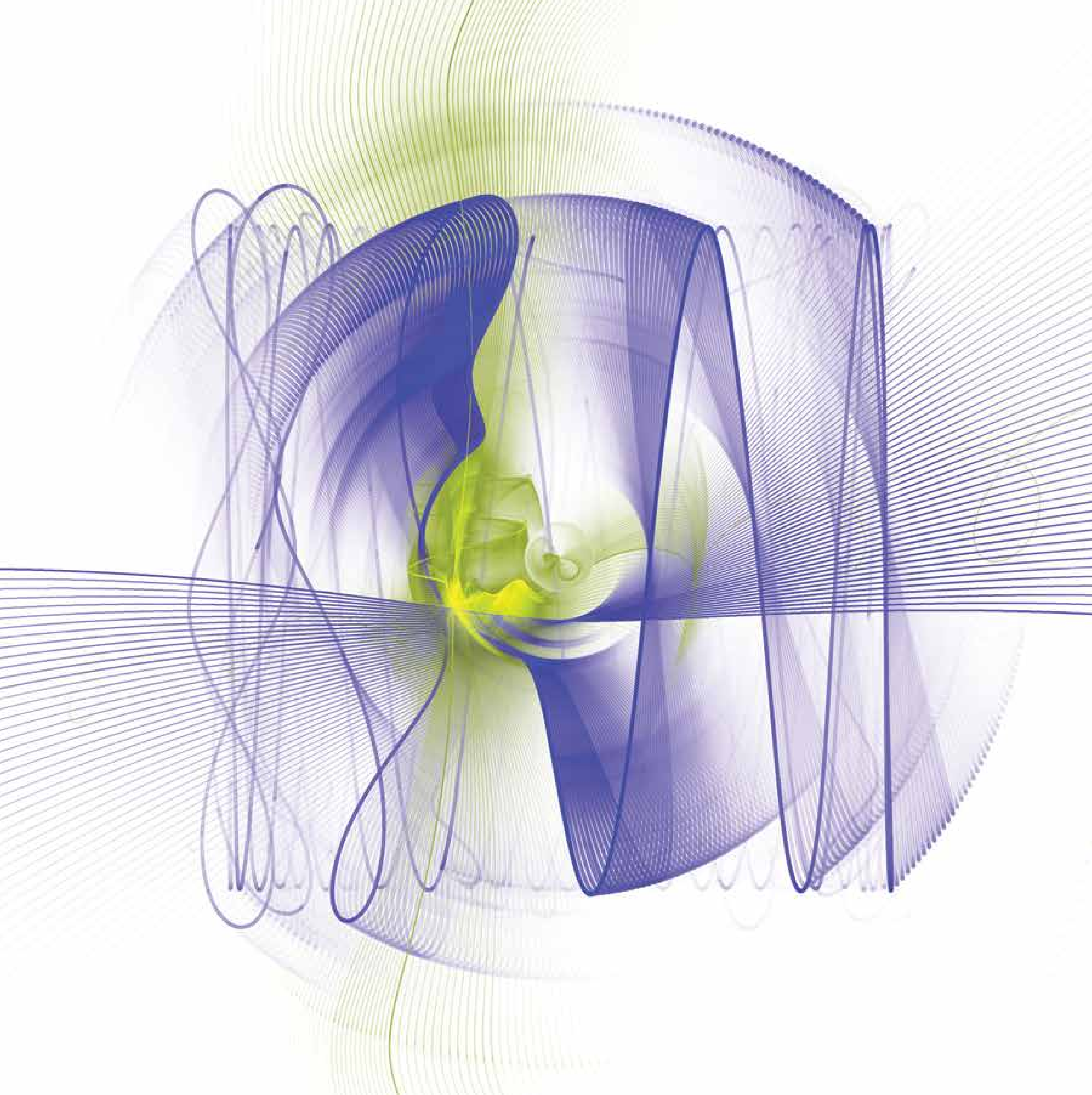

Kuki Chair designed by Zaha Hadid for Sawaya & Moroni

The rotational molding industry weaves a thread through an eclectic mix of industries worldwide. While they are all connected through the elements of the basic process, they are often completely unconnected in terms of application and final requirements: the flexibility and wide-ranging capability of rotomolding allows for varying size and complexity that is unmatched by any other plastic manufacturing process. Medical suppliers producing tiny implants using PVC have very different needs from fuel tank makers using crosslinked polyethylene but both are dependent on the relationship of ratios of rotation. Playball manufacturers and light globe makers aim for consistent wall thickness to meet very different customer requirements but both depend on uniformity of heat transfer. Kayak makers have high expectations for surface finish and appearance whereas chemical tank makers may be focused on wall thickness and long-term performance but both are dependent on the physical and melt flow characteristics of the material they choose. All these manufacturers are part of the family of rotational molders but are separated by their specialties and it is this variety of specialty, coupled with a common entrepreneurial spirit, that makes the industry so vibrant.

As a niche process with only several thousand companies practicing worldwide, rotational molders often find themselves separated by product or by geography. Although well-established in older markets such as Europe, North America and Australia, rotomolders can be found in almost every country around the globe, often following a similar pattern of development in new territories. There is a range of typical products that act as seeds for these new markets: water tanks, road barriers, pallets and children's toys, for example. Moving beyond this range requires a combination of factors including the development of more advanced molding capabilities as well as access to industrial and/or commercial markets which demand plastic components. As a result, the global concentration of the most sophisticated rotomolders is driven by the industrial heartlands of Europe and North America whereas areas such as the Middle East and Africa are hampered by the lack of regional industrial bases. The major growth of rotational molding is therefore most often seen in smaller companies as evidenced by the explosive growth in molder numbers in China, India and Brazil in recent years. Although wide, this base remains at the lower end of sophistication with relatively few companies managing to differentiate themselves in terms of quality, innovation or strong marketing abilities. However, the technology of the process is advancing and modern communication allows even the most remote operation to benefit from new insights and developments. A review of the current state-of-the-art shows that the industry is moving forward and there are new developments in understanding the process, machines, molds and materials.

Process Fundamentals

The essential elements of rotational molding have remained unchanged since its inception: transformation of a polymer in free-flowing powder or liquid form into a uniformly distributed hollow shape using controlled multi-axis rotation and uniform heating and cooling. Indeed, many molders operate with the same set of control and operational parameters today as their pioneering predecessors did in the 1950s. What has changed for those with a more modern approach is the understanding of the process and material transitions in the process, how to monitor them and ultimately how to control them.

Temperature control systems based on air temperature inside the mold or using scanned mold surface temperatures are now readily available as both machine based options and after-market add-ons. Even the most basic molding operation can benefit from the insight provided as the data provides visual indications of the transition of the molding material from free flowing to solid, the level of cure attained and the cooling regime to which it was subjected. For more advanced molders, the ability to 'see' inside the mold is absolutely essential in order to be able to streamline operations and improve part quality. Materials or parts requiring close control such as foaming, multi-layer construction, cross-linked polyethylene, reactive liquid systems, engineering grades or rotolining processes are best controlled with live data from the mold. Temperature data from the mold can also be used on a macro basis to adjust the overall process for changes in ambient conditions or operator-driven issues: rotomolding is heavily dependent on the factory environment for cooling rates and the design of machines employing concurrent processes can multiply small demolding station delays into multi-cycle losses. These changes and losses can now be compensated for automatically by the machine as it monitors the effect directly at the mold either internally or, more conveniently, at the external surface. Direct use of temperature data has now also been supplemented by derivative analysis including measurement of the area under the internal temperature profile during key stages of the process, the slope and duration of the curve during fusion and cure and rates of cooling during the initial molten cooling stage. The next step forward may be to reintroduce camera based systems, first tested in the 1980s, for monitoring transitions and troubleshooting problem areas from inside the mold.

Lighting by COSMO

Machinery

Lean manufacturing principles were embodied in the first 'continuous rotomolding' machines produced by the McNeil Corporation in the 1960s (more commonly referred to as carousel style). Simultaneous heating, cooling and mold servicing stations allowed for relatively efficient use of space and labor. Since then this format for high-volume rotomolding has not changed much in principle – the main developments have been in the quality of machine construction, heat transfer performance and controls.

A broad selection of other machine styles have been developed for a range of products: shuttle machines for large parts or those with long service times, rock-and-roll ovens for long parts such as kayaks, single station clam shell machines for limited space and multiarm, multi-station shuttle machines for high volume production. Automated machines with direct in-mold heating systems have been applied to complex parts which require close control of wall thickness, multiple layers or for high-volumes. And while complete cycle automation from mold filling through to part extraction has been shown to be possible, cost and complexity typically limits its wide application for short-run production. For long-run high-volume production, multi-station carousel machines cannot be outpaced but for short-run custom products, a flexible machine design with quick change molds has proven to be the most suitable.

Tanks for the Chemical Industry

The industry is often labeled as inefficient in energy terms due to the primary heating method being direct gas heating. As a result, there is constant pressure for energy saving even though the cost component for energy in the process is typically low. Innovations such as electrical heating have been used in instances where pricing is economic for an entire convection oven or in a more focused manner in directly heating molds through slip-rings. Energy recovery from motors, heat-exchangers on oven exhaust gases and high-speed recirculation systems have made modern machines incrementally more efficient. Even solar power has been shown to be feasible and may be practical for remote regions but has yet to be demonstrated for mainstream use, especially at night. Infrared systems developed in France are effective in rapid heating but controlling uniformity on complex surfaces has proven challenging. And in the ultimate cross-over process, molders in the past have used molten eutectic salt-spray systems – messy but with fast conductive heating rates.

Rotational molding generates a lot of energy as arms full of molds move in and out of constantly opening and closing ovens and as a result, air conditioned rotomolding plants are rare. Cooling for the process remains heavily dependent on ambient conditions around the machine which means that cycles vary considerably by region and season. Most cooling cycles are a combination of high-speed air fans with intermittent use of fine water sprays or mists producing cooling rates which have been empirically pushed close to limits for controlled shrinkage of polyethylene parts. As molders look for an edge, internal cooling using air circulation or even fine water mist can help move the process towards a more balanced cooling rate through the wall of the molded part, thereby reducing warpage and distortion. An interesting development by automatic machine makers has shown the benefits of mounting cooling fans close to the surface of the mold on the arm of the machine

Tractors for the Agriculture Industry

– shorter distances create more effective heat transfer rates and the system can therefore use smaller fans to greater effect.

Hot factories make difficult work environments and molders are wise to focus on operator work conditions. Cooling systems for personnel, powder handling systems for direct dispensing of powder into the molds, safe platform designs and systems for making mold opening and part handling safer and easier all pay dividends in worker longevity and attitude.

Molds

At the core of the process, rotational molds are thin, hollow shells. They operate within the dichotomy of needing to be thin for fast heat transfer but also needing to be thick enough for durability: it is a delicate balancing act which can teeter between excessive maintenance needs on the one hand and excessive weight and slow cycles on the other.

Mold technology varies greatly around the globe with sheet metal molds being the most common for simple shapes. However, for many applications cast aluminum and nowadays, increasingly more common, machined aluminum molds are an ideal balance for cost, appearance and final part quality. The cost conscious rotomolder often drives the choice of mold construction to its lowest level but a quick review of the benefits of building a higher initial quality mold over the lifecycle of a product can often pay dividends in terms of customer acceptance (and therefore sales). Where the application allows, rotational molds can now be made with multi-zonal heating for wall thickness control, robotic arms can be programmed to rotate outside the standard, fixed biaxial ratios and the future may even hold real-time in-mold part wall thickness monitoring during the cycle. Specialized molders use composite construction for prototyping or short-run production, ceramic or rubber forms for liquid molding at room temperature and even electroformed copper or nickel molds for high speed cycles. Molders have much to be grateful for as mold-makers have proven to be one of the most innovative group of suppliers for the rotomolding industry, particularly in Europe.

Material Changes

Polyethylene continues to be the dominant material used for rotational molding and is readily available in most markets around the world, although quality and suitability for the process do vary. Despite its inherent suitability for the process and the wide range of applications for which it is ideal, there remains a constant demand for new grades outside the current palette. Suppliers have responded over the years with a range of alternatives but commercial demand has been limited and the ability of typical molders to employ special material handling steps or more complex process controls for engineering materials has meant that molders continue to use a group of materials which perform in a similar fashion to polyethylene (nylon, polycarbonate, polypropylene and several fluoropolymers, for example). The process of transforming polyethylene powder into a solid melt under the action of heat and rotation essentially defines the modern rotomolding process: research by leading universities has shown the essential rheology and material properties which are critical in making a grade suitable for rotational molding. Unfortunately, the majority of non-polyethylene materials do not flow well under the low-shear conditions present inside a typical rotational mold meaning that the expansion of the rotomolding palette has been stubbornly slow despite flurries of activity in the 1960s and late 1990s.

Major material suppliers have committed resources to the process at various times but the fragmented nature of the industry, geographically and by end-use, has meant that the economic justification for the considerable effort to develop materials has often been limited. However, there are exceptions and most often it is the middle tier of compounders and distributors who have been innovative with small batch production of specialist grades. Blends and alloys using polyethylene as a base have proven successful for a number of developments as have sugar-based polymers; ethanol derived from sugar-cane can be used to produce polyethylene in essence the same as oil based versions but sugar can also be used to produce stiff polylactic acid (PLA) based materials too. Demand for increased temperature and stiffness has led to revitalized work in polypropylene; permeation and temperature resistance continues to drive demand for nylon. Even the format of the material – powder, micro-pellet, mini-pellet, liquid – can be used to solve specific product requirements. However, the ultimate goal of a scratch resistant, stiff, easy to mold, low-cost general-purpose resin (effectively the ABS grail) remains elusive. The search continues.

But the search for solutions cannot be one-sided. Molders must understand that new grades of material will require new approaches. To expect everything to look-like, mold-like and cost-like polyethylene yet perform at another level is unrealistic. Higher performance materials in any other plastics industry command higher prices due to improved properties and benefits – rotomolders must therefore expect to implement new ways of handling materials, designing molds and controlling the process to suit these new, enhanced properties. A joint approach between molders and material developers (and even end-users) offers the best path to cracking the code.

Floating Pontoons for the Recreation Industry

Moving Forward

The global rotational molding industry is dominated by a wide base of entry-level molders, constantly growing as the process continues to attract entrepreneurs, while established regions such as the US and Europe have remained relatively stable for several decades. The commercial and technical progress of this entry-level group is greatly affected by their location: regional demand for simple products drives molders to the lowest level for competition while OEM end-users drive innovation and differentiation. The ability to respond to such OEM demands depends on technical ability and available technology: machinery and molds are already available to handle the most complex of rotomolded parts but it will be new materials that will be most likely to take the process to a new level. Support your local compounders and distributors – they may be the key to your future.

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